U.S. DEPARTMENT OF ENERGY | OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

CSN CARBON STORAGE NEWSLETTER

VOL. 22, NO. 5

CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

- Carbon Storage Educational Resources
- Program Reports, Plans, and Roadmaps
- Conference Proceedings
- Carbon Storage Portfolio
- Systems Analysis
- Peer Review
- Best Practices Manuals
- Fossil Energy and Carbon Management Techlines

This newsletter is compiled by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon storage. It covers domestic, international, public sector and private sector news in the following areas:

DOE/FECM/NETL HIGHLIGHTS

DOE Announces BIL Effort to Establish DAC Hubs.

The U.S. Department of Energy (DOE) released ***a Notice of Intent (NOI)*** to fund the Bipartisan Infrastructure Law's (BIL) program to capture and store atmospheric carbon dioxide (CO_2) emissions. The Regional Direct Air Capture (DAC) Hubs Program will support four large-scale, regional DAC hubs that each comprise a network of carbon dioxide removal (CDR) projects to help address potential impacts of climate change while creating good-paying jobs and prioritizing community engagement and environmental justice. The widespread deployment of DAC technologies and CO_2 transport and storage infrastructure plays a significant role in delivering on the Biden-Harris Administration's goal of achieving an equitable transition to a net-zero economy by 2050. Each of the projects selected will demonstrate the delivery and storage or end-use of removed atmospheric CO_2. The hubs will have the capacity to capture and store at least 1 million metric tons of CO_2 from the atmosphere annually, either from a single unit or from multiple interconnected units. In the development and deployment of the four regional DAC hubs, DOE will also emphasize environmental justice, community engagement, consent-based siting, equity and workforce development, and domestic supply chains and manufacturing.

From *energy.gov*. May 2022.

CONTINUE

DOE/FECM/NETL HIGHLIGHTS *(cont.)*

DOE Investments to Accelerate CO_2 Storage Projects and Increase CO_2 Storage Sites.

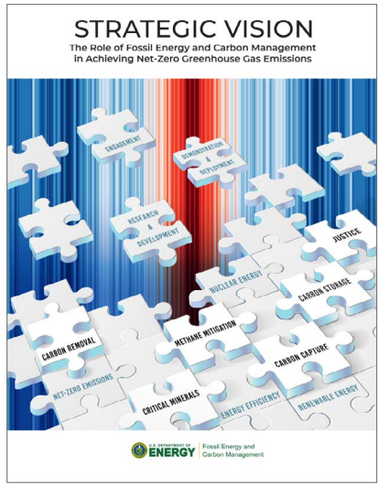
DOE announced two Funding Opportunity Announcements (FOAs) and one NOI to advance carbon storage projects that reduce CO_2 emissions, address potential impacts of climate change, and create good-paying jobs while prioritizing community engagement and environmental justice. DOE first issued an FOA for "***Carbon Management***" to advance a variety of carbon management technologies, including assessments of rock and material resources for CO_2 mineralization. DOE then issued an FOA for "***CarbonSAFE: Phase II - Storage Complex Feasibility***" to increase the number of available CO_2 storage sites in the early developmental levels. The next investment has been announced through an NOI for "***Bipartisan Infrastructure Law: Storage Validation and Testing (Section 40305): Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative: Phases III, III.5, and IV***," which would be funded through the BIL to accelerate commercial-scale geologic carbon storage projects toward operational readiness. CarbonSAFE projects must be capable of storing at least 50 million metric tons of CO_2 within a 30-year operational period. Projects funded under these three opportunities will be managed by DOE's Office of Fossil Energy and Carbon Management (FECM).

From *energy.gov*. May 2022.

FECM Releases Strategic Vision.

DOE's FECM released its strategic vision, "***The Role of Fossil Energy and Carbon Management in Achieving Net-Zero Greenhouse Gas Emissions***." FECM's Strategic Vision will enable DOE to make strategic carbon management decisions and prioritize approaches that minimize the environmental impacts of fossil fuels and carbon-based feedstocks and help the nation achieve net-zero greenhouse gas (GHG) emissions. Three strategic directions were outlined to help the U.S. government achieve a fully decarbonized power sector by 2035 and net-zero emissions by 2050: Advancing Justice, Labor, and Engagement; Advancing Carbon Management Approaches Toward Deep Decarbonization; and Advancing Technologies that Lead to Sustainable Energy Resources. More information on FECM's Strategic Vision is available via ***infographic***.

From *energy.gov*. April 2022.



NETL Report Compares Cost and Performances of Hydrogen Plants With/Without CCS.

The National Energy Technology Laboratory (NETL) released a report that depicts the levelized cost of hydrogen, in real 2018 dollars, as well as the CO_2-equivalent life cycle emissions of select hydrogen production plants. "***Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies***" compares the cost, performance, and emissions profiles of hydrogen production plants that were selected to reflect the capabilities of current, commercial technologies within industrial-scale plant configurations, providing critical prospective for researchers, regulators, and policymakers. The report includes analyses of three natural gas reforming configurations: (1) natural gas steam methane reforming without carbon capture and storage (CCS), (2) natural gas steam methane reforming with CCS, and (3) autothermal reforming with CCS. The NETL team also analyzed three gasification configurations: (1) coal gasification without carbon capture, (2) coal gasification with carbon capture, and (3) coal plus biomass co-gasification with carbon capture. The full report is ***available on the NETL website***.

From *energy.gov*. April 2022.

DOE Invests in DAC and Storage Technology.

DOE announced the award of federal funding for five front-end engineering design (FEED) studies that will leverage existing zero- or low-carbon energy to supply DAC projects, combined with dedicated and reliable carbon storage. ***The studies*** aim to provide a better understanding of system costs, performance, and business case options for existing DAC technologies coupled to durable storage that are capable of removing a minimum of 5,000 metric tons per year net CO_2 from the air, and which are co-located with domestic zero- or low-carbon thermal energy sourced from geothermal or nuclear power plants and low-grade heat from industrial facilities. The funding opportunity was a collaborative effort among DOE's FECM, Office of Nuclear Energy, and Office of Energy Efficiency and Renewable Energy's (EERE) Geothermal Technologies Office. The selected projects will be managed by NETL and support FECM's ***Carbon Dioxide Removal*** and ***Conversion*** Programs.

From *energy.gov*. April 2022.

ANNOUNCEMENTS

DOE to Host Virtual Carbon Negative Shot Summit.

DOE will host the virtual ***Carbon Negative Shot Summit***, July 20–21, 2022. DOE launched the ***Carbon Negative Shot***, the third target within the ***Energy Earthshots Initiative***, to advance the development of the emerging CDR industry. More information about Carbon Negative Shot is available via ***video*** and ***infographic***.

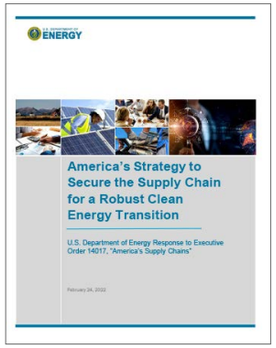
NETL FY 2021 S&T Accomplishments Book Available.

NETL's FY 2021 Science and Technology (S&T) Accomplishments book contains nearly 40 poster presentations that showcase significant accomplishments made by NETL, industries, academia, and other entities, with many projects making progress to meet the Biden-Harris Administration's clean energy goals calling for a net-zero carbon emissions electricity sector by 2035 and economy-wide net-zero emissions by 2050. Accomplishments include efforts to increase the efficiency and lower the cost to capture CO_2 for storage in the subsurface.

FECM/NETL Releases New Version of CCUS Model.

A new, updated version of a carbon capture, utilization, and storage (CCUS) model developed by FECM/NETL has been ***released***. The FECM/NETL CO_2 Transport Cost Model (also known as CO2_T_COM) is a Microsoft Excel-based tool that estimates revenues, capital, and operating and financing costs, as well as the breakeven cost (in $/tonne) for transporting liquid-phase CO_2 by pipeline. A ***user's manual*** and ***overview presentation*** were also released. Model updates include real (and nominal) dollar cost estimate capability, a change to the CO_2 equation of state, and a refined booster pump/pipe size determination algorithm. CO2_T_COM can help evaluate integrated CCUS networks (i.e., connecting a CO_2 source to a storage site) and costs of large-diameter trunklines or shorter, smaller pipelines (e.g., gathering/distribution).

DOE's Supply Chain Assessments.



DOE's report "***America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition***" includes 13 deep-dive supply chain assessments, including the "***Carbon Capture, Transport, and Storage Supply Chain Deep Dive Assessment***." The assessment found that developing CCS can support the U.S. government in achieving its net-zero goals.

Midwest Regional Carbon Initiative Newsletter Released.

MRCI
Midwest Regional Carbon Initiative

The ***Midwest Regional Carbon Initiative (MRCI)*** released the latest edition of the ***MRCInfo newsletter***, which focuses on news in the field of CCUS. MRCI, led by the Battelle Memorial Institute and Illinois Geologic Survey, is one of four individual ***Regional Initiatives*** that support FECM by identifying and addressing challenges to the widespread, commercial deployment of CCUS.

Abstracts Being Accepted for GSA Topical Session on Carbon Storage.

Abstracts are being accepted for the 2022 Geological Society of America (GSA) Topical Session T46 on Geologic Carbon Storage. The 2022 GSA Annual Meeting will be held in Denver, Colorado (USA), October 9–12, 2022. Abstracts in all aspects of geologic carbon storage are being accepted, including site selection, geologic and geophysical site characterization, modeling and monitoring of CO_2 injection/migration, risk evaluation, and case studies of large-scale geologic carbon storage projects. ***Click here*** for more information (search for T46. Geologic Carbon Storage). The submission deadline is July 19, 2022.

Report: CCS Spending Could Quadruple Through 2025.

According to energy research company Rystad Energy, service sector spending on CCS developments has the potential to quadruple from 2022 to 2025. The research found that there are 56 commercial CCS projects in operation globally. Based on already announced projects, nearly 140 CCS plants could be operational by 2025, capturing at least 150 million metric tons of CO_2 per year if the projects move ahead as scheduled. These projects are currently in various stages of development, including feasibility, concept, and construction.

CarbonCure Enters Carbon Credit Agreement.

CarbonCure Technologies signed a 10-year carbon credit purchase agreement supported by its process of mineralizing and storing CO_2 in concrete. CarbonCure measures and tracks CO_2 from the point of capture to mineralization, allowing credit buyers to trace deployment dates and points of the CO_2 they pay to store.

PROJECT AND BUSINESS DEVELOPMENTS

Equinor Awarded CO_2 Licenses.

The Royal Norwegian Ministry of Petroleum and Energy awarded Equinor two licenses to develop CO_2 storage in the North Sea and in the Barents Sea. The two licenses—referred to by Equinor as "Smeaheia" and "Polaris"—are considered building blocks for developing the Norwegian continental shelf. Through these two projects, Equinor aims to contribute to CO_2 reductions equivalent to half of Norway's annual emissions.

From *Equinor News*. April 2022.

LOI to Develop Australia's Offshore Carbon Storage.

Marine geophysics firm PGS ASA (PGS) and CCS project developer deepC Store (DCS) signed a Letter of Intent (LOI) to develop offshore carbon storage in Australia. As part of the collaboration, PGS will provide geologic and geophysics advice on projects developed and operated by DCS.

From *gasworld*. March 2022.

PROJECT AND BUSINESS DEVELOPMENTS *(cont.)*

Proposals Chosen to Develop Canadian Carbon Storage Hubs.

Six proposals to develop Canada's first carbon storage hubs in Alberta were selected. The proposed hubs are located near Edmonton, Alberta, and will store emissions captured from facilities in the Alberta Industrial Heartland zone, which is home to a cluster of refineries and petrochemical and fertilizer plants. The companies behind the selected proposals will next work with the Canadian government to assess whether their proposed locations are suitable for storing carbon.

From *Reuters*. March 2022.

Study to Assess Carbon Storage Potential in Greece.

Halliburton, a products and services provider to the energy industry, was selected to assess the carbon storage potential of the Prinos basin in Greece. Halliburton will collaborate with Energean, the exploration and production company that awarded the study, to evaluate the Prinos area's CO_2 storage complex. The scope of work includes long-term plume modeling, characterizing the storage complex, and a conceptual development plan with performance modeling.

From *Business Wire*. March 2022.

CCUS Commercialization Feasibility Study Launched in Indonesia.

Japanese trading company Mitsui and Indonesian energy corporation PT Pertamina launched a joint feasibility study on CCUS in Indonesia. The study aims to evaluate CO_2 subsurface storage capacity of declining oil and gas fields, such as those in Rokan Block, which are operated by Pertamina. Additionally, the study will examine the CCUS value chain, including capture and transportation of CO_2 emitted from industrial plants, power generation plants, and other facilities.

From *Mitsui*. April 2022.

FEED Study to Begin on CCS Project in Louisiana.

Electric public utility Cleco Power has secured funding to support a FEED study for the Diamond Vault project, which will capture CO_2 emissions from Cleco's Madison 3 plant and store them in geologic formations. The FEED study for Diamond Vault is expected to take approximately 18 months to complete. Sargent & Lundy will serve as lead engineer for the project, with Battelle advising on the characterization of geologic storage capacity and permitting and storage operations.

From *Carbon Capture Journal*. April 2022.

ExxonMobil Begins Studies for Carbon Storage Hubs.

ExxonMobil has begun design studies for its CCS hub in southeast Australia. The CCS hub would use existing infrastructure to store CO_2 in the depleted Bream field off the coast of Gippsland in the state of Victoria. The infrastructure would have the capacity to store up to 2 million metric tons of CO_2 per year, with the potential to be operational by 2025.

From *Reuters*. April 2022.

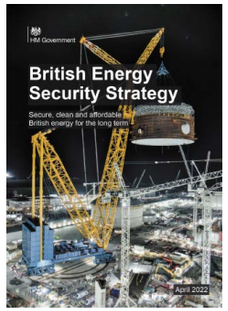
FEED Studies Awarded to Teesside CCS Project.

Costain, a United Kingdom (UK)-based sustainable infrastructure solutions company, was awarded the onshore FEED contract for the East Coast Cluster CCUS by the ***Northern Endurance Partnership (NEP)***. The CCS project will provide the infrastructure to transport CO_2 emissions to secure offshore storage in the North Sea. The East Coast Cluster was selected by the UK's Department for Business, Energy, and Industrial Strategy (BEIS) to move forward as a CCUS cluster in 2021. Genesis, an energy industry advisory company, was ***awarded the offshore FEED***. NEP is a joint venture comprising BP, Equinor, National Grid Ventures, Shell, and Total Energies.

From *Costain News Release*. April 2022.

LEGISLATION AND POLICY

UK Government Invests in CCUS.



The UK government announced financial support for CCUS research. The investment follows the announcement of the "***British energy security strategy***," which, according to the Carbon Capture and Storage Association, reaffirms the UK government's commitment to deliver four CCUS clusters by 2030. The new investment includes funding for an international initiative among 14 countries aimed at accelerating CCUS technologies through funding research innovation projects.

From *Carbon Capture Journal*. April 2022.

Legislation Would Create Regulations for CCS Projects.

The Pennsylvania Geologic Storage of Carbon Dioxide Act would establish legislative intent to facilitate carbon capture in the state; designate property rights around storage sites in geologic formations; assign state regulatory authority to CCS facilities in the state; specify the regulatory and permitting process within the existing federal structure; and create a cash fund for sustaining regulatory operations. The U.S. Environmental Protection Agency currently holds the regulatory authority over CCS projects; a Pennsylvania-specific statute will allow the state to facilitate CCS feasibility studies within its own borders. The legislation will next be introduced into the state Senate.

From *Pennsylvania Business Report*. March 2022.

Canadian Budget Proposes CCUS Tax Credit.

The ***2022 Canadian Federal Budget*** released in April 2022 proposed a refundable investment tax credit for CCUS projects. Under the proposal, from 2022 through 2030, the investment tax credit rates would be set at 60% for investment in equipment for DAC projects; 50% for equipment in other carbon capture projects; and 37.5% for transportation, storage, and use. These rates will be halved for the period from 2031 through 2040.

From *Bloomberg*. April 2022.

EMISSIONS TRADING

RGGI States Initiate Auction Process for Auction 56.

The Regional Greenhouse Gas Initiative (RGGI)-participating states released the ***Auction Notice*** for their 56th quarterly CO_2 allowance auction, to be held June 1, 2022. Auction 56 will offer 22,280,473 CO_2 allowances for sale at a minimum reserve price of $2.44. In addition, an 11,611,278 CO_2 allowance cost containment reserve (CCR) will be made available, as will an emissions containment reserve (ECR) of 10,961,898 allowances. (The CCR is a fixed additional supply of allowances made available if CO_2 allowance prices exceed the CCR trigger price of $13.91. The ECR is a designated quantity of allowances to be withheld if the auction's interim clearing price is less than the ECR trigger price of $6.42.)

From *RGGI*. April 2022.

Report on EU Carbon Market.

The European Securities and Markets Authority (ESMA) published its "***Final Report on the European Union Carbon Market***." Based on key findings and in-depth analysis, the report also formulated policy recommendations to improve transparency and monitoring; identified courses of action for consideration by the European Commission (EC); and provided next steps for the EC, Council of the European Union (EU), and the European Parliament to consider to further regulate the carbon market.

From *ESMA*. March 2022.

SCIENCE

Carbon Storage Using Green Hybrid Concrete.

Scientists from Colorado State University's Systems Engineering Department investigated the use of sustainable concrete with the ability store CO_2. The study, "Toward Carbon-Neutral Concrete through Biochar-Cement-Calcium Carbonate Composites: A Critical Review," focuses on the interaction between biochar and calcium carbonate in sustainable concrete and high-density CO_2 storage possibilities. The paper, ***published in the journal Sustainability***, provides a review of current literature and identifies and explains new research opportunities that will help identify the amounts of these additives and amendments for cement.

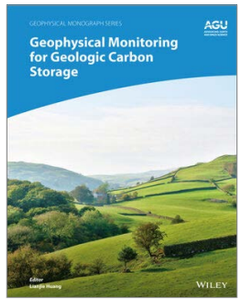
From *AZoMaterials*. April 2022.

PUBLICATIONS

Dimensionally Reduced Model for Rapid and Accurate Prediction of Gas Saturation, Pressure, and Brine Production in a CO_2 Storage Application: Case Study Using the SACROC Field as Part of SMART Task 5.

The following is from the description of this product developed by the Strategic Systems Analysis and Engineering (SSAE) group at NETL for Task 5 of SMART Phase 1: "This study involved the development of deep learning models for CO_2 geologic storage that are capable of accurate prediction of spatio-temporal outputs of CO_2 saturation, pressure, and brine production in three dimensional space over a storage operation's injection and post-injection timeframes. The model framework involves [assembling] multi-layer encoder networks that provide [dimensionality] reduction of geologic inputs with fully connected long short-term memory (LSTM) neural networks that generate time-series prediction This approach offers a means to maximize training time efficiency, reduce computational memory burden, and minimize prediction turnaround."

Geophysical Monitoring for Geologic Carbon Storage.



The following is from the description of this book: "Storing carbon dioxide in underground geological formations is emerging as a promising technology to reduce carbon dioxide emissions in the atmosphere. A range of geophysical techniques can be deployed to remotely track carbon dioxide plumes and monitor changes in the subsurface, which is critical for ensuring for safe, long-term storage. Geophysical Monitoring for Geologic Carbon Storage provides a comprehensive review of different geophysical techniques currently in use and being developed, assessing their advantages and limitations. Volume highlights include: Geodetic and surface monitoring techniques; Subsurface monitoring using seismic techniques; Subsurface monitoring using non-seismic techniques; Case studies of geophysical monitoring at different geologic carbon storage sites." (Purchase may be required.)

Policy Brief: EU ETS Directive Review: A focus on the Article 29a.

The following is from a summary of this European Roundtable on Climate Change and Sustainable Transition policy brief: "The EU ETS Directive, as currently designed, provides two instruments to act when EUA prices fall outside what is perceived as acceptable boundaries: the Market Stability Reserve (MSR), and the Art 29 of the EU ETS Directive addressing price imbalances. So far these instruments are not interlinked, being different from other jurisdictions under ETS regime. Before any modifications to the current rules are implemented, the role of the EU policy maker is to understand the reasons why some sectors of the society are concerned about the current carbon price escalation. Being able to answer fundamental questions about the role of carbon prices, the right definition of market abuse, when intervention in the carbon market is justified, and the role of financial institutions in the carbon market and its impact on contributing or destroying decarbonisation value are a must if we are to come up with the best fit-for purpose design."

Potential for hydrogen production from sustainable biomass with carbon capture and storage.

The following is from the abstract of this article: "Low-carbon hydrogen is an essential element in the transition to net-zero emissions by 2050. Hydrogen production from biomass is a promising bio-energy with carbon capture and storage (BECCS) scheme that could produce low-carbon hydrogen and generate the carbon dioxide removal (CDR) envisioned to be required to offset hard-to-abate emissions. Here, [the authors] design a BECCS supply chain for hydrogen production from biomass with carbon capture and storage and quantify, at high spatial resolution, the technical potential for hydrogen production and CDR in Europe. [The authors] consider sustainable biomass feedstocks that have minimal impacts on food security and biodiversity, namely agricultural residues and waste. [The authors] find that this BECCS supply chain can produce up to 12.5 [million tons (Mtons)] of H_2 per year (currently ~10 Mtons of H_2 per year are used in Europe) and remove up to 133 Mtons CO_2 per year from the atmosphere (or 3% of European total greenhouse gas emissions). [The authors] then perform a geospatial analysis to quantify transportation distances between where biomass feedstocks are located and potential hydrogen users, and find that 20% of hydrogen potential is located within 25 km from hard-to-electrify industries. [The authors] conclude that BECCS supply chains for hydrogen production from biomass represent an overlooked near-term opportunity to generate carbon dioxide removal and low-carbon hydrogen." **Lorenzo Rosa and Marco Mazzotti,** *Renewable and Sustainable Energy Reviews*. (Subscription may be required.)

The importance of biogenic carbon storage in the greenhouse gas footprint of medium density fiberboard from poplar wood and bagasse.

The following is from the abstract of this article: "Carbon storage in long-lived bio-based products is typically ignored or accounted for in a simplistic way in greenhouse gas (GHG) footprint calculations. [The authors] quantified the GHG footprint of medium density fiberboard (MDF) in Iran from poplar wood and bagasse, a by-product from sugarcane production. Inventory data was collected from sugarcane and poplar wood plantations and MDF factories in Iran during 2017–2019 to calculate cradle-to-grave footprints for 1 m^3 of MDF. [The authors] quantify the effect of carbon storage, which depends on the crop rotation time and the economic lifetime of the product, with shorter rotation times and longer storage periods leading to lower footprints. Cradle-to-grave GHG footprints of poplar and bagasse-based MDF without accounting for biogenic carbon storage are 6.8·102 kg CO_2-eq/m^3 and 8.5·102 kg CO_2-eq/m^3, respectively. Footprints are higher for bagasse-based MDF than for poplar-based MDF because of a higher electricity use, higher resin use and larger transport distances in Iran. Taking into account carbon storage periods of 10–60 years decreases the footprints to 345–655 kg CO_2-eq/m^3 for poplar-based MDF and 292–771 kg CO_2-eq/m^3 for bagasse-based MDF. These results emphasize the importance of appropriately accounting for biogenic carbon storage in GHG footprint calculations of long-lived bio based products." **Seyedeh Masoumeh Hafezi, Hamid Zarea-Hosseinabadi, Mark A.J. Huijbregts, and Zoran J.N. Steinmann,** *Cleaner Environmental Systems*. (Subscription may be required.)

PUBLICATIONS *(cont.)*

Analyzing how forest-based amenity values and carbon storage benefits affect spatial targeting for conservation investment.

The following is from the abstract of this article: "[The authors] analyze how two different ecosystem services: forest-based amenity values and carbon storage benefits, affect spatial targeting for conservation investment for protected area acquisition using selected forest clusters in Knox County, Tennessee in the United States. [The authors] determine return-on-investment (ROI) for these two different forest-based ecosystem services by estimating amenity values and carbon storage amounts using hedonic price model and dynamic Terrestrial Ecosystem Model (TEM), respectively, and corresponding acquisition costs at the forest cluster level. [The authors'] findings of the optimal protected area acquisition in the form of forest clusters serve as an empirically informed knowledge base to help both the conservation and planning agencies in prioritizing acquisition of potential protected areas depending on their preferences. By using carbon and amenity ROIs in spatial targeting of forest clusters within the multi-objective optimization set up, [the authors] not only addressed the spatial heterogeneity in the carbon storage benefits and amenity values but also the spatial heterogeneity in cluster acquisition costs. [The authors] also found that selection decisions were dictated by the weakly negative correlation (–0.16) between the carbon and amenity ROIs instead of weakly positive correlation (0.14) between carbon storage benefits and amenity values. Since the spatial distribution of carbon and amenity ROIs were weakly negatively correlated, there were apparent conflicts between the objectives of maximizing forest carbon storage and amenity value. This resulted in concave frontiers with tradeoffs between the objectives implying variation in spatial distribution of the selected forest clusters letting the conservation and planning agencies decide combination of strategies which best fit their preferences." **Bijay P. Sharma and Seong-Hoon Cho,** *Forest Policy and Economics*. (Subscription may be required.)

What is different about different net-zero carbon electricity systems?

The following is from the abstract of the article: "In deeply decarbonized electricity systems with significant shares of variable renewable energy, the additional availability of at least one firm electricity generating technology can overcome reliability challenges and substantially reduce electricity costs. Firm resources can operate at any time of the year and for as long as needed to maintain electricity system reliability. Low- and zero-carbon firm technologies include flexible resources with high variable and low capital costs, such as biogas or hydrogen combustion, capital-intensive resources with low or zero variable cost, including nuclear and geothermal, as well as intermediate resources such as natural gas plants with carbon capture and sequestration (CCS). This paper explains the distinct roles of nuclear, CCS, and combustion of zero-carbon fuels in decarbonized electricity systems as examples of each class of firm resources. [The authors] analyze and compare results from three long-term electricity system capacity expansion models for California and the U.S. Western Interconnection, demonstrating robustness of [the authors'] conclusions to different model assumptions and domains. Individually, each firm technology delivers substantial cost reductions relative to portfolios restricted to wind, solar, and energy storage alone. Additionally, because each technology occupies a distinctive functional niche in the electricity system, having all of these technologies available optimizes the utilization rate of each resource and reduces system costs by up to 10% relative to cases with just one class of firm resource. The analysis highlights the benefits of an expansive range of technology options to meet emissions reductions goals for the power sector while maintaining operational reliability and affordability." **Ejeong Baik, Kiran P. Chawla, Jesse D. Jenkins, Clea Kolster, Neha S. Patankar, Arne Olson, Sally M. Benson, and Jane C.S. Long,** *Energy and Climate Change*. (Subscription may be required.)

Filter Cake Removal during the Cementing and Completion Stages in CO_2 Storage Wells: Current Developments, Challenges, and Prospects.

The following is from the abstract of this article: "Carbon capture and storage (CCS) technology has become one of the most cost-effective and promising ways to achieve global climate change mitigation goals. The CO_2 storage capacity in depleted oil and gas reservoirs is currently the safest and most economical option. The long-term sealing of the cement–formation interface in CO_2 storage wells (CSW) is essential to avoid CO_2 leakage. The filter cake easily affects the interfacial sealing ability, which is a thin impermeable layer formed by drilling fluid residue or solid particles remaining on the borehole wall due to permeable formation. Filter cake removal is essential for favorable cementation and production efficiency. This study highlights the current developments and the main challenges for oil- and water-based mud filter cake removal during the cementing and completion process. Moreover, research ideas and recommendations for various types of filter cake removal are proposed to provide a reference for future work. This information helps deepen understanding with respect to the different filter cake removal options available in the CCS industry and provides a knowledge base that can facilitate the improvement of the cementing quality and production efficiency of existing systems to combat battle CSW safety and production efficiency problems." **Jin Li, Sheng Huang, Zao-Yuan Li, Jian Liu, Xu-Ning Wu, Dong-Hua Su, and Wei-Tao Song,** *Energy Technology*. (Subscription may be required.)

An Advanced Discrete Fracture Methodology for Fast, Robust, and Accurate Simulation of Energy Production from Complex Fracture Networks.

The following is from the abstract of this article: "Fracture networks are abundant in subsurface applications (e.g., geothermal energy production, CO_2 sequestration). Fractured reservoirs often have a very complex structure, making modeling flow and transport in such networks slow and unstable. Consequently, this limits [the] ability to perform uncertainty quantification and increases development costs and environmental risks. This study provides an advanced methodology for simulation based on Discrete Fracture Model (DFM) approach. The preprocessing framework results in a fully conformal, uniformly distributed grid for realistic 2D fracture networks at a required level of precision. The simplified geometry and topology of the resulting network are compared with input (i.e., unchanged) data to evaluate the preprocessing influence. The resulting mesh-related parameters, such as volume distributions and orthogonality of control volume connections, are analyzed. Furthermore, changes in fluid-flow response related to preprocessing are evaluated using a high-enthalpy two-phase flow geothermal simulator. The simplified topology directly improves meshing results and, consequently, the accuracy and efficiency of numerical simulation. The main novelty of this work is the introduction of an automatic preprocessing framework allowing [the authors] to simplify the fracture network down to required level of complexity and addition of a fracture aperture correction capable of handling heterogeneous aperture distributions, low connectivity fracture networks, and sealing fractures. The graph-based framework is fully open-source and explicitly resolves small-angle intersections within the fracture network. A rigorous analysis of changes in the static and dynamic impact of the preprocessing algorithm demonstrates that explicit fracture representation can be computationally efficient, enabling their use in large-scale uncertainty quantification studies." **S. de Hoop, D. V. Voskov, G. Bertotti, and A. Barnhoorn,** *Water Resources Research*. (Subscription may be required.)

ABOUT DOE'S CARBON STORAGE PROGRAM

The **Carbon Storage Program** at the National Energy Technology Laboratory (NETL) is focused on developing and advancing technologies to enable safe, cost-effective, permanent geologic storage of CO_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***.

Get Social with Us

There are several ways to join the conversation and connect with NETL's Carbon Storage Program:

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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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