CSN CARBON STORAGE NEWSLETTER

OCTOBER 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

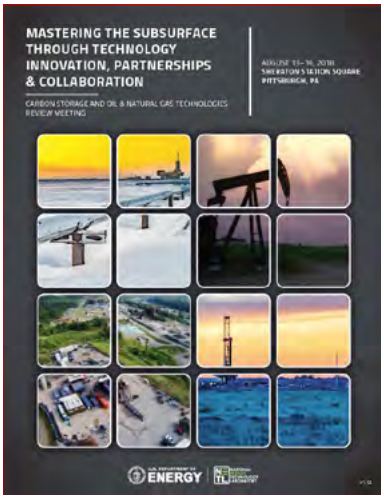
DOE Invests to Advance Associated Geologic Storage.

The U.S. Department of Energy's (DOE) *Office of Fossil Energy (FE)* selected two projects to receive federal funding for cost-shared research and development (R&D). Selected under Funding Opportunity Announcement (FOA) DE-FOA-0001829, "*Developing Technologies for Advancement of Associated Geologic Storage in Basinal Geo-Laboratories*," the projects will address technical research needs and key challenges in advancing associated geologic storage in support of DOE's *Carbon Storage Program*. In addition, the projects will support the development of best practices for commercial implementation of carbon storage technologies. From *energy.gov* on August 28, 2018.

ANNOUNCEMENTS

NETL Issues RFI.

DOE's 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. Stakeholder responses to the 16-question RFI may help DOE develop technical objectives for future FOAs. Responses are due to the National Energy Technology Laboratory (NETL) by December 3, 2018.

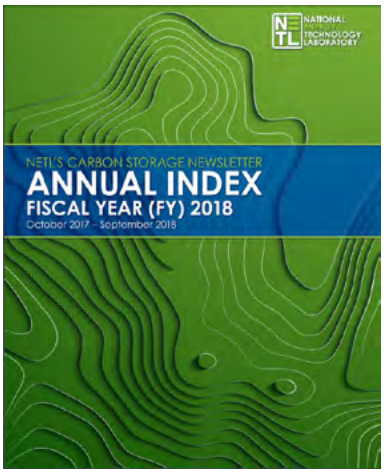


DOE/NETL Conference Proceedings Available Online.

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 FOAs) have been removed.



ANNOUNCEMENTS *(cont.)*

DOE Announces FOA for Transformational Carbon Capture Technologies.

DOE has made available up to $30 million in federal funding for cost-shared R&D under the second closing of FE's "*Novel and Enabling Carbon Capture Transformational Technologies*" FOA. Selected projects must address one area of interest, "Development of Novel Transformational Materials and Processes." The R&D requested in this FOA aligns with the scientific challenges and knowledge gaps identified in the DOE ministerial-level Mission Innovation report, titled "*Accelerating Breakthrough Innovation in Carbon Capture, Utilization, and Storage.*" NETL will manage the projects.

NETL Presents at USAEE Conference.

USAEE
United States Association for Energy Economics

NETL gave four presentations at a recent conference, including one titled "Assessing Key Drivers Impacting the Cost to Deploy Integrated CO_2 Capture, Utilization, Transportation, and Storage (CCUS)." Held in September 2018, the "36th U.S. Association for Energy Economics/International Association for Energy Economics (USAEE/IAEE) North American Conference: Evolving Energy Realities: Adapting to What's Next" highlighted contemporary energy themes at the intersection of economics, public policy, and politics.

Report Addresses Role of CCS in Energy Transition.

A report by the CO_2 Capture Project provides projections for the role of carbon capture and storage (CCS) in the energy sector. The "*Role of CCS in the Energy Transition*" report (subscription may be required) reviewed five leading energy transition scenarios with CCS, estimating the technologies contribution to achieving greenhouse gas (GHG) emissions-reduction goals.

Report Outlines GHG Removal and Storage Methods.

In partnership with the Royal Academy of Engineering, the Royal Society (an independent academy of the United Kingdom [U.K.] and the Commonwealth) produced a *report* and associated *summary* outlining methods of GHG removal, their storage, and how their deployment may be affected. The report also discusses how these methods may be utilized to meet potential goals.

RGGI Compliance Webinar Available.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) made available a webinar on guiding CO_2 budget sources through the interim control compliance process. The 2018 interim control period began on January 1, 2018, and extends through December 31, 2018.

CCS Facility Back Online.

The CCS facility at Unit 3 at the Boundary Dam Power Station (located near Estevan, Saskatchewan, Canada) started operating again after being offline for nearly three months due to a severe thunderstorm. Start-up of the CO_2 compressor began in September 2018 and the CO_2 is now being delivered to Whitecap Resources in western Canada for enhanced oil recovery (EOR).

PROJECT and BUSINESS DEVELOPMENTS

Application Submitted for CO_2 Storage Project.

Partners in the Northern Lights project have submitted an application for an exploration permit for a subsea reservoir for CO_2 injection and storage on the Norwegian Continental Shelf (NCS). The project, which is part of Norwegian authorities' efforts to develop full-scale CCS in Norway, will capture CO_2 from the onshore industrial facilities in eastern Norway and transport it, via ship, to an onshore receiving plant located on the west coast of Norway. From there, the CO_2 will be sent by pipeline on the seabed to injection wells east of the Troll field on the NCS. The first phase of the project has the potential to reach a capacity of approximately 1.5 million tons of CO_2 per year. From *Offshore Energy Today* on September 10, 2018.

Climeworks Launches Third Direct Air CO_2 Capture Plant.

Climeworks launched its third Direct Air Capture (DAC) demonstration plant, which removes CO_2 from the atmosphere. Located in southern Italy, DAC-3 will be in operation for 4,000 hours over the next 17 months. Climeworks also has DAC plants in Switzerland and Iceland; the latter of which annually injects 50 metric tons of CO_2 underground. From *Business Green* on October 1, 2018.

LEGISLATION and POLICY

California Aims for Carbon Neutrality.

An executive order was issued in California (USA), seeking carbon neutrality in the state by 2045. In addition, Senate Bill 100 was also signed, establishing mandatory renewable energy targets of 33 percent by 2020, 50 percent by 2026, and 60 percent by 2030, before implementing a zero-carbon electricity grid by 2045. To achieve its goals, California will reduce carbon emissions; increase carbon storage in forests, soils, and other natural landscapes; and implement programs to improve air quality and public health. From *International Institute for Sustainable Development* on September 20, 2018.

Revised Tax Credit Role on CCUS Commercial Viability.

Research conducted by the Computational Earth Science group at Los Alamos National Laboratory (LANL) (USA) has shown that using CO_2 for CCUS can be commercially viable under the revised 45Q tax regulation. Until recently, there was a limit on the 45Q tax credit, which creates incentives for capturing and storing CO_2; the 2018 revision eliminated the cap. From *Albuquerque Journal* on August 31, 2018.

CARB-Approved Changes Establish CCS Protocol.

The California Air Resources Board (CARB) approved several amendments to their Low-Carbon Fuel Standard (LCFS) Program, one of which establishes a regulatory protocol to set requirements for CCS. In addition, the amendments set a new carbon-intensity target within the state. The LCFS currently requires a 10 percent reduction in California's transportation fuels by 2020; the amendments will require a 20 percent reduction by 2030. From *Ethanol Producer Magazine* on October 1, 2018.

EMISSIONS TRADING

Report on RGGI Investments.

The RGGI-participating states released a report on the investments of proceeds generated from RGGI's regional CO_2 allowance auctions in 2016. According to the report, in 2016 more than $436.4 million in RGGI proceeds were invested in programs such as energy efficiency, clean and renewable energy, GHG abatement, and direct bill assistance. More details, such as state-specific success stories and program highlights, as well as information on both the 2016 and cumulative investments of RGGI, are available in the full report, titled "*Investment of RGGI Proceeds in 2016.*" From *RGGI News Release* on September 19, 2018.

RGGI Inc.

EU, California Strengthen Carbon Market Cooperation.

The European Union (EU) and California (USA) announced intentions to strengthen their bilateral cooperation on carbon markets. According to the announcement, made at the Global Action Summit held in San Francisco, California, in September 2018, officials from the EU and California will focus on sending near- and long-term investment signals for transformative technologies, addressing economic competitiveness, and maximizing public benefits of use of program revenues. In addition, the collaboration will work through the existing "Florence Process" – a workshop that seeks to bring together emission trading scheme (ETS) experts. From *Clean Technica* on September 21, 2018.

Zero Carbon Project Set to Launch.

The U.K.'s Zero Carbon Project announced it will launch in October 2018 in the U.K. and in early 2019 in Australia. The project is designed to mitigate potential climate change through blockchain technology and international carbon credits. From *Market Journal* on September 23, 2018.

ZERO CARBON PROJECT

CLIMATE and SCIENCE NEWS

Plant's Ability to Store CO_2 Studied.

Scientists from the University of Washington (USA) have found that higher levels of atmospheric CO_2 may lead to plants storing less carbon. When CO_2 levels in the atmosphere rise, plants thicken their leaves as a result. The research found that plants with thicker leaves may be less efficient in storing atmospheric CO_2, which models had not considered. In their study, which appeared in the journal *Global Biogeochemical Cycles*, the researchers reported that when this data was incorporated into global models under potentially high CO_2 levels, the global "carbon sink" contributed by plants was less productive, leaving approximately 6.39 million tons of CO_2 in the atmosphere per year. From *Science Daily* on October 1, 2018.

Researchers Develop Battery to Capture, Store CO_2.

Researchers from Massachusetts Institute of Technology (MIT) (USA) have developed a new type of battery that could capture and store CO_2 as a solid carbonate mineral. The lithium-based battery could be made partly from CO_2 capture from power plants; instead of converting the CO_2 to specialized chemicals using metal catalysts, the battery could continuously convert it into a solid mineral carbonate as it discharges. The findings were published in the journal *Joule*, in an article titled "*Tailoring the Discharge Reaction in Li-CO_2 Batteries through Incorporation of CO_2 Capture Chemistry.*" From *Carbon Capture Journal* on September 23, 2018.

Study Looks into CO_2 Storage Potential in the United States.

According to a new study, the United States has the potential to double the amount of CO_2 emissions currently captured and stored worldwide within the next six years. The study, conducted by Princeton University (USA), proposed a pipeline network that would transfer CO_2 from ethanol refineries in the American Midwest to oilfields in West Texas, where it would be used for EOR activities. *According to the study, which was published in the Proceedings of the National Academy of Sciences*, the CCS network could prevent up to 30 million metric tons of CO_2 per year from entering the atmosphere. From *Phys.Org* on September 25, 2019.

JOURNAL ARTICLES

A novel experimental system for the exploration of CO_2-water-rock interactions under conditions relevant to CO_2 geological storage.

The following is the Abstract of this article: "This paper describes the design and experimental validation of a novel flow-through reactor system conceived for experimental studies to determine the kinetics and thermodynamics of mineral precipitation and dissolution in environmental conditions relevant to CO_2 geological storage. The experimental system was designed to work under a confining pressure of up to 150 bar, temperature up to 150°C and corrosive conditions. The unique design allows the injection of precise amounts of liquid CO_2 into the reactor while avoiding the formation of multiple CO_2 phases. The modular design enables the in-situ measurement of pH using a pressure resistant in-line probe and electronic gauges which record pressure and temperature at multiple points. The system enables the user to withdraw liquid samples without disturbing the experimental conditions in the reactor. Customized computer software was developed and connected to the system to provide automatic data-logging capabilities, remote process control and the ability to partially shut-down the system in case of safety issues." **Pedro M. Rendel, Domenik Wolff-Boenisch, Ittai Gavrieli, and Jiwchar Ganor,** *Chemical Engineering Journal.* (Subscription may be required.)

Natural enhancement and mobility of oil reservoirs by supercritical CO_2 and implication for vertical multi-trap CO_2 geological storage.

The following is the Abstract of this article: "The accumulation and production of both deep mantle-derived CO_2 and light oil were discovered in the Huangqiao reservoir, which is located in the Subei Basin, East China. The Huangqiao reservoir shows that both CO_2 and oil are entrapped in and produced from vertical multi-traps. The effects of deep CO_2 on the accumulation and production of oil under natural conditions and the implications for CO_2 geological storage are investigated in detail. The fluid inclusions in quartz or calcite veins from the Silurian Fentou Formation ($S_{2\text{-}3}f$), Permian Longtan Formation (P_2l) and Triassic Qinglong Formation (T_1q) have homogenization temperatures (Ths) that display peak ranges of 180°C–190 °C, 170°C–180 °C and 150°C–160 °C, respectively. The Ths are higher than the formation temperatures. The calcite veins have light carbon and oxygen isotope compositions and have high $^{87}Sr/^{86}Sr$ ratios and positive Eu anomalies. These characteristics reveal the activities of deep CO_2-rich hydrothermal fluids in the basin strata. The feldspar in the $S_{2\text{-}3}f$ and P_2l sandstone reservoirs underwent significant dissolution because of the presence of CO_2-rich fluids, forming of a large amount of secondary pores in the sandstone reservoirs and enhancing the reservoirs' physical properties. The measured porosity reaches 12.3%. CO_2 in a supercritical state extracted or dissolved light petroleum components out of sedimentary rocks and then carried them towards reservoirs. Thus, CO_2 and oil co-accumulated in the enhanced reservoirs, e.g. $S_{2\text{-}3}f$, P_2l and T_1q. During drilling development, this supercritical CO_2 naturally increased the mobility of oil, resulting in the co-production of highly pure CO_2 and light oil. Based on the unique features of the Huangqiao CO_2-oil reservoir, [the authors] propose a new CO_2 geological storage model, namely, a vertical multi-trap geological storage model, which can either entrap large volumes of CO_2 or lower the risk of long-term storage." **Dongya Zhu, Qingqiang Meng, Quanyou Liu, Bing Zhou, Zhijun Jin, and Wenxuan Hu,** *Journal of Petroleum Science and Engineering.* (Subscription may be required.)

The cost of getting CCS wrong: Uncertainty, infrastructure design, and stranded CO_2.

The following is the Abstract of this article: "CCS infrastructure will require industry—such as fossil-fuel power, ethanol production, and oil and gas extraction—to make massive investment in infrastructure. The cost of getting these investments wrong will be substantial and will impact the success of CCS technology. Multiple factors can and will impact the success of commercial-scale CCS, including significant uncertainties regarding capture, transport, and injection-storage decisions. Uncertainties throughout the CCS supply chain include policy, technology, engineering performance, economics, and market forces. In particular, large uncertainties exist for the injection and storage of CO_2. Even taking into account upfront investment in site characterization, the final performance of the storage phase is largely unknown until commercial-scale injection has started. [The authors] explore and quantify the impact of getting CCS infrastructure decisions wrong based on uncertain injection rates and uncertain CO_2 storage capacities using a case study managing CO_2 emissions from the Canadian oil sands industry in Alberta. [The authors] use SimCCS, a widely used CCS infrastructure design framework, to develop multiple CCS infrastructure scenarios. Each scenario consists of a CCS infrastructure network that connects CO_2 sources (oil sands extraction and processing) with CO_2 storage reservoirs (acid gas storage reservoirs) using a dedicated CO_2 pipeline network. Each scenario is analyzed under a range of uncertain storage estimates and infrastructure performance is assessed and quantified in terms of cost to build additional infrastructure to store all CO_2. [The authors] also include the role of stranded CO_2, CO_2 that a source was expecting to but cannot capture due substandard performance in the transport and storage infrastructure. Results show that the cost of getting the original infrastructure design wrong are significant and that comprehensive planning will be required to ensure that CCS becomes a successful climate mitigation technology. In particular, [the authors] show that the concept of stranded CO_2 can transform a seemingly high-performing infrastructure design into the worst case scenario." **Richard S. Middleton and Sean Yaw,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

Policy Insights from the EMF 32 Study on U.S. Carbon Tax Scenarios.

The following is the Abstract of this article: "The Stanford Energy Modeling Forum exercise 32 (EMF 32) used 11 different models to assess emissions, energy, and economic outcomes from a plausible range of economy-wide carbon price policies to reduce CO_2 emissions in the United States. Here [the authors] discuss the most policy-relevant results of the study, mindful of the strengths and weaknesses of current models. Across all models, carbon prices lead to significant reductions in CO_2 emissions and conventional pollutants, with the vast majority of the reductions occurring in the electricity sector. Importantly, emissions reductions do not significantly depend on the rebate or tax cut used to return revenues to the economy. Expected economic costs, as modeled by either GDP or welfare, are modest, but vary across models. These costs are offset by benefits from avoided climate damages and health benefits from reductions in conventional air pollution. Using revenues to reduce preexisting capital or labor taxes reduces costs in most models relative to lump-sum rebates, but the size of the cost reductions varies significantly. Devoting at least some revenue to household rebates can significantly reduce adverse impacts on low income households. Carbon prices at $25/ton or even lower levels cause significant shifts away from coal as an energy source with responses of other energy sources highly dependent upon technology cost assumptions. Beyond 2030, [the authors] conclude that model uncertainties are too large to make quantitative results useful for near-term policy design. [The authors] close by describing recommendations for policymakers on interacting with model results in the future." **Alexander R. Barron, Allen A. Fawcett, Marc A. C. Hafstead, James R. McFarland, and Adele C. Morris,** *Climate Change Economics.* (Subscription may be required.)

JOURNAL ARTICLES *(cont.)*

Tech-economic assessment of second-generation CCS: Chemical looping combustion.

The following is the Abstract of this article: "Chemical looping combustion (CLC) is regarded as the most promising technology for CO_2 capture to mitigate [GHG] effect. In this work, a technical and economic performance of [methane (CH_4)]-feed CLC power plant by means of utilizing promising nickel-, copper-, and ilmenite-based oxygen carriers is studied. Nickel-based CLC power plant has the highest net power efficiency of 50.14%, followed by 48.02% for ilmenite-based case and 45.59% for copper-based case. By contrast nickel-based case has a specific CO_2 emission of 1.44 kg/MW h, which is dramatically lower than the referenced [natural gas combined cycle (NGCC)] with CCS system (40.10 kg/MW h). The economic [analyses] reveal nickel-based case is most economic-benefits due to the lowest cost of electricity (COE) of 71.66€/MW h, approximately 0.32 €/MW h and 13.06 €/MW h COE reduction benefits have been increased in comparison with ilmenite-based and copper-based case, respectively. The natural gas price has an important influence on COE, as approximately 49.73%, 48.60% and 56.30% of COE enhancement is expected with the natural gas price ranging in 4–8 €/GJ for nickel-based, copper-based, and ilmenite-based case, respectively. Finally a comparison between [natural gas combined cycle (NGCC)] and CLC-related power system in terms of economic performance further demonstrates the feasibility of the latter system." **Lin Zhu, Yangdong He, Luling Li, and Pengbin Wu,** *Energy.* (Subscription may be required.)

Mass flow measurement of gas-liquid two-phase CO_2 in CCS transportation pipelines using Coriolis flowmeters.

The following is the Abstract of this article: "CCS is a promising technology that stops the release of CO_2 from industrial processes such as electrical power generation. Accurate measurement of CO_2 flows in a CCS system where CO_2 flow is a gas, liquid, or gas-liquid two-phase mixture is essential for the fiscal purpose and potential leakage detection. This paper presents a novel method based on Coriolis mass flowmeters in conjunction with least squares support vector machine (LSSVM) models to measure gas-liquid two-phase CO_2 flow under CCS conditions. The method uses a classifier to identify the flow pattern and individual LSSVM models for the metering of CO_2 mass flowrate and prediction of gas volume fraction of CO_2, respectively. Experimental work was undertaken on a multiphase CO_2 flow test facility. Performance comparisons between the general LSSVM and flow pattern based LSSVM models are conducted. Results demonstrate that Coriolis mass flowmeters with the LSSVM model incorporating flow pattern identification algorithms perform significantly better than those using the general LSSVM model. The mass flowrate measurement of gas-liquid CO_2 is found to yield errors less than ±2% on the horizontal pipeline and ±1.5% on the vertical pipeline, respectively, over flowrates from 250 kg/h to 3200 kg/h. The error in the estimation of CO_2 gas volume fraction is within ±10% over the same range of flow rates." **Lijuan Wang, Yong Yan, Xue Wang, Tao Wang, Quansheng Duan, and Wenbiao Zhang,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

How China's current carbon trading policy affects carbon price? An investigation of the Shanghai Emission Trading Scheme pilot.

The following is the Abstract of this article: "To better establish a unified carbon market in China, this study evaluates the effect of current carbon trading policy and further investigates the relationship between such policy that is published during the second phase of Shanghai Environment and Energy Exchange (SEEE) and Shanghai Emission Allowance (SHEA) price. [The authors] aim to analyze whether these policies can improve the operation efficiency of current carbon market. By the Mean Reversion Test, Cox-Ingersoll-Ross (CIR) Model, and Event Study Method, [the authors] first analyze the potential price discovery function of SHEA products, thereby describing the transmission channel of current policy to SHEA price. Then [the authors] examine the effect of carbon policies published in different periods on their corresponding SHEA price. By the Auto-correlation Test and CIR simulation, [the authors] find that 3/4 of all auto-correlation values are less than 0 after Apr. 2017, and the minimum cumulative error is 31.3792 under the supply and demand channel. These findings imply that SHEA price has the discovery function at the middle and end of trading period, and the current policy affects SHEA price through its effect on the fundamentals of supply and demand. Further, more than 60% of all r-values (r-value that reflects the response of price to policy) are less than 1, which implies that the published policy will improves future SHEA price. Accordingly, [the authors] argue that SEEE belongs to a policy-oriented market, and the change of carbon price is closely related to emission allocation policies. In this case, China's government should further push forward the smooth operation of current carbon market by the aid of incentive policy in the coming period." **Yazhi Song, Dapeng Liang, Tiansen Liu, and Xiaoqiu Song,** *Journal of Cleaner Production.* (Subscription may be required.)

Carbon pricing and system linking: Lessons from the New Zealand Emissions Trading Scheme.

The following is the Abstract of this article: "Textbook theory of linking carbon systems suggests linking reduces marginal abatement costs. Contrasting theoretical work and policy analyses suggests that linking, or at least unfettered linking, may not always be beneficial. The New Zealand Emissions Trading Scheme (NZ ETS) is unique in that, until 2013, it allowed unlimited use of Kyoto allowances. NZ ETS, thus provides an ideal context to explore the effect of linking and linking restrictions on carbon pricing of small systems. Using data on importation and exportation of allowances, [the authors] provide the first empirical analysis of the determinants of allowance prices in the early phase of the NZ ETS. [The authors'] results indicate that imports of offsets rather than fundamentals have been the major price determinant. Moreover, the pricing of New Zealand units (NZUs) can be placed into three distinct periods, delineated by two structural breaks. In the first period, the system is largely autarkic; in the second period, as international offset prices drop below the NZU price, the system becomes a 'price taker'; in the final period, following policy interventions, the system regains some independence. The case of the NZ ETS shows that small trading systems need to impose, or have the option to impose, quantitative import restriction so as to reap the benefits (lower abatement cost), but not the drawbacks ('importation' of distortions and market integrity issues), of linking." **Ivan Diaz-Rainey and Daniel J. Tulloch,** *Energy Economics.* (Subscription may be required.)

REPORTS and OTHER PUBLICATIONS

ADVANCED FOSSIL ENERGY: Information on DOE-Provided Funding for Research and Development Projects Started from Fiscal Years 2010 through 2017.

The following is from the highlights of this U.S. Government Accountability Office (GAO) document: "DOE provided $2.66 billion in funding, or obligations, for 794 R&D projects started from fiscal years 2010 through 2017 to develop advanced fossil energy technologies. Such technologies include processes for converting coal into synthesis gas composed primarily of carbon monoxide and hydrogen, and recovering methane from gas hydrates. Of the $2.66 billion, DOE provided $1.12 billion in funding for 9 later-stage, large demonstration projects, which were to assess the readiness for commercial viability of CCS technologies. CCS involves capturing man-made [CO_2] at its source and storing it permanently underground. DOE provided the remaining $1.54 billion in funding for 785 other projects in amounts that were relatively small—over half were for less than $1 million. Six demonstration projects researched CCS technologies using coal, while three used other fuels. The nine demonstration projects received funding ranging from $13 million to $284 million."

Estimating Carbon Storage Resources in Offshore Geologic Environments.

The following is the Executive Summary of this NETL document: "Long-term carbon storage in geologic reservoirs is a leading technique for removing excess CO_2 that would otherwise be emitted to the atmosphere as a result of anthropogenic activities. Effective carbon storage requires both safety and permanence. One underutilized national storage scenario involves carbon storage in offshore geologic formations, similar to those that hold oil, gas, or brine. This scenario has been tested in other countries on a small-scale, but is yet unproven in the United States. A major advantage of offshore storage is that the risk of CO_2 leakage into fresh groundwater resources is decreased, and the effect of that leakage on human population centers is minimized. However, as with onshore storage scenarios, there are many uncertainties surrounding offshore storage. These include issues related to both safety and permanence. After an extensive literature review of the current storage methodologies for onshore carbon storage in saline formations, comparing and contrasting the offshore and onshore characteristics of reservoirs, this study makes recommendations about future work to support offshore storage estimates and research. This report concludes with the suggestion that despite important differences between onshore and offshore systems, carbon can be stored safely and permanently in offshore saline geologic formations. This research proposes using the [DOE/NETL's] saline storage methodology with an integration of spatial-statistical tools to adjust for uncertainties."

Technology Roadmap – Low-Carbon Transition in the Cement Industry.

The following is a summary of this International Energy Agency (IEA) document: "The cement sector is the third-largest industrial energy consumer and the second-largest industrial CO_2 emitter globally. Rising global population and [urbanization] patterns, coupled with infrastructure development needs, drive up the demand for cement and concrete and increase pressure to accelerate action in reducing the carbon footprint of cement production. Under a scenario that considers announced carbon mitigation commitments and energy efficiency targets by countries, the cement sector would increase its direct CO_2 emissions just 4% globally by 2050, for an expected growth of 12% in cement production over the same period. However, more ambitious action would be needed to achieve global climate goals. This Technology Roadmap builds on the long-standing collaboration of the IEA with the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD). It provides an update of the Cement Technology Roadmap 2009: Carbon Emissions Reductions up to 2050, and sets a strategy for the cement sector to achieve the decoupling of cement production growth from related direct CO_2 emissions through improving energy efficiency, switching to fuels that are less carbon intensive, reducing the clinker to cement ratio, and implementing emerging and innovative technologies such as carbon capture. The report therefore outlines a detailed action plan for specific stakeholders to 2050 as a reference and a source of inspiration for international and national policy makers to support evidence-based decisions and regulations."

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

The *National Energy Technology Laboratory (NETL)*, part of DOE's national laboratory system, is owned and operated by the U.S. Department of Energy (DOE). NETL supports DOE's mission to advance the national, economic, and energy security of the United States.

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