SSAE Newsletter

DECEMBER // 2023 VOLUME 3.8

// 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:

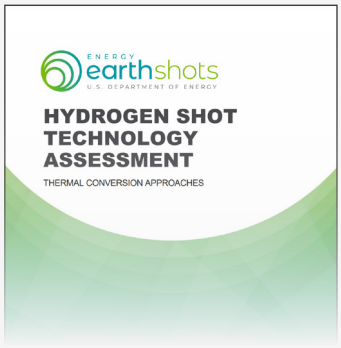
- Process systems engineering research: advanced modeling, simulation and optimization tools for complex dynamic systems
- Process and cost engineering: plant-level synthesis, process modeling and simulation of energy systems with performance estimates
- Resource and subsurface analysis: evaluation of 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 Research to Accelerate Global Climate Action at COP28

During the 28th U.N. Climate Change Conference (COP28) in Dubai, the Department of Energy (DOE) announced new initiatives for reaching its Hydrogen Shot goal, including ramping up investments in research, development, and demonstration. Knowing that decarbonization of future thermal conversion processes are critical options for successfully achieving the Hydrogen Shot goal of reducing the cost of clean hydrogen to $1 per 1 kilogram (kg) in 1 decade, or by 2031,



NETL and SSAE researchers have collaborated to prepare the "Hydrogen Shot Technology Assessment: Thermal Conversion Approaches." The report discusses the thermal conversion technologies that were explored including: SMR, ATR, POX, gasification, plasma pyrolysis, in situ hydrogen generation, chemical looping, and dry reforming. The researchers found that technology advancements may not be enough to reduce hydrogen (H_2) production costs to the $1/kg H_2 goal. Additional factors were examined and did help to reduce cost such as plant scale, market scenarios, plant site location, carbon dioxide (CO_2) transportation and storage optimization, by-product sales, CO_2 valuation, and integration with other energy systems, as shown in Figure 1. SSAE authors include Shannon McNaul*, Charles White*, Robert Wallace*, Travis Warner*, H. Scott Matthews*, Jinliang N. Ma*, Eric Lewis, David Morgan, Megan Henriksen*, John White*, Robert Stevens, and Travis Shultz. Learn more

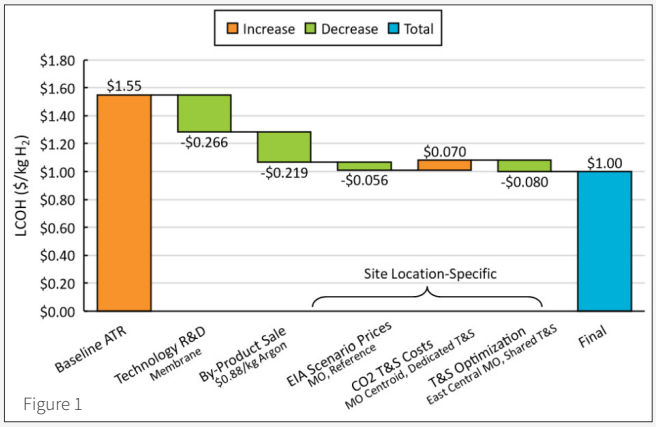


Figure 1

SSAE Research Suggests Tailored, Regional Approach for CCS

An analysis of the Central United States explored variables associated with transporting and storing CO_2. Dividing the region into three impact areas, SSAE researchers A. Sheriff*, A. Guinan*, T. Grant and L. Cunha found that geographic differences had significant impacts on costs and provided a framework to evaluate these impacts. A carbon capture and storage (CCS) network was designed for each regional area that connected different source types at hypothetical locations with geologic storage reservoirs through either (1) a dedicated pipeline connecting a single source to a single storage reservoir site or (2) a trunkline network consisting of pipeline segments and hubs connecting multiple sources to multiple storage reservoir sites (see Figure 2). The analysis resulted in the evaluation of more than 100 integrated source-to-sink matching scenarios, and the results highlighted the significance of the location and type of the CO_2 source, capture rate of a CO_2 source, quality of the saline storage reservoir, and distance between source and sink on overall costs. A poster and presentation are also available on this topic. Learn more.

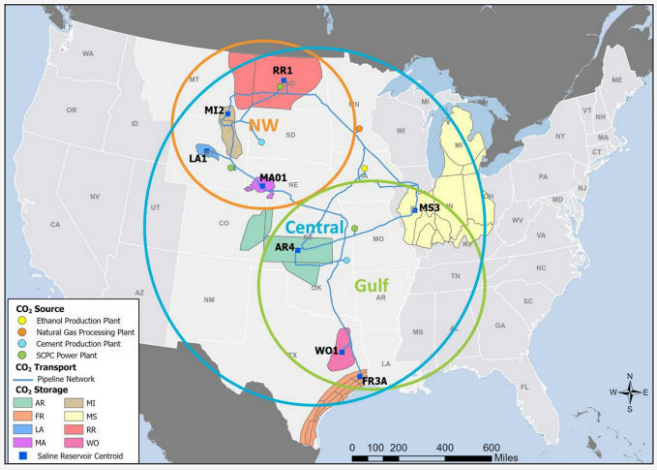


Figure 2

Applying Machine Learning to Fracture Network Mapping

SSAE is supporting work highlighting the application of machine learning for fracture network mapping for a CCUS use case in the Illinois Basin – Decatur Project (IBDP) based on injection data and passive seismic (microseismic) data (workflow is shown in Figure 3). The results will be coupled to the dynamic study for geomechanical impact quantification for monitoring and risk assessment for CO_2 storage. This capability and tool development are part of Phase II of the SMART Initiative (Director Hema Siriwardane) that is funded by the Bipartisan Infrastructure Law (BIL). The authors of "Machine Learning Application for CCUS Carbon Storage: Fracture Analysis and Mapping in the Illinois Basin" are G. Liu, A. Kumar*, W. Harbert*, H. Siriwardane, D. Crandall, G. Bromhal and L. Cunha . A summary of the work was presented at the SPE Annual Technical Conference and Exhibition (ATCE) on October 18, 2023, in San Antonio, TX. The presentation and discussion were well-received with multiple discussions from oil and gas industry peers in both the presentation time slot and at NETL's booth exhibition. Moreover, after the conference the presenter, Guoxiang Liu was invited to join the 2024 SPE ATCE Program Committee Board.

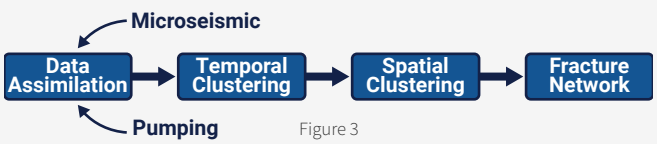


Figure 3

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Staff Spotlight

Travis Warner* is a subsurface energy analyst who has supported SSAE for over four years, focusing on cost and performance modeling of CO_2 pipeline transport and CO_2 storage (saline and EOR), as well as the financial impact of CCS deployment incentives (like 45Q tax credits). He has twelve years of combined professional experience, including seven with EQT production as an R&D geologist and one as a consulting geologist and founder of 30 Microns Consulting, LLC. He has a Bachelor of Science in Forensic and Investigative Sciences and a Master of Science in Geology, both from West Virginia University. Mr. Warner held geology internships and research assistantships at McCrone Associates, EnerVest Operating, LLC, NETL/ORISE, and EQT Production.

Mr. Warner lives in the lower Shenandoah Valley in West Virginia with his wife and three children, where he enjoys slacklining, rock climbing, paddleboarding, practicing Brazilian Jiu Jitsu, and rescuing and rehoming displaced Conococheague Limestone from local construction sites.

// NOTICES

SSAE Well-Represented at USAEE/IAEE Annual Conference

SSAE staff again this year showcased their research at the 40th Annual United States Association for Energy Economics (USAEE) / International Association of Energy Economics (IAEE) Conference November 6–8, 2023. Christopher Nichols and Amanda Harker Steele co-chaired a session on Models, Data, and Analysis to Support Carbon Management which featured presentations given by SSAE members Gregory Hackett and Eric Grol. Additionally, John Brewer presented "Dispatch informed hydrogen production" in the Economic Analysis of Hydrogen Systems session.

- "Representation of Fossil Fuel Power Generation Technologies in NREL's Annual Technology Baseline," presented by Gregory Hackett, provides an assessment of commercial and advanced technology performance and cost data for fossil fuel power generation equipped with solvent-based carbon capture for inclusion in the National Renewable Energy Laboratory's Annual Technology Baseline (ATB). The intent of the NREL ATB is to provide a consistent set of technology cost and performance data to inform electric and transportation sector analysis in the United States. This work improves the representations of U.S. Department of Energy's Office of Fossil Energy and Carbon Management (FECM) equities contained in the ATB.
- "An Analysis of How the IRA's Section 45Q Tax Credit Impacts the Economics of Industrial CO_2 Capture," presented by Eric Grol, discussed how the 2022 Inflation Reduction Act (IRA) amends the 2018 Bipartisan Budget Act (BBA) Section 45Q CO_2 Sequestration Tax Credit ("Section 45Q"), which provides a financial incentive to qualified facilities, including industrial applications. The qualification threshold for industrial applications, originally 100,000 tonnes, was reduced to 12,500 tonnes. NETL's Industrial CO_2 Capture Retrofit Database model was used to calculate the CO_2 capture cost for retrofit of the industrial facilities including ammonia, cement, ethanol, hydrogen, and natural gas processing both with and without the amended Section 45Q tax incentive. The effects of other parameter changes (e.g., CO_2 capture rate, capacity factor, retrofit difficulty, financial assumptions, utility pricing, etc.) were also examined. Results were compared across industrial applications, providing an indication of the types of industries that are likely to benefit most from the Section 45Q amendment.
- In John Brewer's presentation, "Dispatch informed hydrogen production," the cost of hydrogen production was projected to decline over the next several decades alongside the widespread deployment of energy-constrained generating resources and electrification. While today's system can utilize fast-responding thermal generating assets to answer to changes in demand and energy-constrained resource output, the system of tomorrow will more likely rely on price-responsive demands and virtual power plants. Since hydrogen is anticipated to be a primary generating fuel of the future while also providing a large demand base for its production, it is reasonable to evaluate the potential performance of hydrogen production demand as a demand-response resource.

Want to learn more about SSAE's work?

Click here to see previous SSAE newsletter issues

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// PERSPECTIVES

Market Analysis for the Integration of New Power Technologies: A Case Study of the Deployment of Hybrid Fossil-Based Generator plus Energy Storage (ES-FE)

The national landscape of potential hybridized fossil energy power plants with energy storage technologies (ES-FE) is the subject of an SSAE study published in Applied Energy, including a compilation of an ES-FE dataset with over 65 U.S. projects and concepts, comprising approximately 500 MWh of co-located ES capacity with FE power plants. The study estimates the economic feasibility of adding ES to existing FE power plants by characterizing the potential revenues that can be generated by the ES component through flexibility and capacity value. The integration of ES into FE-based power plants may present an opportunity for generators seeking to increase their revenue streams in existing markets and participate in the adoption of new and cleaner technologies.

The analysis focuses on ES technologies with 2- to 10-hour durations located in four U.S. independent system operator (ISO) markets: Midcontinent ISO (MISO), Electric Reliability Council of Texas (ERCOT), PJM Interconnection (PJM), and California ISO (CAISO), which have over 70,000 MW of combined FE power capacity that could add ES. Annual revenues were estimated for the ES component using a what-if-analysis approach for capacity value, price arbitrage, or ancillary services provision. The results show that annual revenues depend on the end-use storage service, wholesale electricity and capacity market prices, and ES technology operation parameters such as discharging duration and cycling frequency. Results also show that the ES component accrues $13–92/kW-year when providing capacity value in MISO and PJM, and approximately $7–178/kW-year via price arbitrage and ancillary services provision in the wholesale and ancillary services markets respectively, in MISO, PJM, CAISO and ERCOT.

Capacity revenues were estimated for a hypothetical 1- MW, 2- to 10- hour duration ES component. For PJM, the clearing prices for the forward capacity auctions of 2020/2021, 2021/2022 and 2022/2023 were used.

Daily and annual revenues were estimated using capacity prices of the last five base residual auctions and effective load carrying capability class rating for ES of 70–95%. Total expected annual revenues for PJM ranged between $12.8–69.4/kW-installed, depending on location and yearly performance of the base residual auctions. MISO capacity prices and volumes over the past five years were used. The reference capacity revenue levels for the ES component range between $0.036/kW-year in the near-zero priced zones and years (Z8–Z10), and $91.9/kW-year in the highest-priced probabilistic risk assessment; (Z1–Z7 and Zone 10) as shown in Figure 4. These estimates assume that the current 95% capacity value of stand-alone storage is applicable to the ES component of ES-FE plants, and that there are no interconnection rights limitations for that level of capacity credit.

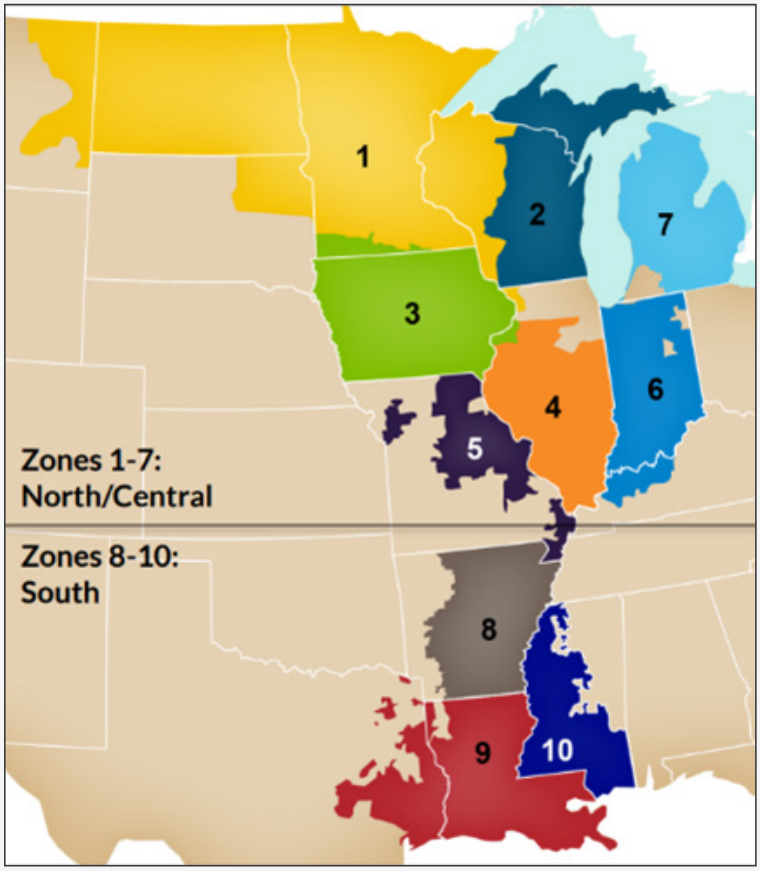

Figure 4. MISO Resource Adequacy Zones*

Revenues accrued in the wholesale and ancillary services markets were estimated for three analysis years, 2018-2020 in all ISOs. The base year was set at 2019 as it was the median year for annual average wholesale market clearing prices for three (MISO, PJM, and CAISO) of the four ISOs. A cycling rate of 250 events (or cycles) was chosen as a rule of thumb to stay close to 1 cycle per day. The base-case time-stacking revenues lie in the range of $10–91/kW-year, where MISO and ERCOT are on the lowest and highest ends of the revenue spectrum, respectively.

A higher number of cycles does not always guarantee a higher overall annual revenue from arbitrage. Responsive reserves in ERCOT are shown to be the highest-paying service. The number of cycles it uses (72 of 250 in 2019) is much less than arbitrage (132 of 250 in 2019), while it still pays more than arbitrage. A similar pattern is observed for PJM. This indicates that in two of four ISOs (ERCOT and PJM), an ES component would be able to earn more while cycling less by engaging in ancillary services of regulation and responsive reserves. In MISO and CAISO, however, engaging in arbitrage is still able to earn higher annual revenues. For all ISOs except MISO, increasing duration also increases annual per-unit revenues. Specifically, ERCOT shows the highest sensitivity to duration, followed by CAISO.

*MISO, (2023). Planning Resource Auction Results for Planning Year 2023-2024, from https://cdn.misoenergy.org/2023%20Planning%20Resource%20Auction%20(PRA)%20Results628925.pdf

// PERSPECTIVES (cont'd)

A cash flow analysis was performed to estimate the net present value (NPV) of the ES addition using a range of ES costs of three ES technologies and durations. The study finds that for most ES technologies considered, revenues alone are insufficient to achieve economic feasibility. Of the 1,645 total runs analyzed, only 7% (115) had positive NPVs. Overall, the 4-hour duration technologies performed better. The 10-hour duration systems had high capital costs, which made turning a profit very difficult because of the initial debt. The 2-hour duration systems had a lower installed cost but a lower revenue stream, which made it hard for the systems to make any money, as shown in Figure 5. The SSAE researchers who performed this analysis are Ivonne Pena Cabra*, Smriti Sharma*, Clare Callahan*, Kirtan Jani*, Yash Kumar*, Victoria Toetz*, and Erik Shuster.

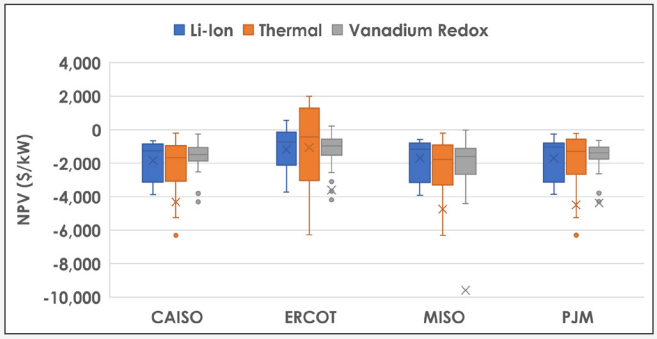

Figure 5. Comparison of lifetime NPVs of ES systems in MISO, ERCOT, PJM, and CAISO

// UPCOMING CONFERENCES AND EVENTS

SSAE federal staff and NETL support contractor personnel will attend or present at the following conferences December 2023–February 2024:

- Midland CO_2 Conference
  Participant: Guoxiang Liu
  Midland, TX: December 4–7, 2023
- 2023 American Geophysical Union (AGU) Fall Meeting
  Presenters: Mackenzie Mark-Moser
  San Francisco, CA & Online, December 11-15, 2023
- 2023 New Mexico Produced Water Research Consortium Annual Meeting
  & PARETO Technical Team Meeting
  Participant: Markus Drouven
  Albuquerque, NM December 13-14, 2023
- DOE CDR workshop
  Participant: Sally Homsy
  Washington, DC: January 9-10, 2024
- Reactive CO_2 Capture Workshop, National Renewable Energy Laboratory
  Participant: Gregory A. Hackett
  Golden, CO: January 24, 2024
- University of Texas Seventh Conference on Carbon Capture and Storage (UTCCS-7)
  Presenter: Joshua Morgan
  Austin, TX, January 23, 2024
- Critical Materials Institute (CMI) Annual Meeting
  Presenter: Thomas Tarka
  Ames, IA, January 24, 2024
- IDAES/CCSI²/PrOMMiS Technical Team and Planning Meeting
  Presenter: Joshua Morgan
  Participant: Alison Fritz, Timothy Fout and Stephen Zitney
  Berkeley, CA, January 30-February 1, 2024
- Orphan, Abandoned, Idle, and Marginal Wells: Opportunities with Plugging, Repurposing, Carbon Credits, and More Workshop
  AAPG/Pittsburgh Petroleum Geology Societies
  Participant: Markus Drouven
  Cranberry Township, PA, February 27-28, 2024
- 8th International Supercritical CO_2 Power Cycles Symposium
  Presenter: Eric Liese
  San Antonio, Texas: February 26-29, 2024

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// RECENT PUBLICATIONS

Articles

- I. Pena-Cabra, S. Sharma, C. Callahan, K. Jani, Y. Kumar, V. Toetz, and E. Shuster, "Market analysis for the integration of new power technologies: A case study of the deployment of hybrid fossil-based generator plus energy storage (ES-FE)," *Applied Energy* 351, 121861, September 14, 2023.

Reports

- S. McNaul, C. White, R. Wallace, T. Warner, H. S. Matthews, J. Ma, M. Ramezan, E. Lewis, "Hydrogen Shot Technology Assessment: Thermal Conversion Approaches," National Energy Technology Laboratory, Pittsburgh, December 5, 2023.

Presentations and Posters

- C. Able, A. Fritz, and E. Grol, "Assessment of Combustion Residual Leachate: Treatment Standards, Wastewater Volumes, and Critical Mineral Recovery," presented at American Institute of Chemical Engineering 2023 Annual Meeting, Orlando, FL, November 6, 2023.
- C. Creason, D. Justman, R. Yesenchak, S. Montross, P. Wingo, R.B. Thomas, and K. Rose, "A Multi-Scale, Geo-data Science Method for Assessing Unconventional Critical Mineral Resources," presented at Geological Society of America Annual Meeting, Pittsburgh, PA, October 17, 2023.
- R. Boswell and S. Pool†, "Evolution of Upper Devonian Marginal-marine Sandstone Lithofacies in the Appalachian Basin," presented at Geological Society of America Annual Meeting, Pittsburgh, PA, October 17, 2023.
- M. Jamieson, "Energy Inputs for LCA," presented at ASTM Workshop on Decarbonization: A Gap Analysis of LCA Standards for Industry, virtual, October 10, 2023.
- E. Lewis, "Strategies for Achieving the DOE Hydrogen Shot: Thermal Conversion Approaches," poster at Global Syngas Technologies Conference, San Diego, CA, October 9, 2023.
- M. Jamieson, "U.S. DOE Special Session: National Energy Technology Laboratory LCA Update," presented at American Center for Life Cycle Assessment 2023, Burlington, VT, September 28, 2023.
- M. Jamieson, "USEPA Tools for Industrial Ecology Modeling (TIEM)," poster at American Center for Life Cycle Assessment 2023, Burlington, VT, September 26, 2023.
- A. Fritz, "Process-level cost benchmarks to establish economic viability of environmentally and socially sustainable unconventional rare earth element feedstocks." ACS Fall Meeting. August 13, San Francisco, CA. Conference Abstract.
- I. Pena Cabra, A. Iyengar, L. Labarbara, R. Wallace, J. Brewer, and P. Balash, (2022, November 20). Decarbonization of the power sector with CCS: Case study in two regions in the U.S. and lessons for Latin America [Conference Abstract/Paper]. IAEE/USAEE/ELAEE Conference, Bogota, Columbia.

// 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

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

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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