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

CSN CARBON STORAGE NEWSLETTER

APRIL 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 Announces Federal Funding for Projects that Advance Associated Geologic Storage.

The U.S. Department of Energy's (DOE) *Office of Fossil Energy (FE)* announced Federal funding for cost-shared research and development (R&D) projects that will address technical research needs and key challenges in advancing associated geologic storage within DOE's *Carbon Storage Program*. Under Funding Opportunity Announcement (FOA) DE-FOA-0001829, "*Developing Technologies for Advancement of Associated Geologic Storage in Basinal Geo-Laboratories*," the National Energy Technology Laboratory (NETL)-managed projects will advance technologies in storage complexes in diverse geologic settings. This FOA focuses on R&D specific to various basins representing diverse geologic settings throughout the United States where opportunities for associated storage exists. From *energy.gov* on April 10, 2018.

NETL-Managed Project Stores One Million Tons of CO_2.

The NETL-managed Midwest Regional Carbon Sequestration Partnership (MRCSP) has safely and permanently stored one million metric tons of carbon dioxide (CO_2). MRCSP stored the CO_2 into a series of depleted oil fields in northern Michigan, USA, for enhanced oil recovery (EOR) operations. The project developed novel approaches for monitoring CO_2 in fields that were in different stages of their production life cycles. Techniques were then tested to track the CO_2 and quantify the amount that is retained after the oil is removed. The data can be used to further optimize CO_2 storage and energy production in other areas, and the work furthers the understanding of the subsurface by assessing potential storage capacity and validating computer models of the subsurface geology. From *energy.gov* on March 12, 2018.

ANNOUNCEMENTS

DOE Announces Carbon Storage Program Funding Opportunity.

DOE's FE announced the availability of funding for cost-shared R&D projects in support of FE's Carbon Storage Program. The projects, which will be selected under DE-FOA-0001826, "*Developing Technologies to Advance the Understanding of State of Stress and Geomechanical Impacts within the Subsurface*," will help to ensure safe and permanent geologic storage of CO_2, reduce risks, and inform policy associated with carbon storage operations. The NETL-managed projects will focus on two areas of interest: "Tools and Methods for Determining Maximum Principal Stress in the Deep Subsurface," which seeks projects to develop tools and methods for determining in-situ stress state in the deep subsurface, and "Methods for Understanding Impact of Vertical Pressure Migration Due to Injection on the State of Subsurface Stress," which seeks projects that will predict and compare with field observations the temporal and spatial stress and pressure changes in the underburden.

NETL Releases CCSI Toolset.

NETL's *Carbon Capture Simulation Initiative (CCSI)* released the CCSI Toolset as open-source software, making it available for researchers in industry, government, and academia. The CCSI Toolset is a suite of computational tools and models designed to help maximize learning and reduce cost and risk during the scale-up process for carbon capture technologies.

CCSI² Carbon Capture Simulation for Industry Impact

Federal Budget Bill Includes Carbon Tax Credits.

Tax credits for carbon storage were included in a recently passed *budget bill*. For every qualifying project, the 45Q tax incentive will generate a tax credit of $50 per ton of CO_2 in underground storage and $35 per ton of CO_2 for utilization or EOR.

ANNOUNCEMENTS *(cont.)*

Scottish Government Recognizes CCS in Publication.

The Scottish government released its *Climate Change Plan*, which sets out specific policies and proposals for meeting Scotland's potential targets. According to Scottish Carbon Capture and Storage (SCCS), the plan recognizes the potential importance of carbon capture and storage (CCS) in reducing greenhouse gas (GHG) emissions.

SaskPower CCS Surpasses Milestone.

The CCS process at SaskPower's Boundary Dam Power Station in Estevan, Saskatchewan, has prevented more than 2 million metric tons of CO_2 from entering the atmosphere since operations began in 2014. SaskPower's strategy is to reduce its GHG emissions by 40 percent from 2005 levels by 2030.

RGGI States Comment on Proposed Virginia Regulation.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) submitted comments on program elements identified in Virginia's (USA) proposed regulations for emissions trading. The comments focus primarily on regulatory compatibility and address Virginia's meeting of the definition of an RGGI Participating State, as set forth in the *2017 Model Rule*.

Boundary Dam Power Station
(image courtesy of SaskPower)

PROJECT and BUSINESS DEVELOPMENTS

DOE Funds Monitoring of Underground Carbon Storage.

DOE is funding a carbon storage monitoring project that will use a novel, real-time monitoring system to track the spread of CO_2 underground. Researchers from Penn State University (PSU), Lawrence Berkeley National Laboratory (LBNL), and the University of Texas at Austin are partnering on the project, which will investigate underground storage in a reservoir, such as a saltwater aquifer or a mineral deposit, using real-time monitoring equipment that is installed during the construction of an injection well. From *Penn State University* on March 14, 2018.

Carbon Capture Utilization Demonstration Plant Opens in UK.

Econic Technologies has opened a carbon capture utilization plant in the United Kingdom (UK) to demonstrate the conversion of CO_2 into plastics. The new demonstration plant, located in the North of England, will be able to produce samples of CO_2-based polyols at lower, industrially relevant temperatures and pressures (previously, the creation of polyols from CO_2 had been performed in plants at high pressures and temperatures). Econic Technologies' catalysts allow manufacturers to reuse waste CO_2 by incorporating it as a feedstock. From *Carbon Capture Journal* on March 1, 2018.

Organizations Collaborate to Advance CCUS.

Two Canadian and Chinese organizations have agreed to collaborate on the development of carbon capture, utilization, and storage (CCUS) technologies to reduce GHG emissions. CMC Research Institutes (CMCRI) and the Guangdong CCUS Centre in China will promote joint R&D, advance the commercialization of CCUS, support training and education through workshops and conferences, and encourage the development of joint projects at the Guangdong CCUS Centre and MCMRI's Carbon Capture and Conversion Institute in Richmond, British Columbia, Canada. The Memorandum of Understanding (MOU) was signed at the 2nd Canada-China CCUS Forum held by Natural Resources Canada. From *JWN Energy* on March 15, 2018.

CCS Study Initiated at Refinery.

Preem, a Swedish fuel company, has initiated a CCS study at their refinery in Lysekil, Sweden. The study is expected to be conducted in spring 2018 and will examine the possibility of building a demonstration plant that will capture CO_2 at Preem's refinery. The west coast geographical location of the refinery exhibits a connection to the Norwegian full-scale CCS project. The overall goal, according to Preem officials, is a full-scale CCS capture plant at the refinery, and then transport of the liquified CO_2 by boat to the planned CCS hub on the Norwegian west coast for permanent storage in a formation below the seabed. From *Carbon Capture Journal* on March 1, 2018.

Australian Government Awards CO_2 Storage Contract.

The Government of Victoria in Australia awarded a contract to AGR Australia to manage its CarbonNet Offshore Appraisal Well Drilling Program. In addition to being responsible for the well engineering, design, supervision, and execution, AGR Australia will also manage the health, safety, and regulatory aspects of the project. The CarbonNet project is investigating the potential for establishing a large-scale CCS network that would unite multiple CO_2 projects in the Australian state's Latrobe Valley, transporting the CO_2, via pipeline, for injection into underground offshore storage sites in Gippsland (Victoria, Australia). From *Offshore Technology* on March 5, 2018.

LEGISLATION and POLICY

Bill Supporting CCUS Introduced.

Legislation to promote carbon utilization and direct air capture R&D has been introduced in Congress. The "*Utilizing Significant Emissions with Innovative Technologies Act*" (USE IT Act) supports Federal, state, and non-governmental collaboration in the development and construction of CCUS facilities and CO_2 pipelines. The legislation would support carbon utilization and direct air capture research, clarify that CCUS projects and CO_2 pipelines are eligible for the permitting review process, direct the Council on Environmental Quality (CEQ) to establish guidance at CCUS facilities and CO_2 pipelines, and establish task forces to update and improve guidance over time. From *Daily Energy Insider* on March 26, 2018.

North Dakota Approved as Carbon Storage State.

The U.S. Environmental Protection Agency (EPA) granted North Dakota (USA) primacy over Class VI injection of CO_2 for long-term storage, making it the first state in the Nation to receive final EPA approval to regulate the geologic storage of CO_2. North Dakota initiated preparations for primacy after the North Dakota legislature gave the Industrial Commission's Oil and Gas Division regulatory authority over geologic carbon storage in 2009. Geologic storage of CO_2 is regulated under the Safe Drinking Water Act's Underground Injection Control Program and is classified as Class VI injection (also known as CCS). From *Bakken.com* on April 10, 2018.

EMISSIONS TRADING

RGGI States Announce Results of 39th Auction.

The RGGI-participating states released the results of their 39th auction of CO_2 allowances, in which 13,553,767 CO_2 allowances were sold at a clearing price of $3.79. Bids ranged from $2.20 to $5.80 per allowance at the auction. None of the 10 million cost containment reserve (CCR) allowances were sold (CCR is a fixed additional supply of allowances only available for sale if CO_2 allowance prices exceed certain price levels [$10.25 in 2018]). Auction 39, the first auction of the fourth control period, generated $51.4 million for reinvestment in strategic programs, such as energy efficiency, renewable energy, and GHG abatement programs. To date, proceeds from all RGGI CO_2 allowance auctions have generated $2.89 billion. From *RGGI News Release* on March 16, 2018.

Britain Announces ETS Plans.

According to Britain's Energy Minister, the country intends to remain in Europe's emission trading system (ETS) until at least the end of Phase III, which runs from 2013 through 2020. Britain has a legally binding target to reduce GHG emissions by 80 percent from 1990 levels by 2050. From *Reuters* on March 21, 2018.

China's Carbon Trading Pilot Boosts Emissions Control.

China's carbon trading system has helped the country reach its 2020 carbon emissions target in 2017, according to officials. China committed to reducing its CO_2 emissions by 40 to 45 percent from 2005 levels by 2020; however, this target was reached early, as China reduced CO_2 emissions by 46 percent from 2005 levels by the end of 2017. China's carbon emissions trading system was initiated in 2011, and transactions totaling 200 million metric tons of carbon emissions quotas were completed via the platform by 2017. According to its next commitment, China will have to reduce CO_2 emissions by 60 to 65 percent from 2005 levels by 2030. From *Xinhua* on March 27, 2018.

CLIMATE and SCIENCE NEWS

Hunting Squid Slowed by Rising CO_2 Levels.

Australian scientists have found that potentially higher levels of oceanic CO_2 may impact the hunting patterns of cephalopods, a group of highly active invertebrates that includes squid, cuttlefish, and octopuses. Led by the James Cook University (JCU) ARC Centre of Excellence for Coral Reef Studies, the investigative group tested the effects of elevated CO_2 on the hunting behaviors of pygmy squid and bigfin reef squid, finding a decrease in the pigmy squids' attacking of prey. When either species of squid did attack, they did so from a further distance and at a slower speed. In addition, both species displayed "more conspicuous body patterns" and increased activity when they were not hunting, which scientists believe could be a result of elevated CO_2 levels altering their "energy budgets." From *Phys.Org* on March 21, 2018.

Study Links Policy, Carbon Emissions from Permafrost.

According to researchers from the U.S. Geological Survey (USGS) and the University of Alaska Fairbanks Institute of Arctic Biology, controlling GHG emissions through policy could reduce potential consequences of carbon releases from thawing permafrost during the next 300 years. Scientists used simulations to study changes in permafrost and carbon storage in the northern permafrost region from 2010 to 2299 using two separate potential scenarios – one with low CO_2 emissions and one with high CO_2 emissions. The results led scientists to believe that GHG controls could lessen the effects on the release of carbon from soils. The study, titled "*Dependence of the evolution of carbon dynamics in the northern permafrost region on the trajectory of climate change*," was published in the journal *Proceedings of the National Academy of Sciences*. From *Eurasia Review* on March 27, 2018.

New Research Studies Underground CO_2 Abatement.

New research has provided a quantifiable look at carbon trapping rates in basalt, providing a baseline to scale-up. Working in collaboration with Pacific Northwest National Laboratory (PNNL), researchers from Washington University in St. Louis collected samples of the rock from Washington state, where a thousand tons of CO_2 gas was previously injected into an underground basalt flow. The rocks were then placed in small reactors to simulate underground conditions and injected with CO_2 to test the variables involved in the carbonization process. Using 3-D imaging, the scientists watched the CO_2 precipitate into the mineral and studied the voids within the basalt it filled, as well as the spots in the rock where the carbonization process began. Once the data were collected and analyzed, scientists predicted 47 kilograms of CO_2 can be converted into mineral inside one cubic meter of basalt. From *Phys.Org* on April 5, 2018.

JOURNAL ARTICLES

Comparative analysis of transport and storage options from a CO_2 source perspective.

The following is the Abstract of this article: "This study evaluated integrated CCS costs from the perspective of a CO_2 source. A source will have captured CO_2 requiring suitable storage and affordable transportation between source and storage. Capture, transport, and storage are the links of the CCS value chain. For this study, capture costs were modeled for six hypothetical sources (various industrial and power-generation facilities) with annual CO_2 capture rates ranging from 0.65 to 3.90 million [metric tons (Mt)]. Seven storage reservoirs located in the Appalachian, Illinois and Gulf Coast Basins—and of various quality with respect to CO_2 storage—were modeled: two within the Rose Run Formation, three within the Mount (Mt.) Simon Formation, one in the Lower Tuscaloosa Formation, and one in the Frio Formation. Storage costs were calculated with the FE/NETL CO_2 Saline Storage Cost Model for the seven selected storage reservoirs under dome and regional dip structural settings. For transportation, a dedicated pipeline system and a trunkline pipeline system were modeled. Transportation costs from source to storage reservoirs were evaluated using the FE/NETL CO_2 Transport Cost Model. A source may not always be able to find suitable proximal storage. Low CCS costs reflect a source's mass of captured CO_2 finding suitable storage within an affordable transportation distance. Economies of scale are present in each link of the CCS value chain. These economies of scale are limited with respect to storage or the distance captured CO_2 can be transported to storage." **Timothy Grant, Allison Guinan, Chung Yan Shih, ShangMin Lin, Derek Vikara, David Morgan, and Donald Remson,** *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Timescapes of CCS Projects: Is Deferring Projects and Policies Just Kicking the Can Down the Road?

The following is the Abstract of this article: "CCS is considered a transition measure to a completely sustainable energy regime. Nonetheless, in recent years, several projects have been cancelled or postponed. This raises some questions about temporal issues. This study defines temporal features (i.e. frame, timing, tempo, and duration) for policy making and deployment of large-scale CCS projects. According to this study, it appears that CCS deployment is lagging behind due to institutional inertia and poor temporal fit. Thus, unless significant progress is made in a very few years, CCS will lose ground to other alternatives. Timing should be taken into consideration in every matter of CCS." **Farid Karimi,** *Energy Procedia*. (Subscription may be required.)

Efficiency of Carbon Dioxide Storage and Enhanced Methane Recovery in a High Rank Coal.

The following is the Abstract of this article: "The high affinity and adsorption capacity of coal to [CO_2] provides an alternative approach for the enhanced recovery of methane from unminable coalfields (CO_2-[enhanced coalbed methane (ECBM)]) by which a potential solution for long-term CO_2 sequestration in deep geological formations can also be achieved. However, due to chemomechanical effects induced by the interactions between CO_2 and coal, the effective methane production and [CO_2] storage can be degraded which has caused uncertainties about the techno-economic feasibility of the CO_2-ECBM process. This study presents an experimental investigation that aims to address key knowledge gaps related to the efficiency of CO_2 storage and [methane (CH_4)] recovery in high rank coals for which a comprehensive experimental data set and analysis are largely missing. Competitive displacements of CH_4 with [nitrogen (N_2)] or CO_2 in an anthracite coal sample from a South Wales coalfield have been studies, based on a series of core flooding experiments. The results show that the N_2 breakthrough time (the time at which 1% of the total gas injected was recovered) was almost spontaneous whereas a considerably delayed breakthrough time was observed for the case of the CO_2-ECBM experiment. In addition it was observed that for the CO_2-ECBM experiment, the ratios of CH_4 recovery with respect to the total amount of gas injected and gas stored were higher by factors of 10 and 2.4, respectively. The results also show that 90% of the total N_2 injected was produced in the outflow gas, whereas for the case of the CO_2 experiment, only 63% of the total injected CO_2 was produced. The presence of a high amount of N_2 in the outflow may lead to additional challenges in order to separate N_2 from CH_4 and thus affect the efficiency of the N_2-ECBM method. Under the conditions of the experiments, the total CH_4 displacement ratio and breakthrough for the case CO_2-ECBM were found to be more favorable compared to those obtained from N_2-ECBM. This study provides new insights into the efficiency of the CO_2-ECBM process and offers a comprehensive experimental data set that can be used for testing the accuracy of predictive models." **Mojgan Hadi Mosleh, Majid Sedighi, Philip J. Vardon, and Matthew Turner,** *Energy Fuels*. (Subscription may be required).

A plant tolerance index to select soil leaking CO_2 bio-indicators for carbon capture and storage.

The following is the Abstract of this article: "Plant response to the leakage of stored CO_2 is a key concern for safe CCS. An understanding of plant tolerance to high soil CO_2 concentrations is urgently required to facilitate bio-indicator selection for both long-term environmental monitoring and prevention of stored CO_2 leakage. In this study, [the authors] propose a new index, the Leaking CO_2 Tolerance Index, LCTI, which assesses plant CO_2 tolerance using the change (downward shift) in index values under leakage treatments. The calculated LCTI reveals that, of the four studied plants, clover was the most tolerant (0.42), followed by alfalfa (0.4), teosinte (0.33), and finally maize (0.29). [The authors'] results suggest that clover, along with other high-LCTI species, should be selected as species that can potentially adapt and respond to CCS leakage. Furthermore, plants such as maize appear suitable as bio-indicators to monitor carbon storage fields, allowing early detection of CO_2 leakage." **Xueyan Zhang, Xin Ma, Yang Wu, Qinzhu Gao, and Yue Li,** *Journal of Cleaner Production*. (Subscription may be required.)

Potential for using municipal solid waste as a resource for bioenergy with carbon capture and storage (BECCS).

The following is the Abstract of this article: "Bioenergy with Carbon Capture and Storage (BECCS) is a carbon removal technology that offers permanent net removal of CO_2 from the atmosphere. One of the significant bioenergy resources is organic waste collected from municipal solid waste (MSW). The goal of this study was to provide an estimate of the global potential for using municipal solid waste as a resource for BECCS and to compare the feasibility of two specific BECCS options: municipal solid waste incineration with carbon capture and storage (MSW-CCS), and landfill gas combusted in a gas turbine with carbon capture and storage (LFG-CCS). To assess the feasibility of MSW-based BECCS options, techno-economic and environmental impact assessments were conducted. In the case of a 'business-as-usual' scenario with no emission policy in effect, the [levelized] cost of electricity production from both BECCS options is higher than a coal power plant with CCS. However, these BECCS systems offer a lower cost of avoided CO_2. Introducing renewable energy certificates or negative emission refund schemes to BECCS has a significant impact on the economic viability of these technologies in coal-dominant power markets. Environmental impact assessment shows that around 0.7 kg CO_2-eq is removed for each kg of wet MSW incinerated, for the MSW-CCS scenario. This translates to approximately negative 2.8 billion tonnes CO_2 if all the available 4 billion tonnes MSW generated per year by 2100 is [utilized] in a MSW-CCS system. The net GHG emission of the LFG-CCS system with an average LFG collection rate of 75% was 0.56 kg CO_2-eq. Challenges include the dispersed nature of MSW resources and the lack of economic support schemes, such as commonly apply to solar and wind. Nonetheless, MSW-based BECCS technologies have significant potential for abating and in some cases removing considerable amounts of the [GHGs] from the atmosphere, thereby contributing significantly to the COP21 emission reduction targets." **Nasim Pour, Paul A. Webley, and Peter J. Cook,** *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

JOURNAL ARTICLES *(cont.)*

The cost of conserved water for coal power generation with carbon capture and storage in Alberta, Canada.

The following is the Abstract of this article: "The impact of CCS technology on the coal-fired power generation was evaluated in this paper. The impact was measured through the cost of conserved water (CCW) as an indicator. This indicator was estimated by combining water demand coefficients and levelized cost of electricity (LCOE). CCW was calculated based on a reference case for each of the developed 66 generic pathways of coal-based power generation with CCS. The current existing mix of power generation in the Province of Alberta, Canada was taken as the reference case in this paper. Water consumption coefficients for coal-based power generation with CCS were found in the range 1.01–4.85 m^3/MWh based on the complete life cycle and 0.15–3.65 m^3/MWh for the power generation stage. Based on the complete life cycle boundary, pathways involved ultra-supercritical configuration and oxyfuel combustion CCS technology offer the lowest CCW, with values less than 0.89 USD per m^3 of water saved for consumption and less than 0.66 USD per m^3 of water saved for withdrawals. In the sensitivity analysis, LCOE for the pathways involved dry cooling was increased by 6.00 USD/MWh over the base case value, and the resulted corresponding increase in the CCW was found in the range 9–33% compared to the base case." **Babkir Ali,** *Energy Conversion and Management*. (Subscription may be required.)

Interactions and coordination between carbon emissions trading and other direct carbon mitigation policies in China.

The following is the Abstract of this article: "China has decided to rely on a variety of policy approaches to achieve its ambitious [GHG] mitigation targets, with carbon emissions trading as the latest policy alongside many existing policies, such as GDP CO_2 intensity reduction, energy efficiency and renewable energy policies. This article is intended to elucidate from a qualitative perspective the interactions between emissions trading and other relevant policies in China through the analysis of their elements, policy processes, characteristics, dimensions, performances and impacts. Intensive interviews were conducted with more than 50 major stakeholders involved in the policy formulation and implementation process, including policy makers at different levels, experts, industries and verifiers. The authors themselves were also deeply involved in the policy formulation and implementation process. The analysis shows that coordination between emissions trading and other policies, which is urgently needed from many aspects, is lacking in most aspects in practice for many reasons, among which institutional vested interests are possibly the most important. It is proposed that coordination should be conducted at both political and technical levels to achieve the full benefits of emissions trading, and starting from technical aspects may be a practical approach." **Maosheng Duan, Zhiyu Tian, Yongqiang Zhao, Mengyu Li,** *Energy Research & Social Science*. (Subscription may be required.)

Remanufacturing with trade-ins under carbon regulations.

The following is the Abstract of this article: "Observing prevalent concerns about the influence of carbon emissions on climate change, [the authors] address the problem of remanufacturing with trade-ins under carbon regulations. [The authors] analyze the optimal pricing and production decisions of the manufacturer under the carbon tax policy and the cap and trade program. The results show that the introduction of carbon regulations can promote sales of remanufactured products while reducing the demands of new products. However, the implementation of carbon regulations has negative impacts on the manufacturer's profits. Nevertheless, the manufacturer's profits can be improved through deliberately designed government subsidy schemes. [The authors] also demonstrate that the government has the incentive to propose such subsidy schemes because the total emissions can be reduced under well-designed regulations, but not at the cost of the manufacturer's profits." **Zhaowei Miao, Huiqiang Mao, Ke Fu, and Yu Wang,** *Computers and Operations Research*. (Subscription may be required.)

REPORTS and OTHER PUBLICATIONS

Reduced-Order Models for Prediction of Groundwater Quality Impacts from CO_2 and Brine Leakage – Application to the High Plains Aquifer.

Los Alamos NATIONAL LABORATORY | NATIONAL ENERGY TECHNOLOGY LABORATORY | Pacific Northwest NATIONAL LABORATORY | Lawrence Livermore National Laboratory | BERKELEY LAB

NRAP Technical Team

The following is the Executive Summary of this National Risk Assessment Partnership (NRAP) document: "In this study, modeling was performed to represent the complex hydrogeological and geochemical conditions in a heterogeneous aquifer by using two separate reduced-order models (ROMs). The first ROM is derived from a high-fidelity model that accounts for the heterogeneous flow and transport conditions in the presence of multiple leakage wells. This ROM, developed by Lawrence Livermore National Laboratory (LLNL) takes into account uncertainties related to flow, transport, and leakage parameters; however, this ROM has a simplified representation of chemical reactions. The second ROM is obtained from models that feature greatly simplified flow and transport conditions, but allow for a more complex representation of all relevant geochemical reactions. This ROM, developed by LBNL takes into account uncertainties related to chemical parameters and reactions. Both ROMs specifically address the physical and chemical properties of the High Plains Aquifer.

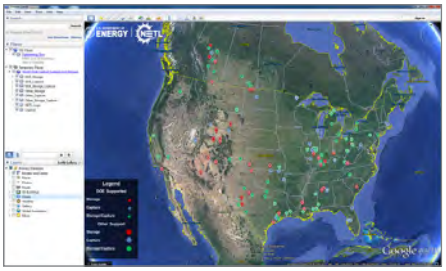
Neither ROM can separately provide an accurate prediction of the risk profile volume because of the simplifications inherent in these models. Accurate prediction could be achieved with a very complex three-dimensional (3-D) reactive transport model; however, this model would be quite demanding computationally. Therefore, development of an alternative approach that allows linking of the two ROMs and, in particular, a correction of the risk profile volumes estimated by the two separate ROMs, was conducted. The development of a linking function was accomplished by: (1) the establishment of two simple models — a one-dimensional (1-D) model with homogenous flow and transport field and single leakage point, but including as many chemical reactions as possible—and a two-dimensional (2-D) model considering aquifer heterogeneity but no reactions; (2) the development of a complex model that incorporates all the parameters and physical and chemical processes of both simple models; (3) multiple runs of both simple and complex models; and (4) estimation of the linking functions based on those runs. This report describes the development and usage of the ROMs and linking function."

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



The *National Energy Technology Laboratory's CCS Database* includes active, proposed, and terminated CCS projects worldwide. The information is taken from publically available sources to provide convenient access to information regarding efforts by various industries, public groups, and governments towards development and eventual deployment of CCS technology. NETL's CCS Database is available as a Microsoft Excel spreadsheet and also as a customizable layer in Google Earth.

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.

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

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

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

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

WEBSITE: *www.netl.doe.gov*

CUSTOMER SERVICE: 1-800-553-7681

Contacts

Traci Rodosta
304-285-1345
traci.rodosta@netl.doe.gov

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