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 Providing Support to NETL Partners on Three Hydrogen Hub Projects

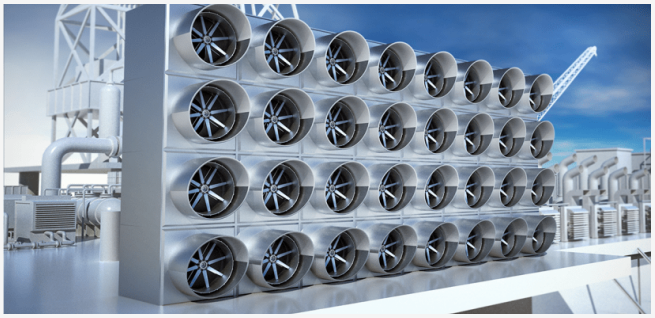
NETL recently announced partnerships "with major industry groups on three of the regional hydrogen hub projects selected by the U.S. Department of Energy (DOE) to accelerate the commercial-scale deployment of low-cost, clean hydrogen": Appalachian Regional Clean Hydrogen Hub (ARCH2); West Virginia, Ohio, Pennsylvania; HyVelocity; Gulf Coast and Heartland Hydrogen Hub (HH2H); Minnesota, North Dakota, South Dakota. Given NETL's long history in carbon management, NETL sought to partner with any proposed hub project that used natural gas to produce hydrogen and store captured carbon dioxide (CO_2) in the subsurface. NETL's systems analysis competencies will evaluate the reduction in CO_2 intensity, prospects for technology advances, workforce issues, and overall competitiveness of hub concepts.

After successful award negotiations, the selected Hub projects, will enter an 18-month Phase 1 period where multiple assessments designed to establish that the Hydrogen Shot goal of $1/kg of clean hydrogen can be achieved. During this period, NETL's Strategic Systems Analysis and Engineering (SSAE) team will offer cross-cutting institutional experience, already-developed tools, methodologies, frameworks, and studies that support technology assessments, for instance Life Cycle Analyses (LCA) and techno-economic analyses (TEA) , as well as economic assessments including energy justice impacts that evaluate market advancement. As each Hydrogen Hub progresses through separately evaluated stage gates toward $1 Billion-plus over 8-plus years, they'll also conduct resource assessments; technology and systems evaluations; Technology Development Demonstrations; and Policy Analysis. These needs are closely aligned with SSAE's mission to employ rigor in systematic decision-making techniques that aim to balance the competing goals of an energy system while accounting for market and policy factors within environmental and technical constraints.

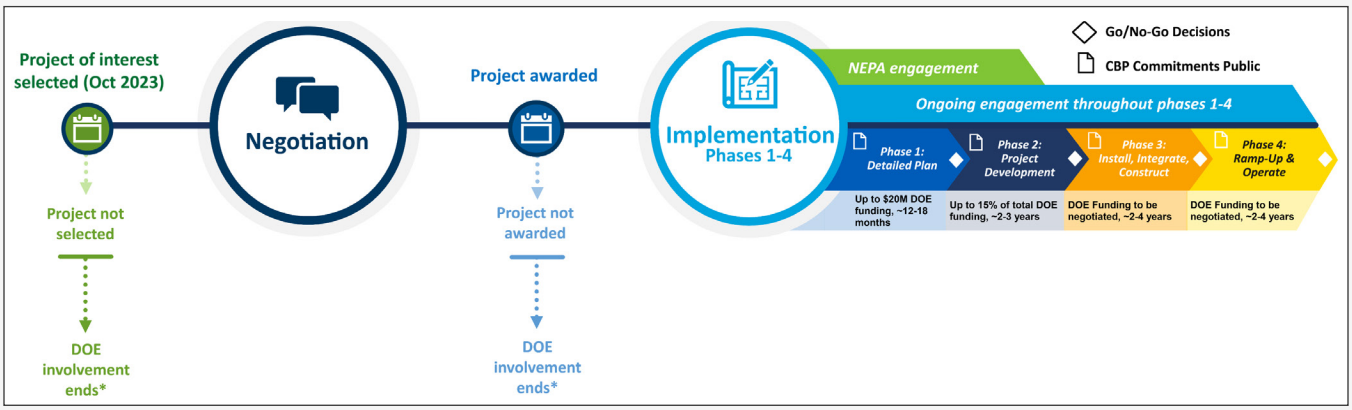
NETL may enter into cost recovery cooperative research and development agreement (CRADA)s with these teams in pursuit of a successful Phase 1 and subsequent project phases. Secondary benefits will likely accrue to NETL through enhancements to its own capabilities with its engagement in this work. Learn more.

Report Finds Promise in Pairing Nuclear Reactors with Direct Air Capture Systems

A new U.S. Department of Energy report finds that nuclear reactors can offer substantial benefits when paired with direct air capture (DAC) systems. The study — conducted by the DOE Office of Nuclear Energy (NE) Systems Analysis and Integration Campaign, with contributions from Argonne National Laboratory, Idaho National Laboratory and NETL SSAE researchers Timothy Fout and Hari Mantripragada — analyzed the performance and costs of using waste heat and carbon-free electricity from advanced-reactor nuclear power plants (NPP) for direct air capture (DAC) systems. A low-temperature solid sorbent DAC (S-DAC) and a high-temperature liquid solvent DAC system (L-DAC) were analyzed. An S-DAC system uses waste heat and electricity from NPP while an L-DAC system uses electricity from NPP and heat from natural gas combustion.



Results for the S-DAC system showed that a 1-gigawatt thermal nuclear power plant can provide enough energy to support the removal of 1.0 to 1.5 million metric tons of CO_2 per year, where the range is due to the different operating temperatures of the three types of nuclear reactors considered with the higher temperature advanced reactors supporting the higher CO_2 removal rates. The L-DAC results showed a net removal of 12 to 15 million tons of CO_2 per year when using the same size nuclear plant combined with an additional 2.2 to 2.7 gigawatts of heat energy from natural gas, where capture of emissions generated by the natural gas combustion is accounted for. When compared to previous NETL studies of DAC systems paired with fossil sources of energy, using a nuclear reactor could decrease the levelized cost by 8 to 13 percent for solid sorbent DAC and 5 to 7 percent for liquid solvent DAC. Learn more.



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NETL's Life Cycle Analysis Team Models Hydrogen Production Pathways

The study modeled eleven hydrogen production pathways from cradle-to-gate including upstream energy and material inputs, water treatment to meet purity requirements of hydrogen technologies, and downstream sequestration of captured carbon as applicable. Modeling of water treatment for hydrogen production is a novel aspect of this study.

Biomass gasification exhibited lower carbon intensity and higher water consumption than fossil-based and electrolysis pathways. The overall greenhouse gas potential and water consumption impact of electrolysis technologies depended largely on upstream electricity generation. For nearly all pathways, carbon capture and storage lowered carbon intensity and increased water consumption. Contributions to total water consumption from losses in the water treatment train ranged from 1% for biomass pathways to about 10% for traditional steam methane reforming.

SSAE researchers Megan S. Henriksen*, H. Scott Matthews*, John White*, Eric Grol, and Matthew Jamieson, as well as Timothy Skone from DOE Headquarters, conducted the study, "Tradeoffs in life cycle water use and greenhouse gas emissions of hydrogen production pathways," that was published in the *International Journal of Hydrogen Energy*. The results can inform decision-makers about the environmental performance of hydrogen production technologies and their potential to help meet decarbonization and other sustainability goals.

Examining Mitigation of Flow Oscillations in Supercritical CO_2 Cycle Operations

The supercritical CO_2 (sCO_2) recompression closed Brayton cycle (RCBC) is a promising flexible, high-efficiency technology to produce power from numerous heat sources, including nuclear, concentrated solar, fossil, and waste heat recovery applications. To advance this technology, the U.S. Department of Energy created the Supercritical Transformational Electric Power (STEP) program, a project to design, construct, commission, and operate an sCO_2 pilot plant test facility in both simple-cycle and 10 MWe RCBC configurations. Researchers at NETL have been examining operational control scenarios such as load ramping, shutdown, and warm startup of this cycle using a dynamic model. As load ramp rates are increased and closer load setpoint following is attempted, oscillatory flow conditions intensify. This phenomenon has been noted by other works in literature, both modeling and experimental.

In the paper, "Control methods for mitigating flow oscillations in a supercritical CO_2 recompression closed Brayton cycle," published in *Applied Energy*, multiple control approaches that mitigate oscillations were examined during load ramping operation. For a load ramp rate of 7.5% MW/min, Fig 1(a) shows the significant increase in system oscillations and the negative impact on ability to maintain close load tracking (PV MW) of the load setpoint (SP MW) as the inventory is removed from the cycle to an inventory storage tank (IST) as indicated by tank pressure (OP bar). One of the approaches, tested by SSAE researchers Eric Liese, Jacob Albright* and Stephen Zitney, uses control of a valve on the CO_2 primary cooler bypass line. The result is shown in Fig. 1(b), which demonstrates the ability to mitigate oscillations and get closer load setpoint following. This option would be available for STEP, and thus could be used should oscillations become problematic. Learn more.

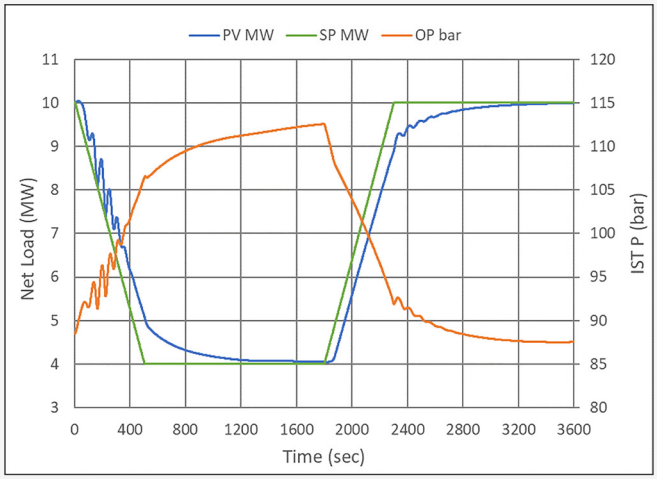

Figure 1(a). Load ramping results for base case using aggressive tuning

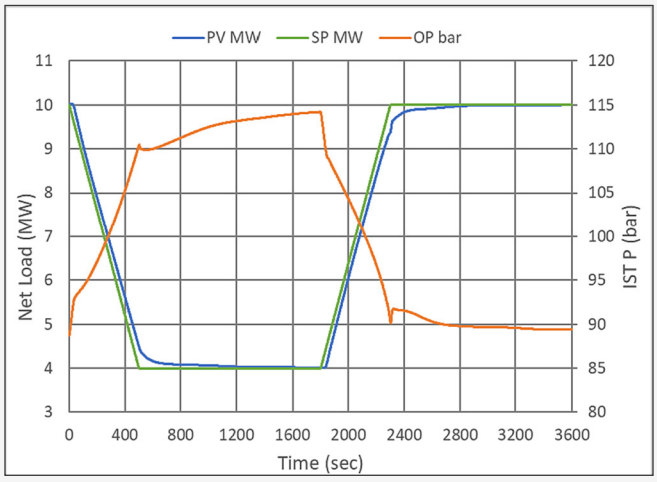

Figure 1(b). Load ramping results for sCO_2 bypass control

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Moving bed CCS with MOF can be competitive compared to conventional MEA solvent-based capture processes for NGCCs

This paper, "Isotherm modeling and techno-economic analysis of a TSA moving bed process using a tetraamine-appended MOF for NGCC applications," discusses a novel development of property and process models for a tetraamine-appended metal-organic framework (MOF) applied to carbon capture on a natural gas combined cycle (NGCC) power plant. A novel isotherm model of a dual, step-like isotherm is presented and applied to a process-scale moving bed process and optimized to minimize the total annualized cost of an NGCC plant with capture. Moving beds have an advantage over fixed bed contactors as they can be operated as a continuous process, as opposed to a batch process for fixed bed systems. Additionally, driving forces for adsorption are maximized because of the counter-current flow of the solids and gases. This paper describes a unique capability in applying sorbent/MOF based materials to a difficult-to-model solid-gas contactor that is not available in commercial modeling tools. Furthermore, the process model was optimized via the Carbon Capture Simulation Initiative (CCSI) Toolset. This work was presented at GHGT-16 in Lyon, France, and was selected for a full publication.

Want to learn more about SSAE's work?

Click here to see previous SSAE newsletter issues

Staff Spotlight

For nearly two years Jack Suter* has supported SSAE mainly working with the Energy Markets Analysis Team. His work is focused on the clean energy transition through critical mineral supply and demand analyses and various carbon-related projects. The team is working to develop volume and cost guidelines to help inform R&D opportunities that are seeking to extract critical minerals from secondary sources (e.g., coal refuse, bauxite residue, titanium dioxide acid waste, and produced water). Jack was a principal author of the "Carbon Capture, Transport, & Storage Supply Chain Deep Dive Assessment," and presented it at the USAEE Conference in Houston in October of 2022. He has done strategy work for the Center for Sustainable Fuels and Chemicals and had an internship at the Naval Undersea Warfare Center in Newport, RI, serving as a test engineer for propulsion systems.

Jack was born and raised in the small rural town of Chester in the rolling hills of northern New Jersey. He received his BS in Mechanical Engineering with a Minor in Electrical Engineering from the University of Vermont, graduating in May of 2020. Having gained valuable experience becoming an Eagle Scout in his youth, Jack continues to enjoy the outdoors through a myriad of activities like mountain biking, snowboarding, backpacking, hiking, and photography. Most recently he hiked rim-to-rim in the Grand Canyon, enjoying a dip in the Colorado River at the bottom.

* NETL Support Contractor

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NETL Presents on Carbon Capture Technologies at A&WMA MEGA Symposium

The Electric Power Transformation: 2023 MEGA Symposium, sponsored by the Air and Waste Management Association (A&WMA) was held in Pittsburgh, PA on September 26-27, 2023. The symposium has a 20+ year history, with this year's event focusing on the transition of the energy generation industry to cleaner, climate resilient electric power that can remain cost-effective and reliable. The conference provided technical information, solutions, and insights on policy developments, methods for managing compliance, and new technologies/ environmental controls.

SSAE Associate Director Peter Balash participated in a plenary session dedicated to key issues for clean and reliable energy. In his presentation, Balash discussed reliability and decarbonization of the power sector with a focus on resource adequacy and resilience.

SSAE's Gregory Hackett presented a high-level overview of the status and challenges associated with carbon capture technologies. The presentation focused on the current development of solvent-, sorbent-, and membrane-based capture technologies that reduce carbon emissions from point sources or remove carbon dioxide directly from the environment, depending on the application. The presentation included information and references to recently released NETL technical reports on direct air capture and carbon capture retrofit cost and performance analysis. The presentation was part of the "Carbon Capture and Storage" track.

SSAE Researchers Present at Post Combustion Conference

Co-hosted by NETL and the International Energy Agency's Greenhouse Gas Programme, the 7th Post Combustion Capture Conference was held on September 25-27, 2023, in Pittsburgh, PA. The conference covered all topics associated with post-combustion capture including process analysis, solvent degradation, environmental effects, and related capture topics (including carbon dioxide removal). The conference had 188 attendees from 17 countries. NETL's Deputy Director and Chief Research Officer David Miller gave a plenary address on the first day of the conference. Learn more.

Presentations given by SSAE staff are as follows:

- Timothy Fout presented "Techno-economic Analysis of Sorbent-Based Direct Air Capture," a high-level summary of a previously released report on sorbent-based DAC, along with some recent updates focused on the natural gas combined cycle (NGCC) that provides power and steam to the DAC system. The NGCC was updated to a specific frame size that can be purchased from the current market. The prior study utilized a "rubber turbine" that was representative of a hypothetical turbine size that could achieve the exact power and steam needs for the DAC system. Additionally, the capture rate of the post-combustion capture system utilized on the NGCC was increased to 97% to allow for minimization of gross DAC capture. Future work will focus on DAC sorbent cost, cycle time and other sensitivities.
- Fout also presented an "Examination of Factors Affecting the Cost and Performance of NGCC with CCS," focused on preliminary results from a study that exercised the NGCC F-Class Turbine with 95% capture case from Revision 4a of the "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity" report. The sensitivities calculated include a variety of ambient conditions (pressure, temperature, and relative humidity), construction parameters (labor rates, productivity, concrete and steel cost, seismic conditions, and contingency), and some additional effects (inflation indices, capacity factor, natural gas price, and financial assumptions). Results indicate that the costs associated with a capture retrofit highly depend on the site conditions, regulations, finances, and configuration. The assumptions used in the baseline report trend toward the lower end of the cost range.
- Sally Homsy presented work titled "Retrofitting Existing Fossil Power Plants with Post-Combustion Capture Technology: Insights from FEED Studies," which summarized five key learnings from the review of seven recent Office of Fossil Energy and Carbon-Management (FECM)-funded Front End Engineering Design (FEED) studies. These studies focused on the examination of retrofitting existing domestic NGCC and coal-fired power plants with carbon capture technology. The talk highlighted the factors that were found to impact the number of parallel capture trains required and noted that under recent market conditions, steam extraction from the host plant was favored over utilizing an auxiliary boiler for steam generation. The presentation also reported on different design approaches for addressing capture from a load-following host plant and recommended future work to address data gaps with regards to stack tie-in design, steam extraction tie-in design, solvent reclamation system design, and air emissions control system requirements.
- Ashley Cutshaw*presented a life cycle analysis of fossil fuel-fired power plant generation environmental impacts based on a study that evaluated the environmental performance of natural gas combined cycle, subcritical pulverized coal, and supercritical pulverized coal power plants with and without carbon capture and storage. The system boundary included fuel extraction, processing, and transport, power plant operations, electricity transmission and distribution, and CO_2 transport and storage (CCS).

  The model in this study incorporated updates from Revision 4a of the Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity published in 2022. The updates included increased net power output and increased capture rates across all plants.

* NETL Support Contractor

// NOTICES cont'd

Global warming potentials (GWP) for plants without CCS were dominated by plant operation emissions; with CCS, the largest contributors to GWP were fuel extraction, processing, and transport. Implementation of CCS resulted in increased environmental impacts except GWP and acidification potential for coal systems, and GWP alone for natural gas systems.

NETL machine learning and data analysis research to be featured at the AIChE 2023 Annual Meeting

Research from SSAE and collaborators within NETL's Research & Innovation Center (RIC) and West Virginia University (WVU) will be showcased at the 2023 American Institute of Chemical Engineers (AIChE) conference in Orlando, Florida, from November 5–10, 2023. The conference typically features a wide range of presentations, workshops, and discussions on various topics related to chemical engineering, including advancements in technology, process optimization, safety, sustainability, and research breakthroughs. The three papers to be presented focus on the application of petroleum data analytics in the context of shale oil and gas production, with a specific emphasis on the Permian Basin in West Texas. The research, conducted in collaboration with a major shale-field operator, explores innovative methods for optimizing field development planning, with a particular focus on optimizing hydrocarbon production and hydraulic inter-well communication, often referred to as "frac hits." This research provides valuable insights for optimizing oil and gas production and decision-making in the industry. SSAE researchers Derek Vikara*, Kolawole Bello*, Guoxiang Liu, and Luciane Cunha are co-authors. The presentations, which are pending publication are:

- "Integrating Public and Private Data for Modeling and Optimization of Shale Oil and Gas Production," is part of the "Unconventional Oil and Natural Gas: Science & Technology Advancement" session. It focuses on comparing the impact of proprietary data with publicly available data on machine learning predictive model performance. The study involved creating workflows and interactive tools to integrate data from diverse sources, both public and proprietary, and employing machine learning and artificial intelligence techniques to assess data quality, identify gaps, and optimize field development planning in near real-time. Using time-series data from the Permian Basin, neural network models were trained to predict daily production for oil, gas, and water (Figure 2). The results demonstrated the utility of the proprietary deep learning model, which achieved high accuracy in production forecasting. Additionally, scenario analysis revealed the economic implications of different pressure drawdown strategies, and further examination estimated significant annualized losses due to 'frac-hit' events in the field.
- "Commercial Applications of Petroleum Data Analytics Using Shale Oil and Gas Data Sets from Permian Operator," to be presented in the "Developments in Shale Gas and Natural Gas" session, focuses on addressing the impact of hydraulic fracturing fluid communication on fluid recovery efficiency. Employing a combination of machine learning techniques such as Random Forest, Fuzzy Set Theory, and Artificial Neural Networks, the research identified hydraulic communication between wells, considering temporal attributes and pressure measurements. The developed workflow showed the potential for near-real-time operational support, with a significant reduction in mean-squared-error as model complexity increased.
- "CCS-Analytics: Application of Artificial Intelligence for Carbon Dioxide Storage Systems," is scheduled for the Engineering Geologic Carbon Dioxide Storage Systems II session. It highlights the importance of using the correct version of artificial intelligence tailored to engineering-related problems, such as CCS-Analytics. It delves into the applications of AI, including smart proxy modeling and AI-based reservoir simulation, in optimizing carbon dioxide storage systems, emphasizing the need for domain expertise and field measurements to enhance the efficiency of these processes.

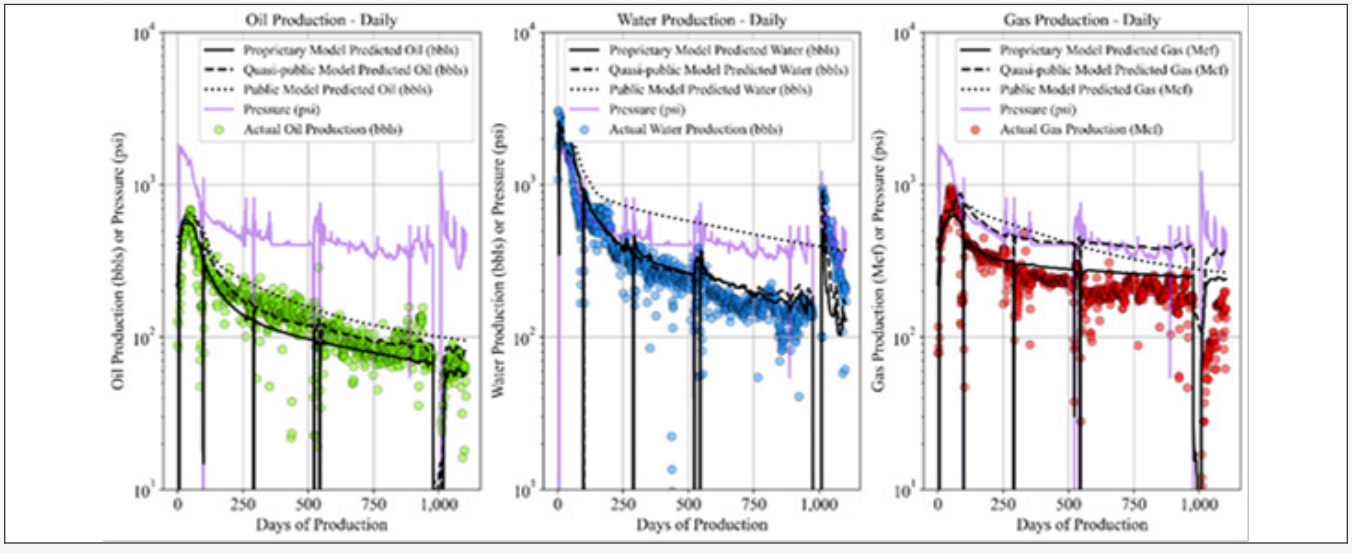

Figure 2. Daily production history for an interrupted well using the production prediction model variants

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Life Cycle Analysis Team Presents at ACLCA 2023

SSAE researchers presented work at the American Center for Life Cycle Assessment (ACLCA) 2023 Conference, held from September 25–28, 2023, in Burlington, VT. Learn more about the conference.

Presentations given by SSAE staff are:

- Megan Henriksen* presented a cradle-to-gate analysis of global warming potential (GWP) impacts associated with producing synthetic natural gas (SNG) from hydrogen (H_2) and captured carbon dioxide (CO_2) across H_2 production technologies, CO_2 sources, and methanation technology pathways. The choice of H_2 production technology was found to drive the carbon intensity of SNG, and biomass gasification with carbon capture exhibited lower impacts than conventional fossil natural gas. Methanation and electrolysis efficiency improvements were identified as recommendations to make SNG more competitive with fossil natural gas.
- Sheikh Moni* provided an overview of the NETL CO2U LCA Toolkit comprising LCA guidance, data, and tools to assist DOE-funded Principal Investigators and LCA practitioners in modeling pathways for converting CO_2 into environmentally responsible and economically viable products. He described addendums for the 45Q tax credit and The Utilization Procurement Grants program (UPGrants); the addenda provide additional instructions, tools, and templates for applicants pursuing these opportunities. Upcoming updates to the toolkit include expansion and improvements to the existing life cycle inventory database and modification of LCA guidelines and tools.
- Roksana Mahmud* presented findings from a review and compilation of over 60 existing environmental life cycle studies relating to critical minerals production. This research identified major geographical regions for mineral reserves and producers, primary products resulting from life cycles, and variations across studies in environmental impact analysis method, system boundary, production units, and data completeness. The study provided recommendations on mining operations, technological development, energy source and operating materials, environmental legislation, and inclusion of stakeholders.
- Matt Jamieson provided a sampling of NETL LCA projects over the past year. Topics included support for the DOE Loan Program Office and Utilization Procurement Grants; LCAs of critical minerals from waste flows, marine carbon dioxide removal, enhanced weathering; electricity baseline tools and updates; and the update to the NETL natural gas LCA baseline

SSAE Welcomes Sally Homsy

Sally Homsy is joining SSAE's Energy Process Analysis Team after working as an NETL site support contractor since March 2021. As a site support contractor, Sally led technoeconomic assessments of emerging and deployable carbon capture and carbon dioxide removal technologies. Sally holds a doctorate in Chemical Engineering from King Abdullah University of Science and Technology, in Saudi Arabia, a MS in Bioengineering, and a Bachelor of Chemical Engineering from the University of Dayton, in Ohio. Her experience spans experimental and system modeling work in the fields of carbon capture, carbon dioxide removal, biofuel production, wastewater remediation, and tissue engineering. Sally has worked in research labs in the U.S., Belgium, Saudi Arabia and Germany, and she enjoys being part of the global community working on addressing the challenges presented by a carbon-constrained world.

// PERSPECTIVES

Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile

For over 10 years, NETL has been evaluating the life cycle emissions of natural gas extraction and power generation. NETL will soon be releasing the latest version of the report titled *Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile*. This serves as the update to the last version of this report, which provided an LCA of 2016 natural gas emissions. This report provides the NETL perspective on what the life cycle emissions are for the average unit of natural gas, coming from the major U.S. production basins through various extraction technologies (the combination of basin and extraction technology referred to as a techno-basin), such as conventional wells, associated gas, tight gas, and hydraulic fracturing in shale wells. Cradle-to-gate lifecycle emissions profiles are provided for delivery of natural gas to large-scale end-users, to small-scale users (i.e., through the natural gas distribution system), and for electricity generation, including the current fleet of natural gas power plants and advanced technologies that include natural gas plants with post-combustion carbon dioxide capture, transport, and storage. Figure 3 provides the natural gas supply chain stages studied in this work.

// PERSPECTIVES (cont'd)

While the report focuses on greenhouse gas emissions with special emphasis on fugitive methane emissions throughout the life cycle, data are provided for a broad suite of emissions including various volatile organic compounds (VOCs), nitrogen oxides (NO_x), and sulfur oxides (SO_x).

As with previous iterations, the *NETL Natural Gas Lifecycle Model* published along with the report uses EPA's Greenhouse Gas Reporting Program data as its primary data source; however, when appropriate, these data are augmented by information from measurement-informed studies that improve upon data provided to the EPA. Additionally, this report includes the regionally specific transmission and distribution emissions based on source and destination regions as documented in this 2022 *Environmental Science & Technology* article. These data enable the present report to estimate GHG emissions associated with all the natural gas delivered to each of six broad areas—Southwest, Southeast, Midwest, Northeast, Rocky Mountain, and Pacific, rather being limited to a selected techno-basin.

This version of the report also provides unprecedented access to the various results. The number of techno-basins in multiple combinations for the delivery areas above total over one hundred. The life cycle inventory results associated with all these combinations and on the different life cycle boundaries of through transmission to a large-scale user, such as a power plant and through distribution, such as residential customers, are provided in multiple spreadsheet files so that users can access the life cycle inventory for their specific use case with relative ease.

Results of the report show significant decreases in greenhouse gas emissions relative to the previous report (LCA of 2016 natural gas emissions) and relative to the report Industry Partnerships & Their Role In Reducing Natural Gas Supply Chain Greenhouse Gas Emissions – Phase 2, which provided results using 2017 data. The major drivers for these reductions are from modeling choices in this version of the model mixed in with actual changes in reported emissions. For example, this version documents significant decreases in the amount of associated gas that eventually reaches end-users, indicating a much lower share of associated gas making it into the natural gas market. This results in increased shares for other techno-basins in the model, notably Appalachian shale, which exhibits some of the lowest emissions intensity of domestic natural gas production.

This work is the culmination of years of effort and SSAE is excited to provide this resource to life cycle analysts throughout the United States. These data will also serve as the basis for other tools and analyses currently under development. — Contributed by Matt Jamieson.

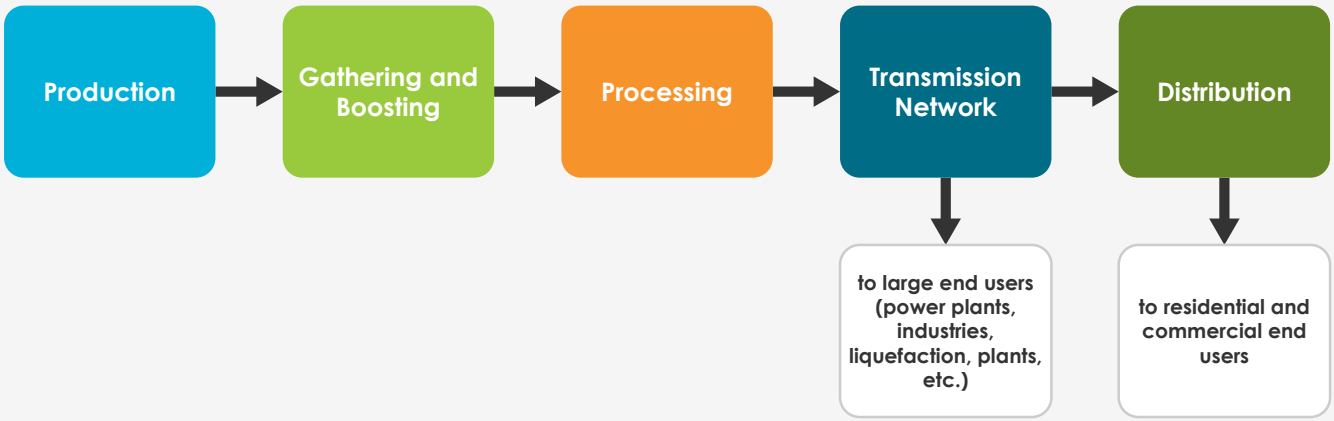

Figure 3. Supply chain stages that compose the overall study boundary

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// UPCOMING CONFERENCES AND EVENTS

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

- 2023 UTSR and Advanced Turbines Program Review Meeting
  Presenter: Eric Liese, NETL Activities in Supercritical CO_2 Systems Analyses
  Participants: Indrajit Bhattacharya, Bob Stevens
  State College, PA, October 30-November 1, 2023
- 2023 AIChE Annual Meeting
  Presenters: Joseph Chou* – Life Cycle Analysis Tools to Evaluate Environmental Footprint of Carbon Conversion Projects, Daison Yancy-Caballero* – Simulation and Sensitivity Analysis of a Cryogenic Carbon Capture System for the Cement Industry, Chad Able* – Assessment of Combustion Residual Leachate: Treatment Standards, Wastewater Volumes, and Critical Mineral Recovery, Radhakrishna Tumbalam-Gooty* – Optimal Design of Liquid Oxygen Storage System for Flexible Operation of a Direct-fired Supercritical CO_2 Power Cycle
  Participants: Luciane Cunha, Stephen Zitney, James Ferguson, Benjamin Omell
  Orlando, FL, November 5–November 10, 2023
- 40th Annual Meeting USAEE/ IAEE North American Conference, United States Association for Energy Economics
  Symposium Co-Chairs: Christopher Nichols, Amanda Harker Steele – Models, Data, and Analysis to Support Carbon Management
  Symposium Presenters: Gregory Hackett – Representation of Fossil Fuel Power Generation Technologies in NREL's Annual Technology Baseline, Eric Grol – An analysis of How the IRA's Section 45Q Tax Credit Impacts the Economics of Industrial CO_2 Capture
  Presenter: John Brewer – Dispatch informed hydrogen production
  Participants: Gavin Pickenpaugh, Justin Adder
  Chicago, IL, November 6–8, 2023
- National Carbon Capture Center Fall/Winter Meeting (non-public)
  Participant: Timothy Fout
  Birmingham, AL, November 7-8, 2023
- Stanford Natural Gas Initiative Annual Meeting
  Moderator: Peter Balash - Panel Session 3: Region-specific Gas Infrastructure Planning – Developing Fit-for-Purpose, Integrated Solution
  Participant: Alison Fritz
  November 8–9, 2023, Palo Alto, CA

// RECENT PUBLICATIONS

Articles

- J. Albright, S. Zitney, and E. Liese, "Control methods for mitigating flow oscillations in a supercritical CO_2 recompression closed Brayton cycle," *Applied Energy*, vol. 53, article 121922, December 2023 (available online September 16, 2023).

Conference Proceedings and Events

- P. Balash, "Reliability and Decarbonization Resource Adequacy and Resilience," National Energy Technology Laboratory, presented at Electric Power Transformation: 2023 MEGA Symposium on Energy, Environment, Policy, Technology; Pittsburgh, PA, September 27, 2023.
- G. Hackett, "Carbon Capture Technologies: Status and Challenges," National Energy Technology Laboratory, presented at Electric Power Transformation: 2023 MEGA Symposium on Energy, Environment, Policy, Technology: Pittsburgh, PA, September 26, 2023.
- S. Homsy, T. Fout, and G. Hackett, "Retrofitting Existing Fossil Power Plants With Post-Combustion Capture Technology: Insights From FEED Studies," National Energy Technology Laboratory, presented at IEAGHG Post Combustion Capture Conference (PCCC-7), Pittsburgh, PA, September 26, 2023.
- A. Cutshaw, J. Chou, D. Carlson, and R. James, "Life Cycle Analysis of Fossil Fuel Power Generation With Carbon Capture: NGCC, SC PC, and Sub PC," National Energy Technology Laboratory, presented at IEAGHG Post Combustion Capture Conference (PCCC-7), Pittsburgh, PA, September 27, 2023.

* NETL Support Contractor

// RECENT PUBLICATIONS cont'd

- S. Moni, J. Chou, M. Henriksen, J. Clarke, and M. Krynock, "National Energy Technology Laboratory CO_2 Utilization (CO2U) Life Cycle Analysis (LCA) Toolkit: Overview, Applications and Recent Updates," presented at ACLCA 2023 Conference, Burlington, VT, September 27, 2023.
- R. Mahmud, T. Davis, Priyadarshini, and S. Sam, "Toward a Sustainable LCA Framework for Rare Earth and Critical Mineral Production," presented at ACLCA 2023 Conference, Burlington, VT, September 27, 2023.
- M.S. Henrikson, S. Moni, J. White, J. Clarke, and M. Krynock, "Life Cycle Analysis of Synthetic Natural Gas Production via Carbon Conversion: Impact of Different CO_2, H_2, and Methanation Pathways," National Energy Technology Laboratory, presented at ACLCA 2023 Conference, Burlington, VT, September 26, 2023.
- C. Gounaris, A. Dowling, J. Sherman, J. Wang, A. Ostace, D. Allen, M. Zamarripa, A. Lee, J. Siirola, and J. Morgan, "Technical Risk Reduction: Model-Based Design of Experiments and Robust Optimization," presented at 2023 FECM/NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 31, 2023.
- D. Morgan, "Task 5: Developing a Tool to Quantify Liability of Geologic Carbon Storage," presented at 2023 FECM/NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 31, 2023.
- E. Grol, "Overview of Industrial CO_2 Capture Analysis at NETL," presented at 2023 FECM/NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 31, 2023.
- M. Mark-Moser, A. Choisser, J. Mulhern, K. Rose, "Data Science for International Offshore Carbon Capture and Storage," presented at 2023 FECM/NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 30, 2023.
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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

FECM/NETL Unconventional Shale Well Economic 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

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Cost of Capturing CO_2 from Industrial Sources

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