

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

Journal Paper Highlights Economic Tradeoffs for Unconventional Well

The economic tradeoffs of pressure drawdown management and the resulting gas production outlooks for a real, producing unconventional gas well in the Marcellus Shale of the Appalachian Basin was evaluated in a recent [study](#) by SSAE. Published in *Gas Science and Engineering*, the study used a techno-economic analysis approach coupled with physics-informed rapid predictive models and was developed under DOE's Science-informed Machine Learning for Accelerating Real-Time Decisions in Subsurface Applications Initiative Phase I, Task 7 efforts. The use of pressure maintenance in hydraulically fractured reservoirs via sustained production drawdowns can improve cumulative recovery and overall resource extraction efficiency compared to more rapid drawdown approaches aimed at generating high initial production. However, oil and gas operators typically pursue production strategies that maximize profitability over resource extraction efficiency due to the inherent variability of oil and natural gas markets. There is a lack of research comparing the economic viability and present value of unconventional wells produced under different strategies. This knowledge gap could spark operators' interest in altering their field development approaches.

Gas production forecast scenarios were generated using a novel physics-informed machine learning workflow and traditional reservoir simulation. The [FECM/NETL Unconventional Shale Well Economic Cash Flow Model \(UShWEM\)](#) was used to evaluate economic implications for different drawdown scenarios given specific reservoir characteristics, capital expenditures, operating expenses, taxes, royalties and market conditions. Statistical methods were used to evaluate the sensitivity of economic and production factors, such as timing and volume of gas production, prevailing economic and market conditions and overall estimated ultimate recovery on key profitability metrics (e.g., internal rate of return and net present value [NPV]), by analyzing 1,300 scenarios (see Figure 1) to identify statistical contrasts in the controlling features.

The results show that there is potential to maximize and improve unconventional well productivity using a slower pressure drawdown technique while still maintaining a profitable project. However, slower pressure drawdowns may delay the time for operators and investors to break even resulting in a lower present value for the project. Considerations of business and investment risks, such as the discount factor of the project's capital, can largely influence the potential present value of scenarios evaluated in the case study. As a result, there is a need for frequent evaluation of production strategies and project economics in near-real time as market dynamics evolve to optimize production operations. For more information on this study, please contact SSAE researchers [Kolawole Bello*](#), [Derek Vikara*](#) or [Luciane Cunha](#).

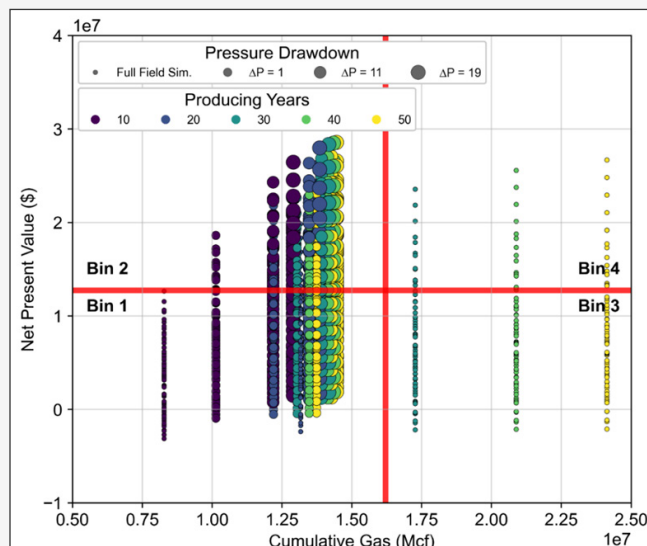


Figure 1. A quad chart highlighting the scenario placement across the spectrum of predicted output NPV and associated cumulative production. Scenario data is binned (1 through 4) for further analysis depending on where it falls in "high" or "low" groupings for NPV and cumulative production.

SCoRE Tool Highlighted in Energy

Replacing legacy high-carbon technologies with new low-carbon technologies, specifically those fueled by variable renewable resources (e.g., wind and solar), can disproportionately influence the costs associated with maintaining a reliable and competent grid system. A recently published [paper](#) in *Energy* detailed the results of a tool developed by SSAE researchers to estimate the system cost of replacement energy (SCoRE) — a metric for estimating how the total systems cost (TSC) might change in response to a technology replacement along the grid. The SCoRE tool was applied to nine replacement scenarios in the Electric Reliability Council of Texas operating region. Results highlight the carbon abatement targets able to be met by each of the new low-carbon technology options considered before changes in the TSC begin to increase exponentially.

Update to Low Rank Baseline Study Released

An independent assessment of the cost and performance of select fossil energy power systems — pulverized coal (PC), circulating fluidized bed and natural gas combined cycle (NGCC) plants at elevation— using a systematic, transparent technical and economic approach was presented in SSAE's recent release of the "[Cost and Performance Baseline for Fossil Energy Plants Volume 3: Low Rank Coal and Natural Gas to Electricity](#)." The cost and performance of fossil fuel-based generation technologies in the report are important inputs to assessments and determinations of technology combinations to be utilized to meet the projected demands of future power markets. The reference plant configurations provide perspective for regulators and policy makers. The report can be used to assess goals and metrics and provide a consistent basis for comparing developing technologies.

// HIGHLIGHTS cont'd

New Baseline Study Released on Flexibility Attributes of Commercial Natural Gas Power Generation Technologies

The output of variable renewable energy (VRE) sources, such as wind and solar power generation, is intermittent, creating challenges to grid stability and reliability. Dispatchable fossil fueled generation is used to provide reliable power during periods of reduced VRE output. Dispatchable generators must be able to accommodate increasing VRE generation as the nation pursues the Administration's target of a decarbonized energy sector by 2035. As energy system experts create models (e.g., capacity expansion) to identify least-cost approaches to decarbonization, accurate cost and performance data characterizing dispatchable generators that operate flexibly at capacity factors that have been declining over time is needed to inform these models. Furthermore, these technologies continue to be a significant source of carbon dioxide (CO₂) emissions, providing the impetus for research and development (R&D), including the advancement and potential incorporation of carbon capture technologies.

To address the data needs of energy system modelers and to serve as a baseline for R&D, SSAFE completed a study to characterize the flexibility attributes —both performance and cost — of nine common commercial natural gas-fueled electricity generating units. Although existing coal-fired power plants have served as baseload resources and have been increasingly relied upon as load-following resources, current natural gas technologies are much better equipped to follow intermittent renewable generation with faster ramping rates, shorter startup durations, higher efficiency, lower minimum loads, lower water usage, lower emissions and lower cost. The study, "[Cost and Performance Baseline for Fossil Energy Plants, Volume 5: Natural Gas Electricity Generating Units for Flexible Operation](#)," can provide valuable data as the nation pursues decarbonization.

The study included cases for reciprocating internal combustion engines (RICE), natural gas simple cycle (NGSC) aeroderivative combustion turbines (CT) and NGCC plants. While these cases do not include CO₂ capture, the data remains highly relevant given the ubiquitous current use of dispatchable, unabated natural gas power generation to back up VRE, and the results of some decarbonization modeling efforts that included the use of low-capacity factor unabated natural gas power generation well into the future. SSAFE is also pursuing work to characterize the flexibility of power generation systems with integrated carbon capture. Figure 2 depicts the cases included in this study, as well as data for key flexibility metrics ([learn more](#)).

Technology Description	HHV Net Plant Efficiency (%)	Nameplate Capacity (MWe)	Cold Start (min)	Warm Start (min)	Hot Start (min)	Ramp Rate (%/min)	Minimum Load (%)
RICE – Spinning Mode (6x0)	41.3	113	N/A	10	5	60	9.7
RICE – Efficiency Mode (6x0)	41.3	113	N/A	10	5	23	0.8
RICE – Spinning Mode (12x0)	41.0	113	N/A	10	5	60	9.7
RICE – Efficiency Mode (12x0)	41.0	113	N/A	10	5	27	0.8
Aeroderivative NGSC (1x0)	38.8	116	N/A	10	8	43	16
Aeroderivative NGSC (2x)	36.0	105	N/A	10	5	95	50
F-Class Fast-Start NGCC (1x1)	52.8	375	130	50	35	11	49
H-Class Fast-Start NGCC (1x1)	54.8	560	130	85	30	11	38
F-Class Fast-Start NGCC (2x1)	52.9	751	120	45	32	11	50
F-Class Conventional-Start NGCC (2x1)	52.9	751	250	140	90	11	50
H-Class Fast-Start NGCC (2x1)	55.0	1,124	120	70	30	11	38

Figure 2. Flexibility metric results for RICE, aeroderivative CT and NGCC plants

Rigorous Comparison of SOFC/SOEC-based Integrated Energy Systems Published

The cost and performance of several types of integrated energy systems based on solid oxide fuel cells (SOFC) to generate power and solid oxide electrolysis cells (SOEC) to produce hydrogen were evaluated in a recently published comprehensive technical report, "[Technoeconomic Evaluation of Solid Oxide Fuel Cell Hydrogen-Electricity Co-Generation Concepts](#)," by the Institute for the Design of Advanced Energy Systems (IDAES) researchers. All systems featured carbon capture rates exceeding 97%. Optimized process models were constructed using the IDAES® Integrated Platform and used to calculate overall production costs following a consistent methodology that facilitated comparisons of these process concepts to one another and to prior NETL cost and performance estimates. The analysis reveals that the best overall system is highly dependent on the assumed prices and demands of electricity and hydrogen because these determine the optimal mode of operation at a given point in time. Additionally, it suggests that integrated systems with the flexibility to produce either hydrogen or electricity can provide significant advantages over standalone systems that produce only hydrogen or only electricity in cases where future electricity prices are anticipated to be bimodal (e.g., distinct periods of low and high electricity prices) — a reasonable possibility in future high VRE grids.



Staff Spotlight

Since joining the Life Cycle Analysis (LCA) Team in May 2022, Roksana Mahmud* has developed biomass models and contributed to an associated screening tool, created a database of critical minerals studies, conducted critical reviews of rare earth extraction LCA reports and characterized feedstocks and pathways for gasification.

Roksana also modeled energy and resource inputs and emissions from biomass life cycle stages and is incorporating profiles into a bio-energy with carbon capture and storage screening tool to evaluate key parameter sensitivities. Under the critical minerals effort, she compiled literature into a database summarizing state-of-the-science LCA and reviewed studies submitted to NETL from external projects.

To support NETL's Gasification Systems Program, she characterized feedstocks for gasification and is currently developing a design basis for hydrogen production from biomass-fueled gasification.

Roksana earned a Ph.D. in Environmental Engineering and Earth Sciences from Clemson University, an M.S. in Chemical Engineering from Oklahoma State University and a B.S. in Chemical Engineering from Bangladesh University of Engineering and Technology. In her doctoral dissertation, she developed an integrated framework for simultaneous techno-economic and environmental evaluation of new products and processes, modeling the Clemson University Wastewater Treatment Plant as a case study.

// NOTICES

SSAE's Process Systems Engineering Research Team to Host SCGSR Fellowship Awardee

The Process Systems Engineering Research Team will [host](#) a Carnegie Mellon University (CMU) doctoral candidate over the summer under [DOE's Office of Science Graduate Student Research \(SCGSR\) Program](#), which provides supplemental funds for graduate awardees to conduct part of their thesis research at a host DOE laboratory/facility in collaboration with a DOE laboratory scientist within a defined award period. CMU's William Strahl is one of 87 awardees from 58 different universities who will conduct research at 16 DOE national laboratories. His fellowship appointment will run from June 12 through September 18, 2023.

Strahl earned a bachelor's degree in chemical engineering from Brigham Young University with a minor in computer science before pursuing his doctorate at CMU under the guidance of Professor Chrysanthos Gounaris. His project will explore algorithms and parallel computing approaches for improving flowsheet initialization, frequently the most computationally expensive step in large-scale process optimizations. Strahl will work collaboratively with several IDAES researchers including Anthony Burgard, Andrew Lee* and John Eslick*.

LCA Team Conducts Carbon Conversion LCA Knowledge Sessions

Since 2019, SSAE's LCA Team has annually conducted CO₂ utilization (CO₂U) LCA Knowledge Sessions to train DOE Carbon Conversion Program funding recipients in meeting requirements for completing LCAs of carbon conversion processes. Principal Investigators (PIs) explore these processes for their potential to reduce environmental emissions relative to alternatives by recycling waste CO₂ and transforming it into valuable products and applications.

Between February and April 2023, Michelle Krynock, Sheikh Moni* and Ben Young* provided six Knowledge Sessions in webinar format covering three distinct topics: 1) an overview of LCA basics and the [NETL CO₂U LCA Guidance Toolkit](#), 2) how to use modeling software openLCA to complete an LCA in conformance with the CO₂U Guidance Document and 3) LCA results analysis and reporting. Each webinar involved a presentation including explanation, toolkit demonstrations and question-and-answer for PIs and other stakeholders.

The sessions navigated through the NETL CO₂U LCA Guidance Toolkit. The toolkit provides a guidance document that outlines analysis requirements; a life cycle inventory database that includes unit process data and an example CO₂U LCA; a results contribution tool for translating results from openLCA into final results; a data and modeling documentation spreadsheet; a report template and additional training resources such as a video series and subject matter expert support.

// PERSPECTIVES

SSAE Releases Updated Carbon Capture Retrofit Reports and Databases

Multiple products related to retrofitting PC and NGCC power plants with post-combustion carbon capture technology were recently released by SSAE. Included in the release were two technical reports that highlighted the cost and performance of the retrofitted plants and two carbon capture retrofit database (CCRD) spreadsheet tools. All products were updated to be consistent in methodology with the recently released Revision 4A to NETL's "[Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity](#)" report (hereafter referred to as "Baseline Study"). The tools provide stakeholders with conceptual-level cost and performance estimates for retrofitting the existing fossil fleet with solvent-based carbon capture technology.

One report, "[Cost and Performance of Retrofitting NGCC Units for Carbon Capture](#)," detailed the cost and performance of F- and H-frame NGCC plants retrofitted with post-combustion carbon capture. In this report, solvent-based (Shell CANSOLV) carbon capture technology was retrofitted onto an existing NGCC plant to capture 90, 95, or 99% of the CO₂ emissions. Being fully integrated, the plant supplies the necessary steam and power to meet the capture system's requirements.

Another report, "[Eliminating the Derate of Carbon Capture Retrofits](#)," detailed the cost and performance of subcritical PC plants retrofitted with Shell CANSOLV carbon capture technology to capture 90, 95, or 99% of the CO₂. In the report, several configurations were assessed including the fully integrated capture system (similar to the NGCC methodology) and two configurations that add separate natural gas-based systems to generate the necessary capture system power and/or steam.

These options serve as a method to "eliminate" the plant derate by not extracting power and/or steam directly from the existing plant. In one configuration, a natural gas boiler was used to generate the necessary steam while the power was supplied by the existing plant. In the second configuration, a NGSC system generated combined heat (steam) and power (in excess) for the capture system.

Although techno-economic analyses of deep decarbonization (≥ 99%) of combustion flue gas have been published by others, the relatively limited experience with design and operation of capture systems that can routinely, reliably and economically achieve very high removal rates requires further study. In these reports, performance and cost estimations for the highest capture rates (97% for NGCC, 99% for PC) were reported in appendix material.

For each report, the retrofit cases were compared to analogous new build and non-capture cases assessed in the Baseline Study. A retrofit difficulty factor (RDF) was applied to scale costs, representing the difficulty associated with retrofitting an existing plant with new technology that it was not originally designed to incorporate. The primary metrics reported in each report compared the cost of capture (in \$/tonne) and cost of electricity (in \$/MWh) to Baseline Study cases. Several studies were conducted to determine the sensitivity of the cost of electricity to RDF, plant capacity factor, cost of natural gas, etc.

The results of these reports represent conceptual-level design and economic analysis, consistent with Association for the Advancement of Cost Engineering Class 4 estimation with -15/+25-30% uncertainty. The design basis for a specific real plant may deviate significantly from the cases assessed. Further analysis (e.g., a front-end engineering design study) is needed to produce budget-level cost estimates for carbon capture retrofits for a specific real facility. These reports did not consider maintenance or

Parameter	SCENARIO #1	
	Fleet Total	Unit Average
Total units, No.	693	—
Units retrofitted with CCS, No.	505	—
Units retrofitted with dry cooling, No.	106	—
Units retrofitted with SCR, No.	343	—
Units retrofitted with FGD, No.	246	—
Units retrofitted with NGSC or NG Boiler, No.	0	—
Pre-retrofit capacity, MW	226,619	449
Pre-retrofit heat rate, Btu/kWh	—	10,755
Pre-retrofit CO ₂ emissions, x1,000 TPY	1,053,535	2,059
Post-retrofit capacity, MW	160,997	319
Post-retrofit heat rate, Btu/kWh	—	14,987
Post-retrofit CO ₂ emissions, x1,000 TPY	84,664	165
Retrofit CO ₂ capture, x1,000 TPY	761,978	1,484
Retrofit parasitic load, MW	65,622	129.9
Makeup/excess power, x1,000 MW/yr	433,861	859.1
Retrofit capital cost (IOC), \$/10 ⁶	593,147	1,175
Retrofit COE, \$/MWh	—	288.5
Cost of CO ₂ captured, \$/tonne	—	225.4
Cost of CO ₂ avoided, \$/tonne	—	100.4
Scenario Assumptions:		
CO ₂ capture rate, %	90%	
CO ₂ capture technology	90% Cansolv	
Average pre-retrofit capacity factor	50%	
Average post-retrofit capacity factor	40%	
Retrofit unit capacity applicability limit, MW	25	
Retrofit cost factor	1.10	
Capital charge factor	0.077	
CO ₂ emissions rate, lb/MMBtu	Varies	
Maximum CO ₂ capture rate per train, TPD	15,772	
Plant capacity metric	Nameplate	
Cost year basis	2018	
Cooling preference	State	
Makeup/excess power costs/credits, \$/MWh	N/A	
Include SCR with retrofit	Yes	
Include FGD with retrofit	Yes	
Additional heat rate penalty, Btu/kWh	N/A	
CO ₂ transport and storage cost, \$/tonne-CO ₂	N/A	

CHART 1 = Multiple Comparison		
X-AXIS		Y-AXIS
Cost of CO ₂ Captured	*	Cost of CO ₂ Captured
Cumulative Capacity		Cumulative Capacity
Cumulative Portion of Capacity		Cumulative Portion of Capacity
Incremental COE		Incremental COE
Cost of CO ₂ Avoided		Cost of CO ₂ Avoided
Unit Capacity		Unit Capacity

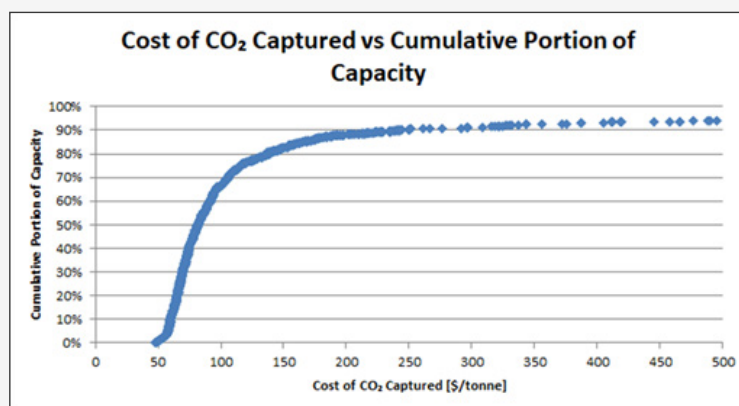


Figure 3. Sample output from the public version of the PC CCRD

// PERSPECTIVES (cont'd)

refurbishment that may be necessary to extend the life of the base plant such that it remains online for the 30-year economic lifetime assumed in estimating retrofit levelized cost of electricity and cost of capture.

The complementary CCRD tools are meant to supply end users with the means to estimate conceptual-level cost and performance details for user-defined power plants retrofitted with solvent-based carbon capture technology. These tools are based on the methodology employed in the reports discussed above and are subject to the same accuracy limitations. They are macro-based spreadsheet tools that calculate plant emissions, incremental cost of electricity and cost of carbon capture broken down into sub-categories (i.e., capital, variable, make-up power, etc.). The tools are customizable, allowing the end user to apply retrofit calculations to specific plant(s) of interest (user defined plant characteristics).

The tools are available for PC ([Pulverized Coal CCRD](#)) and NGCC ([Natural Gas Combined Cycle CCRD](#)) plants (with a similar tool also available for industrial capture [[Industrial Sources CCRD](#)] published last year). Embedded in the spreadsheet tools is a user guide, “User Guide for the Public Power Generation CO₂ Capture Retrofit Database Models,” that explains in detail the functionality of the tools to end users. The user guide for the Industrial Sources CCRD is embedded within the CCRD but also published as a [separate file](#) on NETL’s website. A sample of the PC CCRD output is given in Figure 3. Several SSAE researchers contributed to the PC, NGCC and industrial retrofit products including Gregory Hackett, Kyle Buchheit*, Sally Homsy*, Tommy Schmitt*, Norma Kuehn*, Mark Woods*, Tim Fout, Travis Shultz, Sydney Hughes*, Alex Zoelle*, Samuel Henry*, Sandeep Pidaparti* and Eric Grol. – Contributed by Gregory Hackett

// UPCOMING CONFERENCES AND EVENTS

SSAE federal staff and NETL support contractor personnel attended or presented in May 2023 and will attend or present in June and July 2023 at the following conferences:

- Offshore Technology Conference 2023
Participants: Luciane Cunha and Timothy Grant
Houston, TX, May 1–4, 2023
- Joint NRAP-SMART-EDX4CCS Technical Meeting
Presenter: David Morgan – 1) Quantifying Liability and Life Cycle Cost of Risk–Building a New Computational Module to Link Risk, Risk Management, and Cost and 2) Integration of Economic and Risk Modules with ML-Based Tools (co-presenter)
Participant: Travis Warner*
Santa Fe, NM, May 2–4, 2023
- AISTech 2023
Participant: Eric Grol
Detroit, MI, May 8–11, 2023
- NAWI External Peer Review
Presenter: Timothy Bartholomew – Water treatment Technoeconomic Assessment Platform (WaterTAP)
Berkeley, CA, May 9, 2023
- [NERC Energy Assurance with Energy-Constrained Resources, Standards Drafting Team Meeting](#)
Participant: John Brewer
Hybrid (Virtual and Atlanta, GA), May 9–10, 2023
- Critical Minerals & Materials (CMM) Mini-Symposium
Presenter: Thomas Tarka – PrOMMiS: Applying Novel Modeling Methods to Accelerate Critical Minerals RD³ (poster)
Arlington, VA, May 15, 2023
- World Hydrogen North America 2023
Participant: Peter Balash
Houston, TX, May 15–17, 2023
- Spring National Carbon Capture Center Meeting
Participant: Timothy Fout
Birmingham, AL, May 16–17, 2023
- [2023 CCUS TEA/LCA Workshop on Harmonizing CCUS Assessments](#)
Presenter: Michelle Krynock – Carbon Conversion Life Cycle Analysis at NETL
Co-moderator: Michelle Krynock – Utility of Geospatial Analysis session
Participants: Roksana Mahmud* and Shirley Sam*
Hybrid (Virtual and Ann Arbor, MI), May 16–18, 2023
- [Carbon Intel Forum 2023](#)
Participants: Peter Balash and Luciane Cunha
Houston, TX, May 23–24, 2023
- [18th International Symposium on Solid Oxide Fuel Cells \(SOFC-XVIII\)](#)
Presenter: Gregory Hackett – SOFC-0376–Techno-Economic Analysis of Reversible and Paired Solid Oxide Cell Systems for Hydrogen Production
Co-chair: Gregory Hackett – 1) SOFC–Characterization and Testing 2, 2) SOFC–Characterization and Testing 3 and 3) SOFC–Durability/Reliability and Degradation Mechanisms 1 sessions
Boston, MA, May 28–June 2, 2023

// UPCOMING CONFERENCES AND EVENTS (cont'd)

- [Annual Merit Review and Peer Evaluation Meeting – U.S. Department of Energy Hydrogen Program](#)
Presenters: Anthony Burgard – FE017 Technoeconomic Evaluation of SOFC/SOEC-Based Integrated Energy Systems for the Co-Production of Electricity and Hydrogen (poster) and Alexander Dowling* – FE020 Market-Based Technoeconomic Optimization of Integrated Energy Systems that Co-Produce Hydrogen and Electricity
Participants: Shannon McNaul* and Robert Stevens
Hybrid (Virtual and Arlington, VA), June 5–8, 2023
- [I-West Seminar](#)
Co-presenter: Derek Vikara – Pathways to CO₂ Utilization and Storage for the Intermountain West
Virtual, June 7, 2023
- [International Symposium on Sustainable Systems and Technology \(ISSST\) 2023 Conference](#)
Presenter: Harshvardhan Khutal* – Evaluating U.S. Natural Gas Environmental Performance
Participants: Derrick Carlson* and Shirley Sam*
Fort Collins, CO, June 12 (pre-conference workshops) and 13–15 (conference), 2023
- Snowmass Week 1 “The Pace of Climate Action in a World of Multiple Priorities” Workshop
Participant: Timothy Fout
Snowmass Village, CO, June 19–23, 2023
- [Mineral-X Launch Symposium – “Critical Minerals: efficient exploration and responsible mining”](#)
Participant: Alison Fritz
Stanford, CA, June 20–21, 2023
- [15th Lithium Supply and Battery Raw Materials 2023](#)
Participant: Alison Fritz
Las Vegas, NV, June 20–22, 2023
- NERC Energy Assurance with Energy-Constrained Resources, Standards Drafting Team Meeting
Participant: John Brewer
Virtual, June 22 and 29, 2023
- [ASME Turbo Expo 2023](#)
Presenter: Eric Liese – Modeling a Water-Cooled Printed Circuit Heat Exchanger Condensing CO₂ for Use in sCO₂ Cycle System Optimization Studies
Boston, MA, June 26–30, 2023
- [Hydrogen Technology Expo North America 2023](#)
Participant: Eric Lewis
Houston, TX, June 28–29, 2023
- [NERC Energy Assurance with Energy-Constrained Resources, Standards Drafting Team Meeting](#)
Participant: John Brewer
Virtual, July 6, 2023
- Berkeley Workshop: Past, Present, and Future of Diversity in Computing
Participant: Markus Drouven
Berkeley, CA, July 7, 2023
- [17th International Conference on Energy Sustainability](#)
Presenter: Thomas Tarka – Process-Based Cost Estimation Framework for Assessing Economic Viability of Environmentally and Socially Sustainable Rare Earth Element Feedstocks
Washington, D.C., July 10–12, 2023
- [2023 AAEA Annual Meeting](#)
Participant: Amanda Harker Steele
Washington, D.C., July 23–25, 2023
- [47th International Technical Conference on Clean Energy – The Clearwater Clean Energy Conference](#)
Presenter: Robert Stevens – Bioenergy Carbon Capture and Storage (BECCS): Integrated Power Plant System Study
Co-chair: Robert Stevens
Participant: Benjamin Omell
Clearwater, FL, July 23–27, 2023

// RECENT PUBLICATIONS

Articles

- R. Jacobs, J. Liu, B. Tak Na, B. Guan, T. Yang, S. Lee, G. Hackett, T. Kalapos, H. Abernathy and D. Morgan, “[Unconventional Highly Active and Stable Oxygen Reduction Catalysts Informed by Computational Design Strategies](#),” *Advanced Energy Materials*, vol. 12, no. 25, article 2201203, July 7, 2022.
- Y. Lee, Y. Duan, D. Sorescu, W. Saidi, D. Morgan, K. Thomas, W. Epting, G. Hackett and H. Abernathy, “[Defect Thermodynamics and Transport Properties of Proton Conducting Oxide BaZr_{1-x}Y_xO_{3-δ} \(x<0.1\) Guided by Density Functional Theory Modeling](#),” *JOM*, vol. 74, no. 12, pp. 4506–4526, December 2022.
- J. Wang and A. Dowling, “[Pyomo.DOE: An open-source package for model-based design of experiments in Python](#),” *AIChE Journal*, vol. 68, no. 12, e17813, December 2022.

// RECENT PUBLICATIONS **cont'd**

- P. Akula, A. Lee, J. Eslick, D. Bhattacharyya and D. Miller, "[A modified electrolyte non-random two-liquid model with analytical expression for excess enthalpy: Application to the MEA-H₂O-CO₂ system](#)," *AIChE Journal*, vol. 69, no. 1, e17935, January 2023.
- K. Bello, D. Vikara, A. Sheriff, H. Viswanathan, T. Carr, M. Sweeney, D. O'Malley, M. Marquis, R. Taylor Vactor and L. Cunha, "[Evaluation of the economic implications of varied pressure drawdown strategies generated using a real-time, rapid predictive, multi-fidelity model for unconventional oil and gas wells](#)," *Gas Science and Engineering*, vol. 113, article 204972, May 2023.
- A. Harker Steele, S. Sharma, I. Pena Cabra, L. Clahane and A. Iyengar, "[A tool for measuring the system cost of replacement energy](#)," *Energy*, vol. 275, article 127394, July 15, 2023.
- M. Drouven, D. Cafaro and I. Grossmann, "[Mathematical Programming Models for Shale Oil & Gas Development: A Review and Perspective](#)," *Computers & Chemical Engineering*, vol. 177, article 108317, September 2023.

Database

- National Energy Technology Laboratory, "[Pulverized Coal CO₂ Capture Retrofit Database \(PC CCRD\)](#)," National Energy Technology Laboratory, Pittsburgh, PA, March 2023.

Reports/Supporting Documentation

- T. Shultz, E. Lewis, A. O'Connell, S. Hughes and M. Woods, "[Development of Advanced Ultra-Supercritical \(AUSC\) Pulverized Coal \(PC\) Plants](#)," National Energy Technology Laboratory, DOE/NETL-2020/2152, Pittsburgh, PA, November 11, 2020.
- K. Bello, D. Vikara, A. Sheriff, H. Viswanathan, T. Carr, M. Sweeney, D. O'Malley, M. Marquis, R. Taylor Vactor and L. Cunha, "[Supplementary Data for Evaluation of the Economic Implications of Varied Pressure Drawdown Strategies Generated Using a Real-time, Rapid Predictive, Multi-fidelity Model for Unconventional Oil and Gas Wells by Bello, K., Vikara, D., Sheriff, A., Viswanathan, H., Carr, T., Sweeney, M., O'Malley, D., Marquis, M., Vactor, R.T., and Cunha, L.](#)," DOI: 10.18141/1894134, 2022.
- A. Fritz, C. Able, M. Mauter and E. Grol, "[Supporting Information for Aqueous Bromide Discharges from U.S. Coal-Fired Power Plants: Points of Origin, Concentration Ranges, and Effluent Treatment Costs](#)," supporting information ([final presentation](#)), 2023.
- 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](#)," National Energy Technology Laboratory, DOE/NETL-2023/3852, Pittsburgh, PA, March 20, 2023.
- K. Buchheit and N. Kuehn, "[Eliminating the Derate of Carbon Capture Retrofits – Revision 2](#)," National Energy Technology Laboratory, DOE/NETL-2023/3850, Pittsburgh, PA, March 31, 2023.
- S. Hughes and P. Cvetic, "[Analysis of Carbon Capture Retrofits for Cement Plants](#)," National Energy Technology Laboratory, DOE/NETL-2023/3856, Pittsburgh, PA, March 31, 2023.
- M. Oakes and M. Turner, "[Cost and Performance Baseline for Fossil Energy Plants, Volume 5: Natural Gas Electricity Generating Units for Flexible Operation](#)," National Energy Technology Laboratory, DOE/NETL-2023/3855, Pittsburgh, PA, May 5, 2023.

Conference Proceedings and Events

- J. Ghouse and D. Miller, "[IDAES: A Next-Generation, Multi-Scale Process Systems Engineering Framework for Optimizing Energy Systems and Manufacturing Processes](#)," presentation at the 2022 Smart Manufacturing Experience, Pittsburgh, PA, June 9, 2022.
- W. Epting, Y. Lei, J. Mason, T. Kalapos, H. Abernathy and G. Hackett, "[Rapid Assessment and Optimization of Electrodes for Solid Oxide Fuel Cells and Electrolyzers using Long-Term Performance Modeling and Machine Learning](#)," presentation at the 23rd International Conference on Solid State Ionics, Boston, MA, July 21, 2022.
- A. Deshpande, "[Framework for Optimization, Quantification of Uncertainty, and Surrogates \(FOQUS\)–Demonstration](#)," presentation at the 2022 Carbon Management Project Review Meeting, Pittsburgh, PA, August 16, 2022.
- D. Morgan and T. Warner, "[NETL's Techno-Economic Models for Assessing CO₂ Pipeline Transport and Geologic Storage](#)," presentation at the SPE Workshop: Future Energy Roadmap – Navigating Through the Energy Transition, Galveston, TX, August 22–23, 2022.
- G. Stinchfield, M. Zamarripa, J. Sirola and C. Laird, "[Optimal Design Formulations for Families of Similar Processes with Applications in Energy Systems](#)," presentation at the 2022 INFORMS Annual Meeting, Indianapolis, IN, October 16–19, 2022.
- D. Caballero, R. Hughes, M. Zamarripa, B. Omell, M. Matuszewski and D. Bhattacharyya, "[Isotherm Modeling and Techno-Economic Analysis of Contactor Technologies for New Tetraamine-Appended MOF for NGCC Applications](#)," presentation ([conference proceedings](#)) at the 16th International Conference on Greenhouse Gas Control Technologies (GHGT-16), Lyon, France, October 25, 2022.
- J. Morgan, M. Campbell, K. Rao Putta, M. Ismail Shah, M. Matuszewski and B. Omell, "[Development of Process Model of CESAR1 Solvent System and Validation with Large Pilot Data](#)," presentation ([conference proceedings](#)) at the 16th International Conference on Greenhouse Gas Control Technologies (GHGT-16), Lyon, France, October 26, 2022.

// RECENT PUBLICATIONS **cont'd**

- Y. Girish Shah, Z. Mills, J. Thompson, D. Bhattacharyya, C. Tsouris, C. Finney and G. Panagakos, "[Computational Fluid Dynamics \(CFD\) Modeling of Wetted Wall Absorption Columns for Solvent-Based Post-Combustion Carbon Capture Applications](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 13, 2022.
- N. Susarla, E. Rawlings, J. Ghouse, J. Sirola and D. Miller, "[Conceptual Design and Analysis of a Power Generator with Integrated Thermal Energy Storage and CO₂ Capture](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 13–18, 2022.
- R. Tumbalam Gooty, K. Frick, J. Ghouse, J. Hansen, J. Sirola and D. Miller, "[Techno-economic Assessment of Coupling an Existing Nuclear Power Plant with a Low Temperature Electrolysis Unit](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 13–18, 2022.
- R. Tumbalam Gooty, J. Ghouse, Q. Minh Le, B. Thitakamol, S. Rezaei, D. Obiang, F. da Cruz, E. Simonoff, R. Gupta, J. Zhou, D. Bhattacharyya and D. Miller, "[Incorporation of Market Signals for the Optimal Design and Operation of a Flexible Post-Combustion Capture Systems](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 13–18, 2022.
- J. Ghouse, D. Miller, B. Knueven, J. Sirola, J. Jalving, X. Gao, X. Chen and A. Dowling, "[Multiscale Optimization of Integrated Energy Systems Using Machine Learning Models for Market Interactions](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 16, 2022.
- R. Hughes, D. Caballero, M. Zamarripa, B. Omell, M. Matuszewski and D. Bhattacharyya, "[Isotherm Modeling and Techno-Economic Analysis of Contactor Technologies for New Tetraamine-Appended MOF for NGCC Applications](#)," presentation at the 2022 AIChE Annual Meeting, Phoenix, AZ, November 17, 2022.
- D. Miller, J. Ghouse, R. Gooty, B. Omell, J. Morgan, D. Caballero, M. Zamarripa, S. Homsy, B. Paul and A. Deshpande, "[Future of CO₂-Management Systems: Design and Operations](#)," presentation ([conference paper](#)) at the Foundations of Computer-Aided Process Operations/Chemical Process Control (FOCAPO/CPC) 2023 conference, San Antonio, TX, January 8–12, 2023.
- G. Stinchfield, L. Biegler, J. Eslick, C. Jacobson, D. Miller, J. Sirola, M. Zamarripa, C. Zhang, Q. Zhang and C. Laird, "[Optimization-based Approaches for Design of Chemical Process Families Using ReLU Surrogates](#)," presentation ([conference paper](#)) at the FOCAPO/CPC 2023 conference, San Antonio, TX, January 8–12, 2023.
- D. Allan, V. Dabadghao, M. Li, J. Eslick, J. Ma, D. Bhattacharyya, S. Zitney and L. Biegler, "[NMPC for Setpoint Tracking Operation of a Solid Oxide Electrolysis Cell System](#)," presentation ([conference paper](#)) at the FOCAPO/CPA 2023 conference, San Antonio, TX, January 10, 2023.
- W. Epting, Y. Lei, J. Mason, T. Kalapos, H. Abernathy and G. Hackett, "[A Machine Learning Framework for Rapid Assessment and Optimization of SOC Electrodes from Low Resolution Data](#)," presentation at the 47th International Conference and Expo on Advanced Ceramics and Composites, Daytona Beach, FL, January 25, 2023.
- G. Hackett, "[Techno-Economic Analysis of an SOFC Hybrid Carbon Conversion Concept](#)," presentation at the 2023 Hydrogen & Fuel Cell Seminar, Long Beach, CA, February 8, 2023.
- A. Burgard, S. Zitney and B. Omell, "[Multi-scale Modeling Using IDAES](#)," presentation at the 2023 FECM Spring R&D Project Review Meeting, Pittsburgh, PA, April 19, 2023.
- G. Hackett, "[Status Update on NETL Techno-Economic Analysis of Solid Oxide Cells](#)," presentation at the 2023 FECM Spring R&D Project Review Meeting, Pittsburgh, PA, April 19, 2023.
- E. Grol, "[Overview of Emissions Control R&D at NETL](#)," presentation at the 2023 FECM Spring R&D Project Review Meeting, Pittsburgh, PA, April 20, 2023.
- A. Guinan, A. Sheriff and T. Grant, "[Comparative Economic Analysis of Capture, Transport, and Storage from a CO₂ Source Perspective](#)," presentation at the SPE/AAPG/SEG CCUS 2023 conference, Houston, TX, April 26, 2023.
- A. Guinan, A. Sheriff, D. Morgan, T. Grant, T. Warner, K. Bello, D. Vikara, N. Wijaya and L. Cunha, "[Techno-Economic Models are Instrumental in Analyzing Decarbonization Strategies](#)," presentation at the SPE/AAPG/SEG CCUS 2023 conference, Houston, TX, April 26, 2023.
- D. Vikara, J. Eppink, T. Vactor, T. Warner, B. Chen, S. Matthews, D. Morgan, A. Guinan, M. Marquis, Z. Ma, B. Ahmed, R. Pawar and L. Cunha, "[Pathways to CO₂ Utilization and Storage for the Intermountain West](#)," presentation at the SPE/AAPG/SEG CCUS 2023 conference, Houston, TX, April 27, 2023.
- N. Wijaya, D. Morgan, D. Vikara, T. Grant and L. Cunha, "[Comparative Study of Commercial-Scale CO₂ Storage Options in Single and Stacked Saline Formations in Managing Reservoir Pressure Buildup](#)," presentation at the SPE/AAPG/SEG CCUS 2023 conference, Houston, TX, April 27, 2023.
- M. Krynock, "[Carbon Conversion Life Cycle Analysis at NETL](#)," presentation at the 2023 CCUS TEA/LCA Workshop on Harmonizing CCUS Assessments, Hybrid (Virtual and Ann Arbor, MI), May 18, 2023.

// REFERENCE SECTION

Models / Tools / Databases

[Carbon Capture Simulation Initiative \(CCSI\) Toolset](#)

[FECM/NETL CO₂ Transport Cost Model](#)

[FE/NETL CO₂ Saline Storage Cost Model](#)

[FE/NETL CO₂ Prophet Model](#)

[FE/NETL Onshore CO₂ EOR Cost Model](#)

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