# 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

## NETL Releases Latest Update to Industrial Sources Report

A techno-economic analysis that examined the costs of retrofitting a variety of industrial processes with state-of-the-art carbon dioxide ($CO_2$) capture systems was recently released (learn more). The study examined the cost of capture for facilities in nine industries — ammonia, ethylene oxide, ethanol, natural gas processing, coal-to-liquids, gas-to-liquids, cement, hydrogen refining and iron and steel production (see figure below). The release of this information is important given major initiatives to decarbonize the economy by 2050, a priority goal of the Biden Administration.

Even in the absence of any regulatory driver, several of the industries evaluated already require separation of $CO_2$ as part of routine practice to generate a purified product. In these cases, the incremental cost of decarbonization is minimal because the separation of a high-purity $CO_2$ stream is already integral to the process. For the nine specific sectors evaluated, the high-purity cases tended to be in niche applications not responsible for significant industrial $CO_2$ emissions. Among the cases considered, the majority of United States (U.S.) industrial $CO_2$ emissions come from applications that do not already separate $CO_2$ emissions to generate purified products, but instead emit a gas stream that is relatively dilute in $CO_2$. Research guidance for many of these same sectors is also provided in the U.S. Department of Energy's (DOE) "Industrial Decarbonization Roadmap."

The report is accompanied by the Industrial CCRD, which is a spreadsheet database model populated with manufacturing facilities in five sectors, and its associated user's guide. The model allows users to estimate the cost of $CO_2$ capture retrofits on these units by specifying a variety of input parameters including capture rate, utility pricing (such as natural gas and additional purchased power) and expected final disposition of captured $CO_2$.

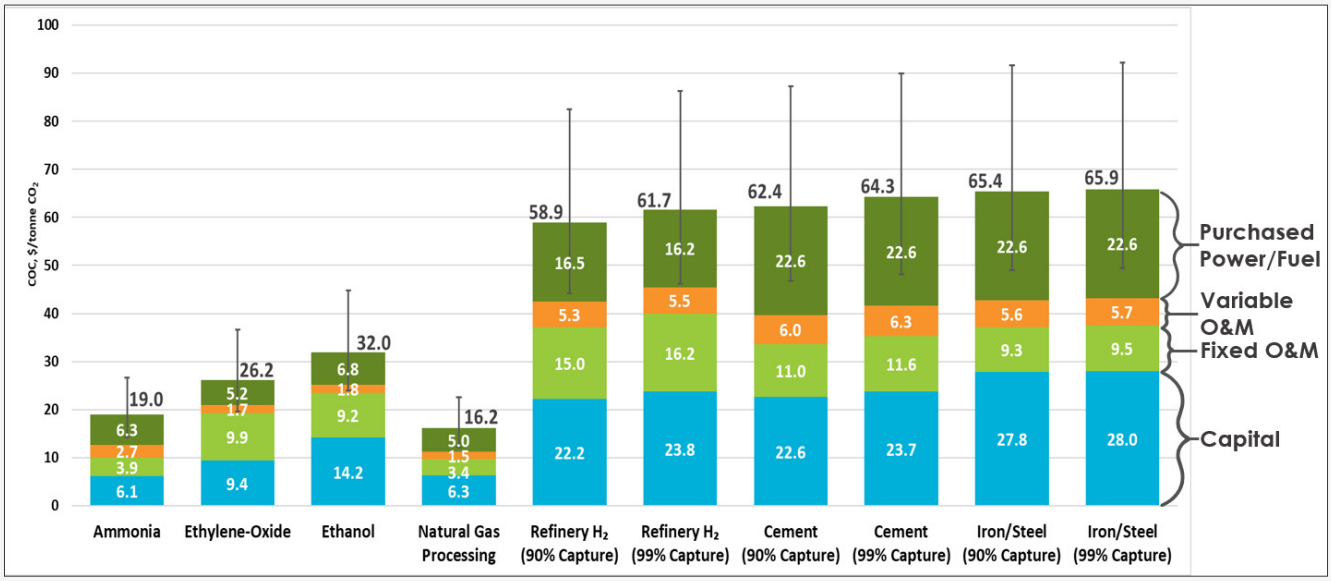
## LCA Team Evaluates Alaskan LNG Greenhouse Gas Emissions

The report, "Life Cycle Greenhouse Gas Emissions from the Alaska LNG Project," included in the draft Supplemental Environmental Impact Statement (SEIS) prepared by DOE's Office of Fossil Energy and Carbon Management (FECM), was recently published. DOE invited public comment on the SEIS from July 1, 2022 through August 15, 2022.

The Alaska LNG Project, proposed by the Alaska Gasline Development Corporation, would commercialize natural gas resources from the Alaska North Slope for export as liquified natural gas (LNG) by Alaska LNG Project LLC and domestic use. The SEIS is part of the federal approval process.

Prepared by SSAE life cycle analysis (LCA) researchers (Timothy Skone, Mackenzie Pias*, Harshvardhan Khutal*, Matthew Jamieson, H. Scott Matthews* and Michelle Krynock), the report evaluates greenhouse gas emissions associated with natural gas extracted from the North Slope, transported via pipeline to a proposed liquefaction facility, exported by vessel from Alaska to Japan, China, South Korea and India and used in natural gas combined cycle (NGCC) plants with and without carbon capture and storage (CCS).

The study found that two proposed scenarios, one storing $CO_2$ 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 of current Alaska North Slope oil production and U.S. Lower 48 natural gas production and export.




Cost of $CO_2$ capture summary for industrial sources



* NETL Support Contractor

### Staff Spotlight

Andrew Lee* was born in Melbourne, Australia and grew up in the city of Townsville alongside the Great Barrier Reef. He attended James Cook University where he received a Bachelor of Engineering (2003) and Ph.D. (2008) in chemical engineering. Lee first joined NETL in 2010 as an Oak Ridge Institute for Science and Education (ORISE) Fellow in Morgantown, WV working with SSAE's Senior Fellow David Miller to develop computational models for bubbling fluidized bed reactors for sorbent-based carbon capture processes. He briefly returned to Australia to take a post-doctoral position at the University of Melbourne from 2012 to 2014 working on modeling solvent-based $CO_2$ absorption processes before returning to NETL in 2015 as a site support contractor working on the development of the Institute for the Design of Advanced Energy Systems (IDAES) Integrated Platform in Pittsburgh, PA.

Within IDAES, Andrew leads the Platform Integration task, which is responsible for developing and maintaining the core code base. In this role, he has served as the "chief architect" of the modeling platform and has led the development of the underlying modeling infrastructure. He is also responsible for developing a large part of the thermophysical property model library. More recently, he has been involved with the Water Technoeconomic Assessment Platform (Water-TAP) project where he has assisted with developing models for a wide range of desalination and wastewater treatment operations.

# // NOTICES

### PARETO Wins Hart Energy Meritorious Engineering Innovation Award

The PARETO framework, developed by NETL and Lawrence Berkeley National Laboratory, was named a winner in Hart Energy's 2022 Special Meritorious Awards for Engineering Innovation (MEA) for its water management capabilities. The MEAs recognize new products and technologies that provide significant changes and improvements to sectors across the upstream petroleum industry (e.g., carbon management, drilling systems, subsea systems and water management).

The free and publicly available PARETO framework is Python-based and leverages NETL's IDAES Integrated Platform and DOE's National Alliance for Water Innovation's (NAWI) water treatment process models library (Water-TAP). PARETO can help determine where and how to build out produced water infrastructure while improving the coordination of water deliveries over time given user provided water production, demand and transportation data.

To address the challenges associated with large oil and gas operators spending millions of dollars annually on water activities associated with oil and gas development, DOE launched a three-year, $5 million produced water optimization initiative, Project PARETO, for produced water management and beneficial reuse in 2021.

PARETO is meant to empower practitioners, researchers and policymakers to identify cost-effective and environmentally sustainable ways to manage, treat and beneficially reuse (when possible) produced water from oil and gas operations.

### NETL Develops Process to Manufacture Items from REEs-CMs Recovery

SSAE researchers Alison Fritz and Thomas Tarka are part of a research team that developed an approach to manufacture several items, (e.g., computers, clean energy technologies and defense systems) using rare earth elements and critical minerals (REE-CM) extracted from coal and coal-processing materials and waste streams including bottom ash, fly ash, ponded ash and landfill ash. This environmentally friendly and cost-effective technology, Targeted Rare Earth Extraction (TREE) process, was developed to help build a strong domestic supply chain of REEs-CMs since the United States currently imports greater than 80% of its REEs-CMs from offshore suppliers.

TREE, which was a finalist in the 2022 R&D 100 Awards competition in the Process/Prototyping category, can improve current REE-CM extraction methods, help fill U.S. manufacturers' REEs-CMs needs for producing several products (e.g., solar panels, wind turbines and electric and hybrid vehicles) and support the development of technologies for decarbonizing the U.S. electricity sector by 2035 and the economy by 2050.

# // NOTICES cont'd

### SSAE Welcomes Indra Bhattacharya

Indra Bhattacharya recently joined SSAE's Process Systems Engineering Research Team. Prior to joining NETL, Indra worked at Tri-State Generation and Transmission Association Inc. as the Research and Development (R&D) Program Manager primarily reviewing new technologies for power generation, CCS, bulk energy storage, potential of hydrogen as low carbon fuel, advancements in high voltage transmission line material, customer load disintegration, farm in a box, etc. Also, at Tri-State, he was fortunate to work on the IDAES project's collaboration with the Escalante plant in New Mexico. Before that, Indra worked in the new technology development group at American Electric Power with similar focus on power generation R&D, which included working at a 20-MW scale CCS project at a coal-fired plant.

Outside of work, Indra loves spending time with his four-year-old son Rishav and his wife Moumita. They cook, try out new cuisines, watch documentaries, travel and bike ride when time permits (regular road bike, not hill/mountain bike). Indra earned his Ph.D. from Ohio State University in Microwave Remote Sensing and admits to getting excited about Buckeyes football.

# // PERSPECTIVES

### NETL and the GMLC – Water Risk for the Bulk Power System: Asset to Grid Impacts

NETL participates in the Grid Modernization Laboratory Consortium (GMLC), a joint venture of multiple national laboratories and non-government organizations. One project focuses on Water Risk for the Bulk Power System: Asset to Grid Impacts. The goal of this effort is to develop an analysis platform that can provide environmental and economic benefits by aiding short-term operational and long-term investment decisions.

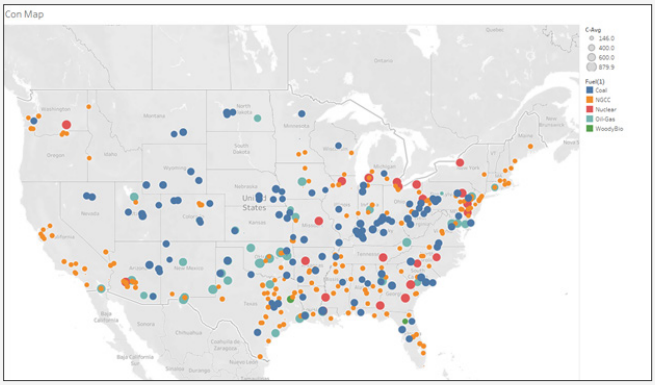



Figure 1. U.S. water consumption for recirculating cooling plants (gal/MWh)

NETL's role is to provide accurate, up-to-date water withdrawal and consumption factors for thermoelectric power plants. These power plants include nuclear, NGCC, natural gas steam, oil steam, coal-fired and biomass combustion electricity generating power plants. Accurate water use factors are necessary in modeling water stress. The water use factors developed by NETL will be used in the National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS) Model and other models that support the GMLC project. SSAE's Erik Shuster and Tim Skone lead the NETL team for this effort.

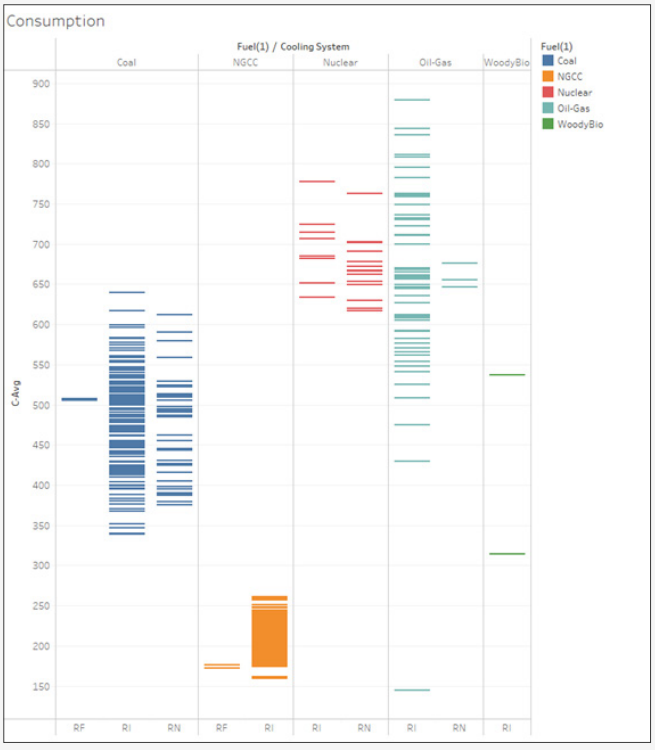



Figure 2. Water consumption factors by recirculating cooling technology and fuel type (gal/MWh)

In addition to developing the unit level water use factors, a journal manuscript is being developed to publish the results and methodology and compare them to those of eight other papers on this topic. Unique contributions of the NETL study include a five-year study period (2016 –2020) with monthly as well as annualized data to enable identification of seasonal trends and the public release of individual power plant water use factors data. The overall

# // PERSPECTIVES cont'd

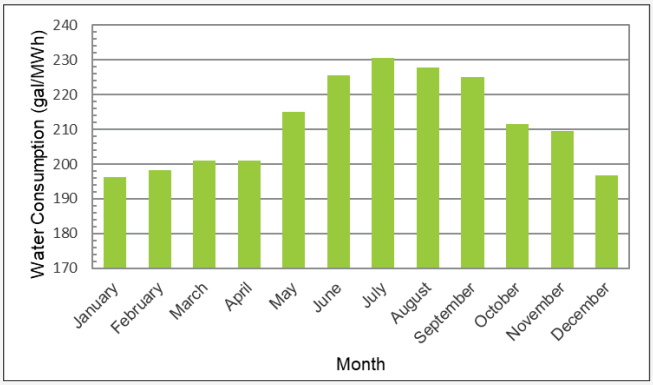



Figure 3. Seasonal water consumption variations (gal/MWh)

focus of the study was to increase the granularity of the data, accounting for variations in water use factors with local climate and operational practices as well as fuel and cooling technology.

Water use is a general term covering both withdrawal and consumption. Water withdrawal is the water removed from a body of water, and water consumption is the water that is not returned. Water use factors are further categorized by the fuel used to generate the electricity and by cooling technology. Cooling technologies can be broken down into wet once-through, wet recirculating and dry cooling. Recirculating systems can be broken down into induced (RI), forced (RF) and natural draft (RN) units. Once-through systems withdraw huge amounts of water and return most or all of it, resulting in zero to near zero water consumption. Recirculating systems use cooling towers and withdraw much less water than once-through systems; however, recirculating systems consume water through evaporation.

Figures are provided to show some data for recirculating cooling systems. Water use factors are reported as the volume of water used to generate 1 MWh of electricity. This study reports these factors in gal/MWh. Figure 1 shows water consumption by fuel type for power plants that use recirculating cooling technologies. Figure 2 illustrates the water consumption factors for various fuel types for recirculating cooling systems. In comparison, once-through systems withdraw water in the 20,000 to 70,000 gal/MWh range depending on fuel type and plant efficiency. Figure 3 shows seasonality changes in water consumption at a high-level average of all fuels. – Contributed by Erik Shuster, SSAE's Energy Markets Analysis Team

# // UPCOMING CONFERENCES AND EVENTS

**SSAE Federal staff and NETL support contractor personnel will attend or present at the following conferences and events in October 2022:**

- 2022 SPE Annual Technical Conference and Exhibition
  Participant: Luciane Cunha
  Houston, TX, October 3–5, 2022
- European Climate and Energy Modelling Platform (ECEMP 2022)
  Presenter: Amanda Harker Steele – A State Contingent Production Function Approach to Modeling Power System Disruptions from Variable Renewable Resources (poster)
  Virtual, October 5–7, 2022
- 2022 Evolving Energy Conference
  Panelist: Amanda Harker Steele – Emerging Technologies for Decarbonization
  Morgantown, WV, October 6 –7, 2022
- 18th International Rare Earths Conference
  Participants: Alison Fritz and W. Morgan Summers
  Las Vegas, NV, October 17–19, 2022
- Midwest Regional Carbon Conversion/Utilization Procurement Grant Workshop
  Presenter: Gregory Hackett – Overview of Techno-Economic Analysis Methodology
  Hybrid (Virtual and Minneapolis, MN), October 18, 2022

# // UPCOMING CONFERENCES AND EVENTS (cont'd)

- Carbon Capture Summit USA 2022
  Participant: Patricia Cvetic*
  Long Beach, CA, October 19–20, 2022
- 39th USAEE/IAEE North American Conference
  Presiding: Peter Balash, 2022 USAEE President
  Presenters: Timothy Grant – Economic Analysis of Potential for Carbon Capture, Utilization and Storage in the Gulf of Mexico; Amanda Harker Steele – System Cost of Replacement Energy (SCoRE): A Tool for Assessing CCUS and Other Low Carbon Alternative Technology Substitution Pathways to Decarbonization; Jack Suter* – Supply Chain Vulnerabilities of the Energy Transition with a Focus on Carbon Capture, Transportation and Storage; Nadejda Victor* – Hydrogen Present and Future in the U.S. Energy Sector and Connie Zaremsky* – Influence of Environmental, Social and Governance (ESG) Investing on Growth of CCUS in the United States
  Session Chairs: Amanda Harker Steele – Barriers & Opportunities for CCUS; Christopher Nichols – The Infrastructure Investment and Jobs Act – the View from the Inside and Nadejda Victor – The Role of CCUS & Hydrogen in Decarbonization
  Participant: Justin Adder
  Houston, TX, October 23–26, 2022
- 16th Greenhouse Gas Control Technologies Conference (GHGT-16)
  Presenters: Michael Matuszewski* – Isotherm Modeling and Techno-Economic Analysis of Contactor Technologies for New Tetraamine-Appended MOF for NGCC Applications and Joshua Morgan* – Development of Process Model of CESAR1 Solvent System and Validation with Large Pilot Data
  Participant: Timothy Fout (IEAGHG CCS Cost Network Steering Committee Meeting [Invite-only, Members-only])
  Lyon, France, October 23–27, 2022
- 2022 Resource Sustainability Annual Project Review Meeting
  Presenters: Markus Drouven and Miguel Zamarripa-Perez* – Project PARETO – DOE's Produced Water Optimization Initiative
  Participants: Luciane Cunha, Alison Fritz, Eric Grol, W. Morgan Summers and Thomas Tarka
  Pittsburgh, PA, October 25–27, 2022
- 23rd Annual Solid Oxide Fuel Cell Program Project Review Meeting
  Participant: Gregory Hackett
  Coraopolis, PA, October 25–27, 2022
- 2022 Global Syngas Technologies Conference
  Participant: Eric Lewis
  Tucson, AZ, October 26–28, 2022

# // RECENT PUBLICATIONS

### Models/Tools/Databases

- National Energy Technology Laboratory, "Industrial $CO_2$ Capture Retrofit Database (IND CCRD)," National Energy Technology Laboratory, Pittsburgh, PA, September 14, 2022.

### Reports/Supporting Documentation

- C. Able, S. Pidaparti, C. White, N. Weiland, E. Liese, T. Shultz and M. Woods, "Techno-economic Analysis of Indirect $sCO_2$ Cycle Deployment in NGCCs," National Energy Technology Laboratory, DOE/NETL-2021/2802, Pittsburgh, PA, November 13, 2020.
- S. Pidaparti, C. White, E. Liese, T. Shultz and N. Weiland, "Optimized Performance and Cost Potential for Exemplar Indirect $sCO_2$ Coal Plants," National Energy Technology Laboratory, DOE/NETL-2021/2801, Pittsburgh, PA, August, 27, 2021.
- H. Singh, L. Clahane, A. Harker Steele, C. Callahan, T. Warner and R. Wallace, "Appalachian Hydrogen Infrastructure Analysis," National Energy Technology Laboratory, DOE/NETL-2022/3772, Pittsburgh, PA, March 20, 2022.
- C. Callahan, E. Larson and C. Noack, "Upcycling Associated Natural Gas into Liquid Chemical Intermediates," National Energy Technology Laboratory, DOE/NETL-2022/3794, Pittsburgh, PA, May 11, 2022.



* NETL Support Contractor

# // RECENT PUBLICATIONS cont'd

- S. Hughes and A. Zoelle, "Cost of Capturing $CO_2$ from Industrial Sources," National Energy Technology Laboratory, Pittsburgh, PA, July 15, 2022.
- National Energy Technology Laboratory, "User Guide for the Public Industrial $CO_2$ Capture Retrofit Database Models," National Energy Technology Laboratory, Pittsburgh, PA, July 18, 2022.
- M. Jamieson, M. Krynock, S. Moni, M. Mutchek and T. Skone, "NETL 45Q Addendum to the CO2U LCA Guidance Toolkit," National Energy Technology Laboratory, DOE/NETL-2021/2852, Pittsburgh, PA, September 6, 2022.
- M. Oakes, J. Konrade, M. Bleckinger, M. Turner and S. Hughes, "Conceptual Design of Pulverized Coal Electricity Generating Units for Flexible Operation," National Energy Technology Laboratory, DOE/NETL-2022/3315, Pittsburgh, PA, September 6, 2022.

**Conference Proceedings and Events**

- T. Fout, "Techno-Economic Analyses for Direct Air Capture (DAC) – Overview," presentation at the Direct Air Capture Kickoff Meeting, Virtual, February 24, 2021.
- S. Pidaparti, "Optimized Performance and Cost Potential for Indirect Supercritical $CO_2$ Coal Fired Power Plants – GT2021-58865," presentation at the ASME 2021 Turbo Expo, Virtual, June 7–11, 2021.
- N. Wijaya, D. Vikara, D. Morgan, T. Grant and D. Remson, "Basin Management of Geologic CO2 Storage: Effect of Well Spacing on CO2 Plume and Pressure Interference," presentation (paper) at the 2022 SPE Western Regional Meeting, Bakersfield, CA, April 26, 2022.
- S. Henry and G. Hackett, "Carbon Conversion Technologies – NETL Techno-Economic Analysis Guidelines," presentation at the 2022 CCU TEA and LCA Guidance – A Harmonized Approach Workshop, Hybrid (Virtual and Ann Arbor, MI), May 19, 2022.
- J. Chou, S. Moni, M. Krynock, M. Mutchek and T. Skone, "Life Cycle Analysis of Mineralization of Concrete Products for $CO_2$ Utilization," presentation at the 29th International Symposium on Sustainable Systems and Technology (ISSST 2022), Pittsburgh, PA, June 22, 2022.
- M. S. Henriksen, J. White, J. Grove, L. Walsh, H. S. Matthews, M. Jamieson, E. Grol and T. Skone, "Life Cycle Greenhouse Gas Emissions and Water Consumption From Existing and Emerging Hydrogen Pathways," presentation at the ISSST 2022, Pittsburgh, PA, June 22, 2022.
- S. Moni, S. Sam, M. Krynock and T. Skone, "Life Cycle Analysis of Emerging $CO_2$ Utilization Technologies: Challenges and Current Best Practices," presentation at the ISSST 2022, Pittsburgh, PA, June 22, 2022.
- J. Brewer, "Natural Gas-Electric Interdependency Through 2030 (22PESGM3806)," presentation during panel session "Future Reliability and Resilience Study of Electrical and Gas Systems under Extreme Weather Events" at the 2022 IEEE Power & Energy Society General Meeting, Denver, CO, July 18, 2022.
- C. Able, "Treatment Technology Assessment for Landfill Leachate," presentation (video presentation) at the ASME Power 2022 Conference, Pittsburgh, PA, July 19, 2022.
- T. Fout, M. Woods, H. Mantripragada, K. Buchheit and S. Homsy "Update to Techno-economic Analysis of BECCS Systems," presentation at the 46th International Technical Conference on Clean Energy – The Clearwater Clean Energy Conference, Hybrid (Virtual and Clearwater, FL), August 1, 2022.
- R. Stevens, "Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies," presentation at the 46th International Technical Conference on Clean Energy – The Clearwater Clean Energy Conference, Hybrid (Virtual and Clearwater, FL), August 1, 2022.
- T. Fout, T. Shultz, R. James, T. Schmitt, S. Leptinsky, M. Turner, S. Hughes, A. Zoelle, C. White and M. Woods, "Updated Cost and Performance Results for Natural Gas Combined Cycles (NGCC)," presentation at the 46th International Technical Conference on Clean Energy – The Clearwater Clean Energy Conference, Hybrid (Virtual and Clearwater, FL), August 2, 2022.
- S. Hughes, T. Fout, T. Shultz, R. James, A. Zoelle, S. Homsy, S. Henry, S. Pidaparti, N. Kuehn and M. Woods, "Updated Cost and Performance of $CO_2$ Capture and Compression from Industrial Sources," presentation at the 46th International Technical Conference on Clean Energy – The Clearwater Clean Energy Conference, Hybrid (Virtual and Clearwater, FL), August 2, 2022.
- K. Bello, D. Vikara, D. Morgan and L. Cunha, "Application of Dimensionality Reduction in Machine Learning Modeling of $CO_2$ Storage," poster at the 2022 Carbon Management Project Review Meeting, Pittsburgh, PA, August 16, 2022.
- T. Fout, S. Homsy, M. Woods, A. Zoelle, J. Valentine, N. Roy, A. Kilstofte, M. Sturdivan and M. Steutermann, "Direct Air Capture Case Studies: Sorbent System," poster at the 2022 Carbon Management Project Review Meeting, Pittsburgh, PA, August 16, 2022.
- T. Grant, C. Nichols, J. Adder, P. Balash, S. Forbes, M. Webler and L. Cunha, "Economic Analysis of Potential for CCUS in the Gulf of Mexico," poster at the 2022 Carbon Management Project Review Meeting, Pittsburgh, PA, August 16, 2022.

# // RECENT PUBLICATIONS cont'd

- T. Fout, T. Shultz, R. James, T. Schmitt, S. Leptinsky, M. Turner, S. Hughes, A. Zoelle, C. White and M. Woods, "High $CO_2$ Capture Rate Cost and Performance for F- and H-Class Natural Gas Combined Cycles (NGCC)," presentation at the 39th Annual International Pittsburgh Coal Conference, Virtual, September 19–22, 2022.
- R. James, T. Shultz, M. Woods, M. Turner, T. Schmitt, M. Oakes, J. Konrade, M. Bleckinger and M. Sturdivan, "Cost and Performance Baseline for Fossil Energy Plants, Volume 3 – Low Rank Coal and Natural Gas to Electricity," presentation at the 39th Annual International Pittsburgh Coal Conference, Virtual, September 19–22, 2022.
- National Energy Technology Laboratory, "Overview of Techno-Economic Analysis Methodology," presentation at the Eastern/Mid-Atlantic Regional Carbon Conversion Procurement Grant Program Workshop, New York, NY, September 27, 2022.

# // 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 LCA CO2U 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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