

SSAE Newsletter

JUNE // 2021

VOLUME 1.1



// ABOUT

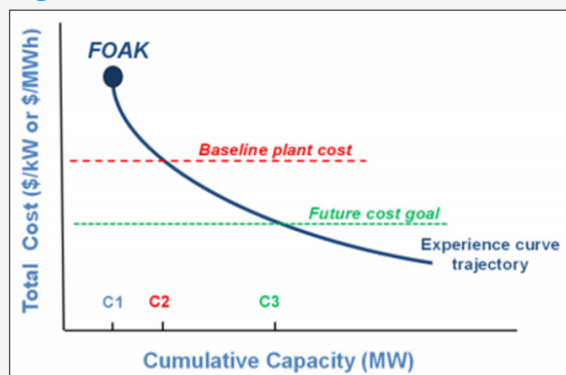
The Strategic Systems Analysis and Engineering (SSAE) directorate provides the decision science and analysis capabilities necessary to evaluate complex energy systems. The directorate's capabilities address technical, economic, resource, policy, environmental, and market aspects of the energy industry. 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 Researchers Co-author White Paper to Improve CCS Costing Guidelines



“Towards improved guidelines for cost evaluation of carbon capture and storage” is a white paper released in March 2021 by a 14-member international team from nonprofit research, intergovernmental, and university organizations and three NETL researchers—Tim Fout, Michael Matuszewski, and Joshua Morgan. This extends an earlier paper establishing a common costing methodology for carbon capture and storage (CCS) by addressing costing of technologies at early developmental stages and in sectors other than generation, and uncertainty analysis. This topic was featured at the 15th International Virtual Conference on Greenhouse Gas Control Technologies from March 15–18, 2021 where NETL participated as panelists and provided papers. [Learn more.](#)

Model in Development to Evaluate 45Q Tax Credit Impacts for CCS Projects

SSAE is developing a spreadsheet-based 45Q Tax Credit Monetization Model that will help users determine the optimal allocation and use of 45Q tax credits, as enacted, for a CCS project based on user-defined operational and financial inputs for each eligible CCS project participant within a tax equity partnership structure. The model will also determine, if necessary, the amount of further subsidy needed (in addition to 45Q tax credits) to make the CCS project economically feasible on a stand-alone basis. This tool will position NETL as a leading institution for evaluating 45Q tax credit impacts on integrated CCS systems.

NETL Part of Several Studies Evaluating Marcellus Resource Estimate

NETL supported a trio of studies that provide an estimate of resources within the West Virginia Marcellus play, addressing two primary issues: (1) assessment of the likely recovery factor within the Marcellus, a poorly known parameter of relevance to programmatic metrics; and (2) documenting the performance of West Virginia’s Marcellus wells, which has greatly exceeded estimates of available resources, and providing new methodologies for estimating such resources, both in-place and technically recoverable. These studies, two reports with the West

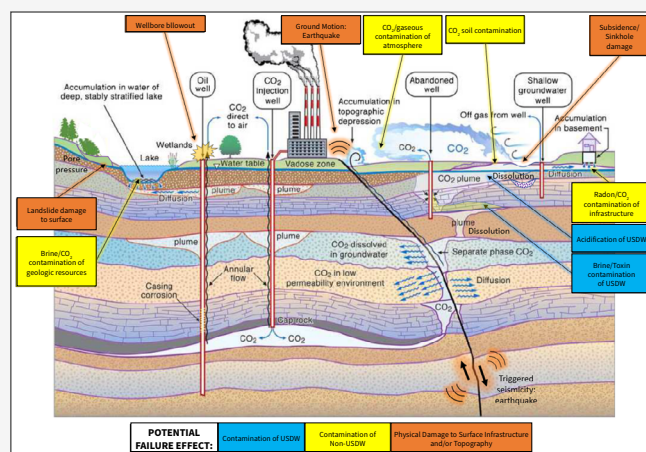
Virginia Geological & Economic Survey (WVGES) and a technical paper presented at the 2020 Society of Petroleum Engineers Virtual Annual Technical Conference and Exhibition, result from a collaboration between NETL (Ray Boswell), WVGES, and Northeast Energy LLC. Learn more about the [reports](#) and [paper](#).

SSAE Develops FE/NETL Onshore CO₂ EOR Evaluation System to Enhance Users’ Ability to Quickly Model Recovery at an Oil Field

SSAE has developed the FE/NETL Onshore CO₂ EOR Evaluation System to simulate CO₂ EOR and estimate the cost of CO₂ EOR operations to help understand the potential for CO₂ EOR to produce oil and store CO₂ in conventional oil fields and residual oil zones. The evaluation system consists of the 1) FE/NETL CO₂ Prophet Model, a streamline/stream tube reservoir simulator that can simulate water flooding and CO₂ EOR for an oil field pattern, 2) FE/NETL Onshore CO₂ EOR Cost Model, estimates the CO₂ stored, oil produced, and project economics of the oil field using outputs from the prophet model, and 3) FE/NETL Onshore CO₂ EOR Evaluation Tool, a Python script that can be used to evaluate the application of CO₂ EOR on multiple oil fields. The prophet model allows for transparent generation of results and only requires 5–20 seconds to simulate 30 years of CO₂ EOR at an oil field. Both the prophet model and cost model and their user’s manuals are publicly available, whereas the evaluation tool is planned to be released later this year. Learn more about the [prophet model](#) and [cost model](#).

SSAE Report Examines Environmental Impacts and Compliance Best Practices for CCS

Produced for the U.S. Department of Energy’s (DOE) Loan Programs Office (LPO), this report provides information on the current state of the science for geologic storage of CO₂, relevant to completion of environmental reviews under the National Environmental Policy Act. The report presents failure modes, impacts, and best practices to prevent, detect, or mitigate failures that may occur during CO₂ injection and storage. This effort marks new SSAE support with LPO outside of current LCA work. [Learn more.](#)



Source: EPA (modified), Geologic Sequestration of Carbon, August 10, 2015

// NOTICES

Welcome Markus Drouven, New SSAE PSERT Member



Markus Drouven is a new member of SSAE's Process Systems Engineering Research Team (PSERT). Markus joins NETL with nearly

a decade of experience in developing and deploying mathematical modeling and optimization solutions. Markus has primarily focused on optimizing advanced energy systems, particularly in the oil and gas industry. Markus grew up in Germany and moved to Pittsburgh in 2013 when he enrolled in the Process Systems Engineering doctorate program at Carnegie Mellon University. He is passionate about cars, motorcycles, and motorsports, and enjoys hiking and canoeing with his wife and daughter.

IDAES Platform Earned R&D 100 Award

Last fall, NETL's Institute for the Design of



IDAES
Institute for the Design of
Advanced Energy Systems

Advanced Energy Systems (IDAES), a center of excellence for the identification, synthesis, optimization and analysis of innovations to meet the nation's growing energy needs, captured a prestigious R&D 100 award, which recognized the developers of the 100

most technologically significant products introduced into the marketplace in the previous year. IDAES received the recognition in the Software/Services category.

Led by NETL Senior Fellow, David Miller, IDAES is a collaboration with Sandia National Laboratories, Lawrence Berkeley National Laboratory, West Virginia University, Carnegie Mellon University and the University of Notre Dame. The IDAES Integrated Platform optimizes the design and operation of complex, interacting technologies and systems by providing rigorous modeling capabilities to increase efficiency, lower costs, increase revenue, and improve sustainability. [Learn more.](#)

Anthony Burgard Received Prestigious Award from Pittsburgh Federal Executive Board



Anthony Burgard, the supervisor of SSAE's PSERT, received a Gold Award in the Outstanding Contribution to Science

category (non-medical) for leading the development of an innovative suite of science-based computational modeling tools by a diverse team of researchers from across DOE's laboratory complex.

These first-of-a-kind modeling tools are capable of significantly increasing the efficiency and flexibility of power plants, as demonstrated under a Cooperative Research and Development Agreement with Tri-State Generation and Transmission Association Inc.'s Escalante Power Plant. Also, these tools identified an innovative opportunity to improve overall plant efficiency through a new sliding pressure approach to flexible operations while simultaneously balancing equipment degradation resulting from highly dynamic operations. Through Burgard's technical leadership and scientific advancement, these new computational modeling tools and capabilities can be applied to other power plants, significantly reducing greenhouse gas emissions and operating costs while improving flexibility and resiliency.

Burgard and other winners of the 2021 Excellence in Government Awards were announced as part of Public Service Recognition Week, which is a nationwide public education campaign held in May to honor the men and women who serve our nation as federal, state, county and local government employees. [Learn more.](#)

In Tribute

Joel Theis, a member of SSAE's Energy Markets Analysis Team (EMAT), passed away in December 2020. Joel had more than 30 years' experience in resource and energy economics, particularly energy sector financing. After a career beginning with the Public Service Company of Colorado and extending through several private-sector consulting firms, Joel moved to Pittsburgh in 2009 to join NETL as an economist for the Integrated Electric Power Systems group within the Office of Systems Analysis and Planning. Joel examined power industry finances, competition, and regulation for the planning team within the Office of Strategic Energy Analysis and Planning from 2010 to 2015 and subsequently for EMAT within the Systems Engineering and Analysis Directorate of the Research and Innovation Center. Outside of NETL, Joel enjoyed sports, particularly hiking, cycling, and skiing, and took pleasure in writing, having authored two books, including his recently published novel "The Liver's Fund" in 2018. Joel leaves behind an impressive legacy, and his professional and personal accomplishments will not be forgotten.

// PERSPECTIVES

U.S. Energy Economy Begins Rebound as Pandemic Wanes

The first U.S. case of COVID-19 was confirmed on Jan. 20, 2020. Since then, according to the Centers for Disease Control and Prevention (CDC), more than 32.2 million (M) new cases of COVID-19 have been confirmed in the nation. The CDC also notes that more than 580 thousand (K) COVID-19-related deaths have been reported in the U.S. since the start of the pandemic.

However, there are recent positives to report. Most notably, as of May 12, 2021, nearly 264.7M COVID-19 vaccines have been administered in the U.S. while 117.7M people are identifying as being fully vaccinated.

At the start of the pandemic, to prevent further spread of the virus, many U.S. states implemented stay-at-home orders. These orders led to overall reductions in consumer spending and investment, which impacted energy markets in two ways: 1) consumer demand for energy services declined, resulting in lower energy prices, and 2) capital expenditures necessary to sustain energy production were curtailed, decreasing production from major providers. As vaccine administration continues to roll out and stay-at-home orders continue to be lifted, the effects of the pandemic on the energy and overall economy are beginning to subside.

According to the U.S. Department of Labor (DOL) the highest reported number of seasonally adjusted initial claims for unemployment insurance occurred in the first week of April 2020, topping out at 6.2M claims. Approximately one year later, the DOL reported the number of these claims to be 740K. According to the Bureau of Labor Statistics the seasonally adjusted U.S. unemployment rate in April 2020 was 14.8%. Between April 2020 and August 2020, this rate dropped 6.4 percentage points to 8.4% and has continued to improve since then. As of April 2021, it was 6.1%.

COVID-19 also had a significant impact on the stock market, which began to

plummet in response on Feb. 28, 2020. At that time, there were only 64 confirmed U.S. cases of COVID-19. Since then the value of the Dow Jones Industrial Average Index and S&P 500 Index have rebounded considerably. According to S&P global, April year-to-date returns for the Dow Jones Industrial Average Index and S&P 500 Index were 11.32% and 10.68%, respectively.

According to the Transportation Security Administration (TSA), domestic air passenger travel has rebounded since May 2020. The TSA reports daily average air passenger travel for the first week of May 2021 as being approximately 1.45M individuals. For that same week in 2020, TSA reported daily average air passenger travel as being approximately 160K individuals. This travel has not yet fully returned to pre-pandemic levels. For the first week of May 2021 it was equal to 63% of daily average air passenger travel for the first week of May 2019, when daily average air passenger travel was 2.3M individuals.

The average weekly spot prices for West Texas Intermediate (WTI) and Brent crude oil, reported by the U.S. Energy Information Administration (EIA) for the first week of May 2021, were both above \$60/barrel, coming in at an average of \$65.10 and \$68.99/barrel, respectively. Compared to nearly a year ago, when the U.S. EIA reported average weekly spot prices for WTI and Brent crude oil of \$15.71 and \$17.05/barrel, respectively, average weekly spot prices for both oil grades have more than quadrupled.

Between the first week of March 2021 and first week of May 2021, the weekly average Henry Hub spot price for natural gas has remained between \$2 to \$3/MMBtu. Weekly average Henry Hub spot prices for natural gas over the same period in 2020 were consistently below \$1.90/MMBtu. Pre-pandemic prices over the same period more closely resemble weekly average Henry Hub spot prices for natural gas prices between the first week of March 2021 and first week of May 2021, coming in between \$2.70 to \$2.95/MMBtu, according to the U.S. EIA.

For the week ending May 8, 2021, estimated U.S. coal production totaled approximately 11.3M short tons (MMst). For the same week in 2020, the U.S. EIA estimated domestic coal production to be 8.4MMst. Natural gas production witnessed a similar increase. Rig counts for oil and natural gas increased by 17.8% and 28.8%, respectively, for the week ending May 4, 2021, compared to the previous year.

Finally, service-related and industrial consumer demand for electricity decreased significantly in response to the pandemic. While residential demand did increase in response to stay-at-home orders, the increase was only enough to partially offset decreased demand from other industries. From the middle of March (week of March 15) to the first week of May (week of May 7) 2020, cumulative (all industries combined) average weekly demand for electricity was a little over 2 TWh less than cumulative, average weekly demand for electricity during the same period in the previous year. Demand for electricity started to rebound in October 2020 so that cumulative, combined average weekly demand for electricity from the middle of Mar. to the first week of May 2021 closely resembled cumulative, average weekly demand for electricity in 2019.

Prices

	2019	2020	2021
WTI Crude Oil* (dollars per barrel)	56.99	39.17	58.91
Brent Crude Oil (dollars per barrel)	64.34	41.69	62.26
Gasoline* (dollars per gallon)	2.60	2.18	2.68
Diesel* (dollars per gallon)	3.06	2.55	2.97
Heating Oil* (dollars per barrel)	3.00	2.44	2.89
Natural Gas* (dollars thousand cubic feet)	10.46	10.83	11.16
Electricity* (cents per kilowatt-hour)	13.01	13.20	13.50
Coal* (dollars per million Btu)	2.02	1.92	1.96

*West Texas Intermediate

*Average regular pump price

*On-highway retail

*U.S. Residential average

*Electric power generation fuel cost

Source: EIA Short-Term Energy Outlook, May 11, 2021

// PERSPECTIVES (cont'd)

Reports Help Chart Paths to the New Hydrogen Economy as SSAFE Studies Use of Fossil Resources as a 'Bridge' to Hydrogen Economy

Hydrogen (H₂) is receiving considerable interest as a potential clean, bulk energy storage solution under future high variable renewable energy scenarios. This emerging technology could serve as an alternative to advanced battery-based bulk energy storage and has the ability to decarbonize traditionally difficult segments of the economy.

The International Energy Agency (IEA) and Global CCS Institute (GCCSI) have provided a decent H₂ economy pathway. Two recent reports by these institutions provided contemporary views of the potential for coal and natural gas, coupled with CCS or CCUS, to play significant roles in the future of low-carbon H₂ production.

IEA Clean Coal Centre's (IEA CCC) May 2021 draft report, "Hydrogen Production from Coal," was the topic of an April 14, 2021, webinar and May 7, 2021 feature article in Coal Age Magazine. This report highlights current significant cost advantages of using fossil energy with CCS (blue H₂) and without CCS (grey H₂) over electrolysis or water splitting driven by renewable electricity (green H₂). Learn more about the [webcast](#) and [feature article](#).

GCCSI issued its report on blue H₂ in April 2021. In the report, a production cost analysis showed an enormous cost advantage for both coal and natural gas, with and without CCS, over renewables and electrolysis-based H₂ production. It also pointed out the distinction between renewables with electrolysis H₂ production costs dependent upon using either dedicated renewable electricity supply or using "otherwise curtailed" renewable electricity. [Learn more](#).

A key difference between these two reports was the emphasis placed on the potential for net-negative emissions when co-processing fossil energy and biomass with CCS. The GCCSI report only refers to net-negative emissions in the context of bioenergy with CCS, or pure biomass with CCS, as many contemporary energy transition reports tend to do. The IEA CCC report highlights a critical factor

that has become a dominant concern for technology acceptability as state and federal policies, as well as foreign government policies, have taken on a "zero-carbon" requirement. In the case of California's zero carbon by 2045 mandate, regulators have explicitly defined the current policy as allowing CCS only if 100% capture is attained. As noted in the Coal Age Magazine article, "Co-firing a portion of biomass or waste with the coal feedstock, coupled with CCUS, could lead to net zero or even negative CO₂/kgH₂, which would help 'future proof' the gasification plant." This notion was explicitly stated in the July 2020 IEA CCC report "Carbon Capture, Utilization and Storage – Status, Barriers and Potential." "CCUS capture levels will need to increase from the current 85-90% to closer to 100% to allow the power plants to continue to operate in a net-zero emission future as any residual CO₂ emissions from CCUS facilities will not be compliant without offset from negative CO₂ emissions elsewhere. Where auxiliary plants are used to provide steam and energy for the CCUS facility, they will also need to include CCUS to achieve very high capture levels overall."

Numerous references indicate that fossil-based technologies offer the lowest H₂ production cost. These technologies also offer a near- to mid-term "bridge" to a renewable-based H₂ economy or, alternatively, a cost-effective approach to decarbonize broader areas of the economy. Thus, SSAFE is involved in setting a H₂ technology environment to provide a current understanding of the performance and costs of commercial-scale fossil fuel-based H₂ production, using the best commercial technologies and at relevant scales.

A 2011 report, "Assessment of Hydrogen Production with CO₂ Capture Volume 1: Baseline State-of-the-Art Plants," evaluated several cases to analyze potential plant configurations to determine their

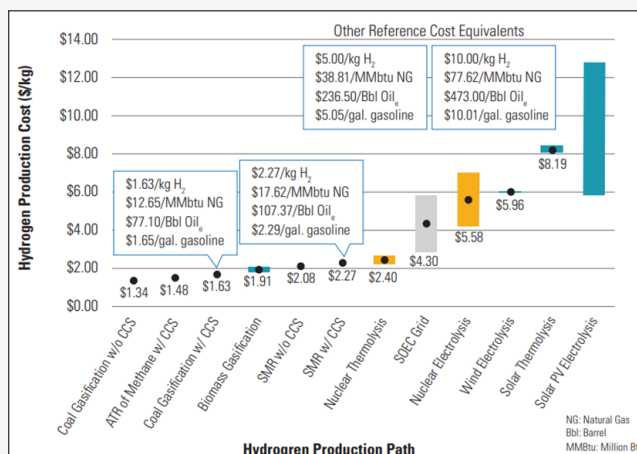
baseline performance and cost of producing H₂ from natural gas and coal. Estimated costs of H₂ production were reported in 2007\$/kg. [Learn more](#).

Additionally, in June 2019, SSAFE investigated gasification of municipal solid waste feedstock in a small-scale FastOx (Sierra Energy) gasifier in a combined heat and power configuration as part of a collaborative study with the Air Force Institute of Technology. Two cases were evaluated with several items, including gross power and environmental emissions, estimated.

In June 2020, SSAFE prepared a quick turnaround screening analysis of four H₂-based power generation routes for the Office of Fossil Energy and Carbon Management. In all cases, H₂ produced was converted to electricity via a combined cycle and LCOE was estimated in 2018 dollars, employing NETL Bituminous Baseline Rev 4 methodology.

A current study is looking to develop a reference study for commercial H₂ production technologies, with particular emphasis on coal gasification and co-gasification of coal and other feedstocks to achieve net negative emissions. The desired figure of merit is the levelized H₂ production cost (2018 \$/kg). A secondary objective of this study is to identify ample areas of R&D to further improve the performance and cost of fossil fuel-based H₂ production. On top of this work, support is expected with joint program offices and several members of SSAFE are part of a larger H₂ group.

[Learn more about the figure below.](#)



// UPCOMING

SSAE federal staff, research associates in the Oak Ridge Institute for Science and Education (ORISE) program, and NETL support contractor personnel will attend or present at the following meetings and conferences in July 2021:

Jessica Valentine (participant)

Intersolar North America and Energy Storage North America conference and trade show
Digital Summit, July 14–15, 2021

Hayri Sezer (presenter)

17th International Symposium on Solid Oxide Fuel Cells (SOFC-XVII)
Digital Meeting, July 18–23, 2021

Chad Able (presenter)

45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Eric Lewis (participant)

45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Robert Stevens (participant)

45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Thomas Tarka (presenter)

45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Stephen Zitney (presenter)

45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

// CONFERENCES AND EVENTS

- ASME 2021 Turbo Expo
Virtual, June 7–11, 2021
- IEA-Peking University launch of Net Zero by 2050: A Roadmap for the Global Energy Sector
Livestream, June 8, 2021
- 2021 Process Development Symposium
Virtual, June 8–10, 2021
- NETL 2021 FE R&D Virtual Project Review Meeting: Crosscutting Research and Advanced Energy Systems Project Review Meeting
Virtual, June 8, 10, & 15, 2021
- Financing Clean Energy Transitions in Emerging and Developing Economies
IEA Webinar, June 9, 2021
- 2021 Wood Mackenzie Northeast Asia Gas Forum
Webinar June 9, 2021
- The DNA of Innovation in a Post COVID World: Sustainability, Digitalisation & Regulation
Webinar, June 9, 2021
- Wood Mackenzie Focus: Grid Edge, Drivers of the U.S. Microgrid Market
Webinar, June 10, 2021
- Policies for People – Best Practice in People-Centred Policymaking
IEA Webinar, June 10, 2021
- Introduction to Petrochemicals: June EMEARC/Americas Online Training, June 11, 2021
- SPE Virtual Workshop: EOR for More Sustainable Future: The Role of Chemical and Hybrid EOR
Virtual, June 15–16, 2021
- How Industrial Operators Can Reduce Electricity Cost and Improve Sustainability with Energy Storage as a Service
Webinar, June 16, 2021
- Power & Renewables Conference: APAC
Virtual, June 22–24, 2021
- The Next Chapter in the Bakken - Learning from the Past and Opportunities for the Future
Virtual Forum, June 22–July 1, 2021
- IEA Energy Efficiency Policy and Digital Tools Workshop
IEA Webinar, June 23, 2021
- Introduction to Petrochemicals: June EMEARC/APAC Online Training, June 24, 2021

// CONFERENCES AND EVENTS

(cont'd)

- Columbia Energy Straight Talk with Cheryl LaFleur and David Hill | Public Power and the Energy Transition: A Discussion with Gil Quiniones and Steve Wright
Webinar, June 28, 2021
- EPRI Electrification 2021: A Net-Zero Energy System for All
Virtual, June 28–30, 2021
- SPE Virtual Workshop: Bridging Gulf to Gulf: The Digitally Augmented Post-Pandemic Reality
Virtual, June 29–30, 2021
- Small Scale LNG - Is it a Deal Breaker?
AIChE Webinar, June 30, 2021
- SPE Virtual Workshop: Integrated Water Injection Management
Virtual, July 6–8, 2021
- 2021 Summer Study on Energy Efficiency in Industry
Virtual, July 12–15, 2021
- 2021 Global Coal & Steel Raw Materials Forum
Virtual, July 13–15, 2021
- Haynesville Basin, the Next Chapter in Unconventionals - Learning from the Past and Opportunities for the Future
Virtual Forum, July 13–22, 2021
- Intersolar North America and Energy Storage North America conference and trade show
Digital Summit, July 14–15, 2021
- 17th International Symposium on Solid Oxide Fuel Cells (SOFC-XVII)
Digital Meeting, July 18–23, 2021
- Global Hydrogen Safety Codes and Standards
AIChE Webinar, July 21, 2021
- Unconventional Resources Technology Conference
Houston, TX and Virtual, July 26–28, 2021
- 45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
Virtual, July 26–29, 2021
- Verge: Net Zero – Accelerating the Transition to a Climate-Positive Future
Virtual, July 27–28, 2021

// RECENT PUBLICATIONS

Manuscripts

- A. Dudchenko, T. Bartholomew and M. Mauter**, “Cost optimization of multi-stage gap membrane distillation,” *Journal of Membrane Science*, vol. 627, no. 1, June 2021.
- A. Harker Steele, T. Warner, D. Vikara, A. Guinan and P. Balash**, “Comparative Analysis of Carbon Capture and Storage Finance Gaps and the Social Cost of Carbon,” *Energies Special Issue: Alternative Energy Policy*, vol. 14, no. 11, May 21, 2021.
- A. Iyengar, B. Koepfel, D. Keairns, M. Woods, G. Hackett and T. Shultz**, “Performance of a Natural Gas Solid Oxide Fuel Cell System With and Without Carbon Capture,” *Journal of Energy Resources Technology*, vol. 143, no. 4, April 2021.
- P. Akula, J. Eslick, D. Bhattacharyya and D. Miller**, “Model Development, Validation, and Optimization of an MEA-Based Post-Combustion CO₂ Capture Process under Part-Load and Variable Capture Operations,” *Industrial & Engineering Chemistry Research*, vol. 60, no. 14, pp. 5176–5193, March 2021.
- N. Isenberg, P. Akula, J. Eslick, D. Bhattacharyya, D. Miller and C. Gounaris**, “A generalized cutting-set approach for nonlinear robust optimization in process systems engineering,” *AIChE Journal*, vol. 67, no. 5, January 2021.
- D. Arent, S. Bragg-Sitton, D. Miller, T. Tarka, J. Engel-Cox, R. Boardman, P. Balash, M. Ruth, J. Cox and D. Garfield**, “Multi-input, Multi-output Hybrid Energy Systems,” *Joule*, vol. 5, no. 1, pp. 47–58, January 2021.
- D. Vikara, D. Remson and V. Khanna**, “Machine learning-informed ensemble framework for evaluating shale gas production potential: Case study in the Marcellus Shale,” *Journal of Natural Gas Science and Engineering*, vol. 84, December 2020.
- E. Liese, J. Albright and S. Zitney**, “Startup, shutdown, and load-following simulations of a 10 MWe supercritical CO₂ recompression closed Brayton cycle,” *Applied Energy*, vol. 277, November 2020.
- O. Sarwar, B. Sauk and N. Sahinidis**, “A Discussion on Practical Considerations with Sparse Regression Methodologies,” *Statistical Science*, vol. 35, no. 4, pp. 593–601, November 2020.

// RECENT PUBLICATIONS (cont'd)

Reports

S. Roussanaly, E. Rubin, M. van der Spek, G. Booras, N. Berghout, T. Fout, M. Garcia, S. Gardarsdottir, V. Kuncheekanna, M. Matuszewski, S. McCoy, J. Morgan, S. Nazir and A. Ramirez, "Towards improved guidelines for cost evaluation of carbon capture and storage," U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA, March 2021.

J. Theis, "Quality Guidelines for Energy Systems Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance," U.S. Department of Energy, National Energy Technology Laboratory, NETL-PUB-22580, Pittsburgh, PA, February 2021.

S. Rai, J. Littlefield, S. Roman-White, G. Zaimes, G. Cooney and T. Skone, "Industry Partnerships & Their Role in Reducing Natural Gas Supply Chain Greenhouse Gas Emissions - Phase 2," U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2020/2607, Pittsburgh, PA, February 12, 2021.

S. Pool, R. Boswell, J. Saucer and B. Carney, "Estimates of Natural Gas Resources and Recovery Efficiency Associated with Marcellus Development in West Virginia," West Virginia Geological and Economic Survey, WVGES Reports of Investigation - 36, 2021.

M. Turner, A. Iyengar and M. Woods, "Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO₂ Capture Rate in Coal-Fired Power Plants," U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA, December 23, 2020.

T. Warner, D. Rampton, D. Morgan, G. Bromhal, W. Harbert and Z. Wang, "Using Geophysical Technologies Deployed in Inexpensive Monitoring Wells to Monitor the Evolution of a CO₂ Plume: Potential Benefits and R&D Needs," U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2021/2635, Pittsburgh, PA, October 1, 2020.

G. Pickenpaugh, "U.S. Coal Industry Perspective (2020)," U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA, 2020.

Conference Proceedings and Events

E. Rubin, N. Berghout, G. Booras, T. Fout, M. Garcia, S. Nazir, A. Ramirez, S. Roussanaly and M. van der Spek, "Toward Improved Guidelines for Advanced Low-carbon Technologies," in 15th Greenhouse Gas Control Technologies Conference, Panel Discussion "Improving Quality of CCS Cost Estimation Techniques", Virtual, March 15, 2021.

M. van der Spek, G. Booras, T. Fout, M. Garcia, M. Matuszewski, S. McCoy, J. Morgan, V. Kuncheekanna, S. Nazir, A. Ramirez, S. Roussanaly and E. Rubin, "Towards improved guidelines for uncertainty analysis of carbon and storage techno-economic studies," in 15th Greenhouse Gas Control Technologies Conference, Virtual, March 2021.

J. Morgan, B. Omell, M. Matuszewski, D. Miller, M. Isamil Shah, C. Benquet, A. Beate Nesse Knarvik, T. de Cazenove, C. Anderson-Cook, T. Ahmed, C. Tong, B. Ng and D. Bhattacharyya, "Application of Sequential Design of Experiments (SDoE) to Large Pilot-Scale Solvent-Based CO₂ Capture Process at Technology Centre Mongstad (TCM)," in 15th Greenhouse Gas Control Technologies Conference, Virtual, March 2021.

R. Boswell, B.J. Carney and S. Pool, "Using Production Data to Constrain Resource Volumes and Recovery Efficiency in the Marcellus Play of West Virginia," paper presented at SPE Annual Technical Conference and Exhibition, Virtual, October 2020.

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Book Chapter

R. Boswell, S. Hancock, K. Yamamoto, T. Collett, M. Pratap and S. Lee, "6 - Natural Gas Hydrates: Status of Potential as an Energy Resource," in Future Energy: Improved, Sustainable and Clean Options for our Planet, Third Edition, vol. 4, Elsevier, 2020, pp. 111-131.

// REFERENCE SECTION

Models/Tools

[FE/NETL CO₂ Transport Cost Model](#)

[FE/NETL CO₂ Storage Cost Model](#)

[FE/NETL CO₂ Prophet Model](#)

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

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