SSAE Newsletter

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// ABOUT

The Strategic Systems Analysis and Engineering (SSAE) directorate provides the decision science and analysis capabilities necessary to evaluate complex energy systems. The directorate's capabilities address technical, economic, resource, policy, environmental and market aspects of the energy industry. These capabilities are critical to strategic planning, direction and goals for technology R&D programs and the generation of market, regulatory and technical intelligence for NETL senior management and DOE. SSAE offers a range of multi-criteria and multi-scale decision tools and approaches for this support:

- Process systems engineering research: advanced modeling, simulation and optimization tools for complex dynamic systems
- Process and cost engineering: plant-level synthesis, process modeling and simulation of energy systems with performance estimates
- Resource and subsurface analysis: evaluation of technologies, approaches and regulations for subsurface energy systems and storage
- Market and infrastructure analysis: economic impacts and program benefits
- Environmental life cycle analysis: cradle-to-grave emissions and impacts

These tools and approaches provide insights into new energy concepts and support the analysis of energy system interactions at the plant, regional, national and global scales.

// HIGHLIGHTS

SSAE's LCA Team Finalizes Alaskan LNG Greenhouse Gas Emissions Study

The final Supplemental Environmental Impact Statement (SEIS) evaluating environmental effects of the Alaska LNG Project was published by DOE. Proposed by the Alaska Gasline Development Corporation, the project would commercialize natural gas resources from the Alaska North Slope for export as liquified natural gas (LNG) by Alaska LNG Project LLC and for domestic use.

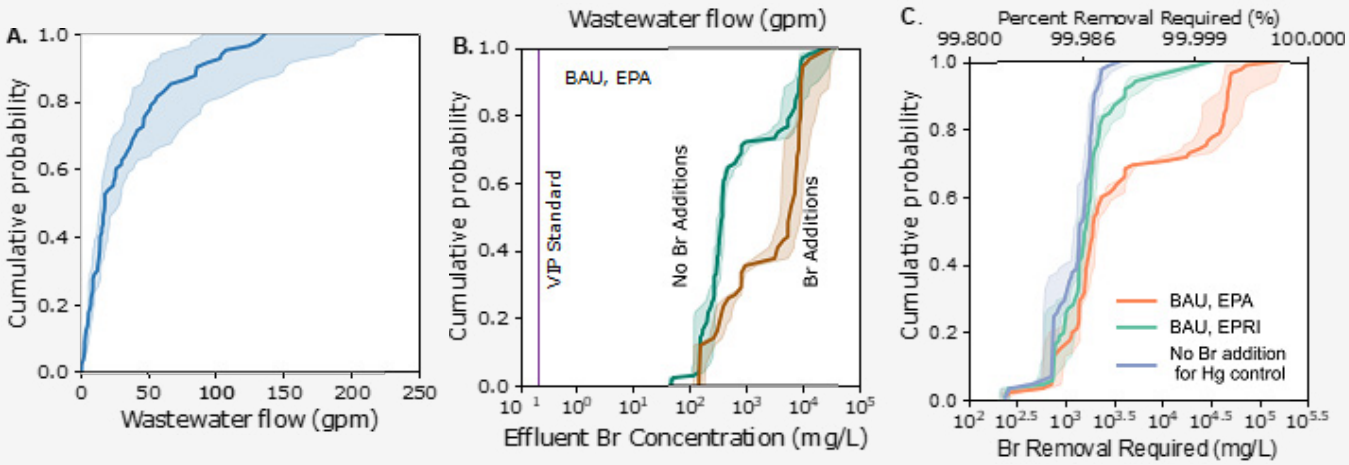
Revisions in response to public comments received in July and August of 2022 were included in the final SEIS, which also included revisions by life cycle analysis (LCA) researchers Timothy Skone, Harshvardhan Khutal*, Matthew Jamieson and H. Scott Matthews* to the report "Life Cycle Greenhouse Gas Emissions from the Alaska LNG Project." Results for the social cost of greenhouse gas emissions (social cost of carbon [SCC]) and use of alternative Global Warming Potential (GWP) methods were added. To analyze SCC, speciated emissions on an annual basis for multiple emission categories, including emissions from the nine-year project construction schedule, were specified. Results from GWP methods presented in the Intergovernmental Plan on Climate Change Fifth Assessment Report and Six Assessment Report were also incorporated.

Like the draft SEIS, the final SEIS concluded that two proposed scenarios, one sequestering carbon dioxide (CO_2) from the gas treatment plant in a reservoir and another using CO_2 for enhanced oil recovery, would not increase emissions relative to the business-as-usual scenario (BAU) of current Alaska North Slope oil production and U.S. Lower 48 natural gas production and export.

Aqueous Bromide Discharges from U.S. Coal-Fired Power Plants Characterized in Recent Paper

Bromide discharges from coal-fired power plants have received increased attention from regulatory bodies due to their contribution to the formation of disinfection by-products in downstream drinking water treatment plants. Although no mandatory federal bromide emission standards currently exist, the U.S. Environmental Protection Agency (EPA) has established voluntary standards that some coal-fired power plants are choosing to adopt, and utilities are also increasingly having to control bromide emissions to comply with local permitting requirements.

A recently published paper co-authored by SSAE researchers Alison Fritz, Chad Able* and Eric Grol characterized the relative contributions of bromide from coal feedstocks and bromine-based mercury (Hg) control processes, estimated the distribution of bromide concentrations at 85 active coal-fired power plants across the United States with wet flue gas desulfurization (FGD) units and estimated the cost of bromide removal from wastewater discharge. Bromide discharges were estimated at the plant level using a combination of the reported coal rank and composition combusted, estimates of bromide addition in Hg control techniques under multiple halogen addition scenarios and the estimated FGD wastewater flow rate. The study suggests that application of the best available technology would need to remove more than 99.8% of bromide to reach a voluntary federal emission limit of 0.2 mg/L. The total cost of treatment depends on whether waste disposal is on- or off-site; the average costs for all plants combined come to an average of $110 million ($95.2/kgal) in 2021 U.S. dollars for on-site disposal, or $134 million ($115/kgal) for off-site disposal. Although the EPA does not currently regulate bromide emissions, it is anticipated that it will in the future. This work is expected to be an important technical and cost resource that may be the basis for any rulemaking that will occur.



Simulated distributions in the year 2020 for A. FGD wastewater flow rates, B. concentration of bromide (Br) in FGD wastewater effluent for all plants that do not add Br (teal) and plants adding Br for Hg control (brown) and C. required Br removal to meet voluntary standards under three scenarios

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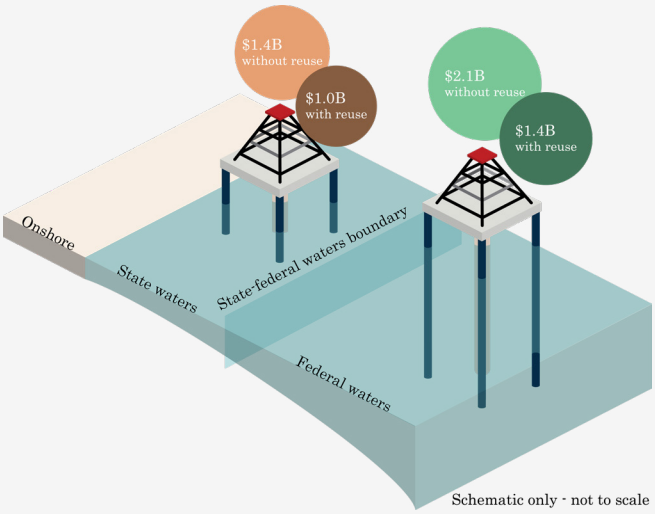
// HIGHLIGHTS cont'd

Offshore Pilot-Scale Projects for Storing CO_2 in the GoM Explored in Initial Assessment

As the United States moves toward a decarbonized future, management strategies for CO_2 emissions, such as carbon capture and storage (CCS), will become vital. Storing CO_2 from a source (e.g., fossil-fueled power plant or industrial facility) is part of the CCS process. Besides onshore CO_2 storage, offshore CO_2 storage can also be an option for sources looking to store their CO_2 for several reasons including its additional resource potential and location away from population centers. However, offshore CO_2 storage is still exploratory, particularly in the United States, with limited assessments of offshore resources available. Given this notion, it is important to understand the challenges and gaps pertaining to technical and logical/feasibility requirements for deploying CCS in the offshore to facilitate the development of offshore pilot- and commercial-scale projects.

Geologic and technical requirements for offshore saline storage of CO_2 in the GoM were assessed in a recent study by SSAE's Subsurface Analysis Team for two conceptual pilot-scale CO_2 injection sites that were high-graded for evaluation (one in federal waters and one in Texas state waters) to demonstrate the feasibility of storing CO_2 in geologic formations in the Gulf of Mexico (GoM). Subsequent commercial-scale projects would store greater than pilot-scale quantities of CO_2. Geologic, technical and cost parameters were evaluated at each location, with both sites being determined suitable for an injection rate of 0.5 million tonnes/year for 12 years. Exploratory evaluation of project costs indicates that the reuse of existing oil and gas infrastructure could potentially offer a cost reduction from $2.1 billion to $1.4 billion for the federal waters scenario and $1.4 billion to $1.0 billion for the Texas state waters scenario (see figure below). However, these project costs are preliminary estimates and could be higher or lower depending on modeling assumptions including (but not limited to) costs to retrofit, inspect and repair existing equipment and types of equipment selected in modeling cases.

Ongoing and future work may include (but is not limited to) identifying main cost drivers, exploring cost regression development for trend analysis and coordinating with the Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement on data sharing efforts.



Offshore CO_2 storage costs for federal waters and Texas state waters scenarios estimated from initial modeling with potential cost savings by reusing existing infrastructure

Staff Spotlight

Victoria Toetz*, who joined in February 2022, has supported SSAE's Energy Markets Analysis Team by working on projects related to tracking electricity prices, quantifying U.S. biogas supply and assessing energy storage economics. She is looking forward to working on new projects this upcoming year, building on existing work and answering questions related to decarbonization and our energy future.

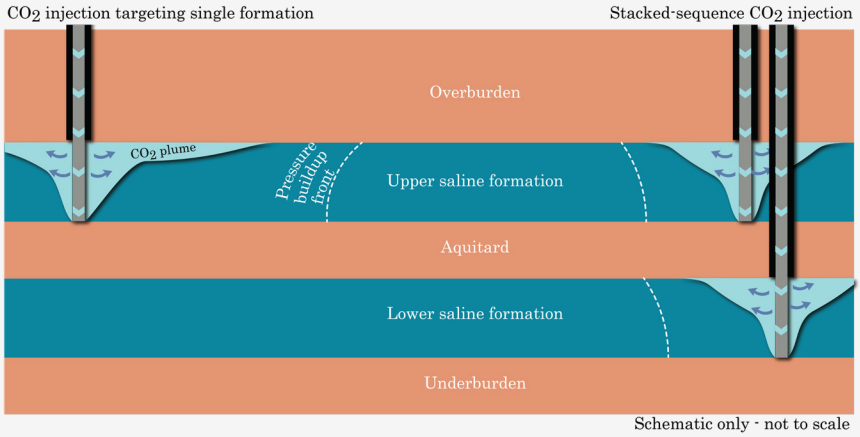
In the summer of 2019, Victoria first worked at NETL as a Mickey Leland Fellow for SSAE's John Brewer. During that summer, she looked at how water emissions in the Electric Reliability Council of Texas changed under different market conditions. She spent a second summer at NETL (virtually) in 2021 as an Energy Efficiency and Renewable Energy Intern looking at how greenhouse gas emissions changed based on balancing authority when grid scale energy storage was deployed.

Victoria received her bachelor's degree in Physics from Wittenberg University and her master's degree in Mechanical Engineering from the University of Colorado Boulder.

// NOTICES

SSAE Investigates CO_2 Storage in Stacked Sequence of Saline Formations

Large-scale decarbonization using CCS is likely to involve many commercial-scale CO_2 storage projects in close proximity that inject CO_2 from many sources. The potential proximity of projects raises concerns over pressure interference between adjacent operations. Pressure interference between injection and storage efforts can reduce the practicable CO_2 storage resource and force wells to inject CO_2 at lower rates to avoid fracture pressure thresholds per EPA Class VI well regulations meant to preserve injection and confining zone integrity and mitigate the risk of induced seismicity.



General schematic of multi-layered subsurface formations to illustrate CO_2 injection into a single, deep saline formation (left) and a stacked sequence of deep saline formations (right).

SSAE's Subsurface Analysis Team has started looking into this situation by modeling CO_2 injection and storage into a stacked sequence of saline formations to evaluate how stacked injection can help alleviate pressure interference among nearby injection wells. Initial modeling indicates that stacked injection could help reduce the resulting pressure buildup by approximately 46% in comparison to injection targeting a single formation. Initial findings also highlight that stacked injection could reduce the CO_2 aerial footprint. This analysis draws attention to the importance of greater coordination among storage operators and regulatory stakeholders to foster the upscaling and deployment of CCS.

Analysis Provides Assessment of Carbon Capture Retrofits for Cement Plants

In response to the Portland Cement Association's expressed interest in developing further analyses for cement plant CO_2 capture systems during their technical review of the "Cost of Capturing CO_2 from Industrial Sources" report, SSAE has performed a more in-depth analysis of solvent-based capture costs at a variety of representative cement kilns across a range of realistic operating conditions. This retrofit analysis evaluates the effects of kiln fuel types, kiln configurations, CO_2 capture heat sourcing potential at the host plant, increasing values of sulfur oxide and nitrogen oxide contaminants from the kiln and false air ingress into the emissions stream. It also illustrates how key industry operating conditions (including the effects of air ingress, fuel type, kiln configuration and flue gas pre-treatment) affect capital and operating costs, as well as the costs associated with the purchase of supplemental natural gas and electric power (which is an additional cost burden for industrial CO_2 capture applications, typically not appearing in electric power capture cases).

An updated revision of the "Cost of Capturing CO_2 from Industrial Sources" report, which evaluated nine representative industrial plants (including a cement manufacturing facility) to determine the levelized cost of CO_2 capture, was published in September 2022. Cement plant CO_2 emissions represent an impactful source for decarbonization efforts, and alongside DOE goals for net zero emissions by 2050, the Portland Cement Association's dedication to emissions reductions, as outlined in their "Roadmap to Carbon Neutrality – A more sustainable world is Shaped by Concrete," allows for collaborative analyses between industry leaders and SSAE. The retrofit analysis is a potential start to more collaborative analyses and will serve as a point of comparison for similar cement cases employing alternative capture technologies such as an in-progress techno-economic analysis of membrane capture at cement plants.

SIP Site Tour Provides Opportunities

The Bruce Mansfield Power Plant, located in Shippingport, Beaver County, Pennsylvania, 30 miles northwest of Pittsburgh, began operating its first unit in 1976. The plant's three coal-fired units had the capacity to generate 2,500 MW of power. After 43 years of providing power to the PJM area, the Bruce Mansfield Plant closed its doors in 2019. The Frontier Group of Companies (FGC) purchased the plant and associated property in 2022 with the intent to bring new economic development to the area by repurposing the property into a world class industrial park for which the project could attract well over $2 billion of private investment.

// NOTICES cont'd

In January 2023, DOE employees from various national laboratories (including NETL SSAE's Erik Shuster) and Headquarters, met with FGC for a discussion and site tour of the former Bruce Mansfield Power Plant, newly renamed Shippingport Industrial Park (SIP). The purpose of the meeting was to provide an overview of the company, discuss what activities DOE is doing in the energy asset transformation space and review where FGC currently is with their recent acquisition. The site is being decommissioned and remediated. This process includes entering the site into the state's voluntary remediation program. SIP presents a tremendous opportunity for new development that will restore the investments and jobs that have characterized the site for decades.

This meeting was arranged in support of DOE's Energy Asset Transformation program. Created in 2022, this program intends to reuse and revitalize retired energy assets, including fossil, which provide economic benefits to those communities with recently lost, energy-related industries.

// UPCOMING CONFERENCES AND EVENTS

SSAE federal staff and NETL support contractor personnel will attend or present at the following conferences and events in March 2023:

- MINEXCHANGE SME 2023 Annual Conference & Expo
  Participant: Thomas Tarka
  Denver, CO, February 26–March 1, 2023
- 2023 Permian Basin Water in Energy Conference
  Presenter: Markus Drouven
  Midland, TX, February 28–March 2, 2023
- CERAWeek 2023
  Participant: Justin Adder
  Houston, TX, March 6–10, 2023
- 5th European sCO_2 Conference for Energy Systems
  Presenter: Sandeep Pidaparti* – Performance and Cost Potential for Direct-Fired Supercritical CO_2 Natural Gas Power Plants
  Prague, Czech Republic, March 14–16, 2023

// RECENT PUBLICATIONS

Articles

- V. Dabadghao, J. Ghouse, J. Eslick, A. Lee, A. Burgard, D. Miller and L. Biegler, "A complementarity-based vapor–liquid equilibrium formulation for equation-oriented simulation and optimization," *AIChE Journal*, e18029, 2023.
- A. Fritz, C. Able, M. Mauter and E. Grol, "Aqueous Bromide Discharges from U.S. Coal-Fired Power Plants: Points of Origin, Concentration Ranges, and Effluent Treatment Costs," *Energy & Fuels*, vol. 37, no. 5, pp. 3854–3864, 2023.
- A. Atia, J. Allen, E. Young, B. Knueven and T. Bartholomew, "Cost optimization of low-salt-rejection reverse osmosis," *Desalination*, vol. 551, article 116407, April 2023.
- R. Tumbalam Gooty, J. Ghouse, Q. Minh Le, B. Thitakamol, S. Rezaei, D. Obiang, R. Gupta, J. Zhou, D. Bhattacharyya and D. Miller, "Incorporation of market signals for the optimal design of post combustion carbon capture systems," Applied Energy, vol. 337, article 120880, May 2023.

* NETL Support Contractor

// RECENT PUBLICATIONS cont'd

Model/Tool

- National Energy Technology Laboratory, "NETL UPGrants LCA Guidance Toolkit," National Energy Technology Laboratory, Pittsburgh, PA, January 31, 2023.

Reports/Supporting Documentation

- N. Wijaya, D. Vikara, K. Bello, R. T. Vactor, M. Tarhoni, T. Grant, D. Morgan and L. Cunha, "Exploratory Analysis of Offshore CO_2 Storage Pilot Project in the Gulf of Mexico: Geologic, Infrastructure, and Cost Considerations," National Energy Technology Laboratory, DOE/NETL-2023/3818, Pittsburgh, PA, December 9, 2022.
- National Energy Technology Laboratory, "Basis for Techno-Economic Analysis – Carbon Utilization Procurement Grants," National Energy Technology Laboratory, DOE/NETL-2023/3838, January 30, 2023.
- K. Bello, D. Vikara and L. Cunha, "Evaluating Production Implications of Pressure Maintenance in Unconventional Oil and Gas Wells using a Machine Learning Modeling Approach: Case Study in the Permian Basin," National Energy Technology Laboratory, DOE/NETL-2023/4379, Pittsburgh, PA, January 31, 2023.
- M. Krynock, M. Jamieson and T. Skone, "NETL UPGrants Addendum to the CO2U LCA Guidance Toolkit," National Energy Technology Laboratory, DOE/NETL-2023/3840, Pittsburgh, PA, January 31, 2023.
- National Energy Technology Laboratory, "NETL UPGrants LCA Report Template," National Energy Technology Laboratory, Pittsburgh, PA, January 31, 2023.

Conference Proceedings and Events

- D. Carlson, M. Krynock, S. Roman-White, G. Cooney and T. Skone, "Modeling the Life Cycle Impacts of U.S. Coal Mining at a Regional Level," presentation at the International Symposium on Sustainable Systems and Technology (ISSST) 2018 Conference, Buffalo, NY, June 27, 2018, revisions made January 20, 2023.
- M. Turner, "NETL's Updated Performance and Cost Estimates for Power Generation Facilities Equipped with Carbon Capture," presentation (presentation video) for USEA Webinar, Virtual, February 2, 2023.

// REFERENCE SECTION

Models / Tools / Databases

Carbon Capture Simulation Initiative (CCSI) Toolset

FECM/NETL CO_2 Transport Cost Model

FE/NETL CO_2 Saline Storage Cost Model

FE/NETL CO_2 Prophet Model

FE/NETL Onshore CO_2 EOR Cost Model

Life Cycle Analysis Models

NETL CO2U LCA Guidance Toolkit

NETL UPGrants LCA Guidance Toolkit

IDAES Integrated Platform

IDAES Power Generation Model Library

Pulverized Coal Carbon Capture Retrofit Database (CCRD)

Natural Gas Combined Cycle CCRD

Industrial Sources CCRD

Key Reports

Baseline Studies for Fossil Energy Plants

Cost of Capturing CO_2 from Industrial Sources

Quality Guidelines for Energy System Studies

Life Cycle Analysis

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