SSAE Newsletter

JULY // 2021 VOLUME 1.2

// 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

IDAES Advances Power Plant Efficiency

NETL's Institute for the Design of Advanced Energy Systems (IDAES) released a modeling library to help develop more efficient, reliable and flexible power plants while providing a foundation for deploying integrated energy systems to support decarbonization.

Most existing fossil-fuel power plants were designed for baseload operation. However, intermittent, renewable energy sources cause these plants to cycle their loads more frequently and rapidly than their intended design, resulting in temperature and pressure changes that damage plant components.

The IDAES Dynamic Power Plant Modeling Library can be leveraged to improve power plant efficiency and explore tradeoffs between the short-term benefit of quick ramping capacity with the long-term impact on equipment. Learn more.

SSAE Supports Gas Hydrate Program

SSAE's support for the gas hydrate program aims to enrich communication between external stakeholders and enhance NETL's standing as global leaders in gas hydrate science. Ray Boswell is one of the experts leading this effort to help enable ideal representation and reporting of gas hydrate program accomplishments. Last year, Boswell was highlighted as among the top 2% of scientists in the world based on his career-long citation impact up until the end of 2019 in an analysis published by the journal PLOS Biology.

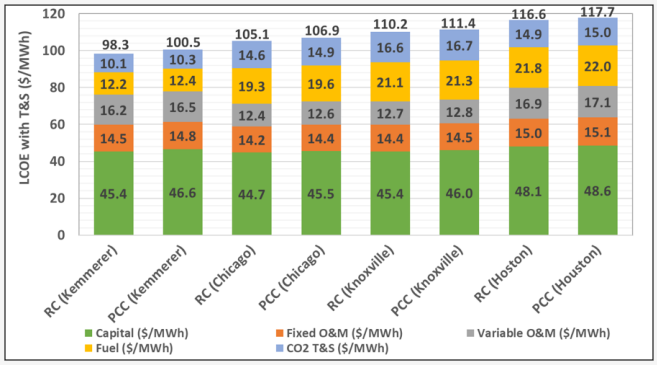
Gas hydrates are found wherever methane occurs in the presence of water under elevated pressures and at relatively low temperatures (e.g., beneath permafrost or in shallow sediments along deep-water continental margins). When brought to the surface, one cubic foot of gas hydrate can release 164 cubic feet of natural gas.

SSAE develops the U.S. Department of Energy Methane Hydrate Program's annual Report to Congress, represents accomplishments and status to the Methane Hydrate Federal Advisory Committee and Interagency Technical Coordination Committee, serves as technical advisor to the program's Gulf of Mexico drilling project, and acts as point of contact and technical advisor for international agreements with India, Korea and Japan.

NETL Researchers Shine at Turbo Expo 2021

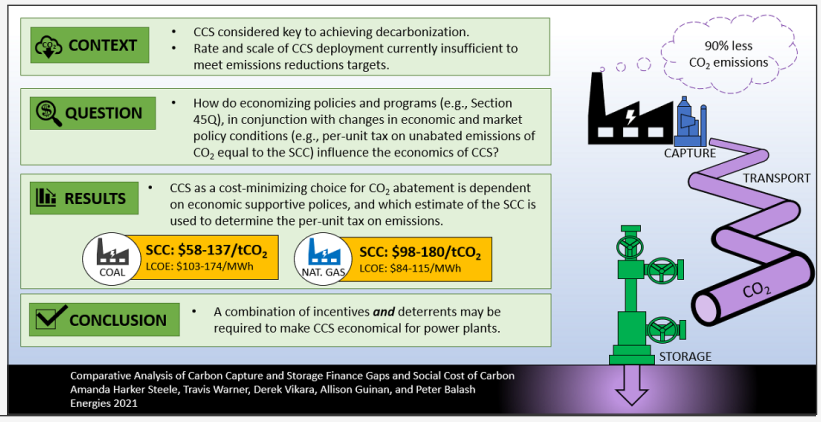
NETL researchers were featured at the Turbo Expo 2021, which was held in June. Presented by the American Society of Mechanical Engineers, Turbo Expo encompassed topics spanning the turbomachinery industry.

- **Selcuk Can Uysal**, **Douglas Straub** and **James Black** shared results from "Impact on Cycle Efficiency of Small Combined Heat and Power Plants From Increasing Firing Temperature Enabled by Additive Manufacturing of Turbine Blades and Vanes." The study used analytical models to estimate impact on performance by increasing turbine firing temperature and improving turbine blade cooling for a 6-MW scale gas turbine.
- **Sandeep Pidaparti**, **Charles White** and **Nathan Weiland** presented results from the study "Optimized Performance and Cost Potential for Indirect Supercritical CO_2 Coal Fired Power Plants," which evaluated four power cycle configurations — recompression cycle with and without turbine reheat and partial cooling cycle with and without turbine reheat. The study also examined the use of indirect-fired supercritical CO_2 power cycles as an alternative to steam Rankine cycles.
- The same team listed above also shared findings from "Impact of Plant Siting on Performance and Economics of Indirect Supercritical CO_2 Coal Fired Power Plants." The researchers examined ambient conditions, coal types and prices, captured carbon dioxide (CO_2) transportation and storage costs, and other parameters to complete techno-economic analyses at four U.S. power plant sites.



Study Evaluates Impacts of Market and Policy Conditions on CCS Costs

Amanda Harker Steele, **Travis Warner**, **Derek Vikara**, **Allison Guinan** and **Peter Balash** published the paper "Comparative Analysis of Carbon Capture and Storage Finance Gaps and the Social Cost of Carbon." The work evaluated how changes in market and policy conditions, including the establishment of a per-unit tax on unabated emissions of CO_2 set equal to estimates of the social cost of carbon, influence the economics of carbon capture and storage (CCS).



// NOTICES

SSAE Charts Path to Deploy DAC

NETL is well-positioned to lead the development of direct air capture (DAC) technology to pull CO_2 from the Earth's atmosphere. As the technology gains traction, Tim Fout and his SSAE colleagues are undertaking techno-economic analyses and case studies to ensure that researchers advancing DAC innovations are pursuing optimal routes for success. Look for two case studies to be published in September 2021.

"The CO_2 in the atmosphere is much more diluted than, for instance, flue gas from a power station or a cement plant. This contributes to higher energy needs and costs for direct air capture as compared to other CO_2 capture technologies and applications," said Fout, a member of SSAE's Energy Process Analysis Team. Learn more.

Timothy Skone Invited to Present on Sustainable Water Management

Timothy Skone, member of SSAE's Energy Systems Analysis Team, discussed "Sustainable Water Management for Decarbonizing Fossil Power Generation" during a free EarthShift Global webinar on July 15. This presentation will also be discussed on August 20 for Darcy Partners Oil and Gas Innovators group.

In many U.S. regions, water scarcity is a significant issue. Water use intensity is expected to increase for leading decarbonization pathways for fossil power generation such as fuel switching (biomass and hydrogen) and CCS.

Skone leads Life Cycle Analysis Research efforts within the Office of Fossil Energy and Carbon Management. His areas of expertise include carbon utilization technologies, alternative transportation fuels, advanced power generation systems and energy water impacts. Learn more.

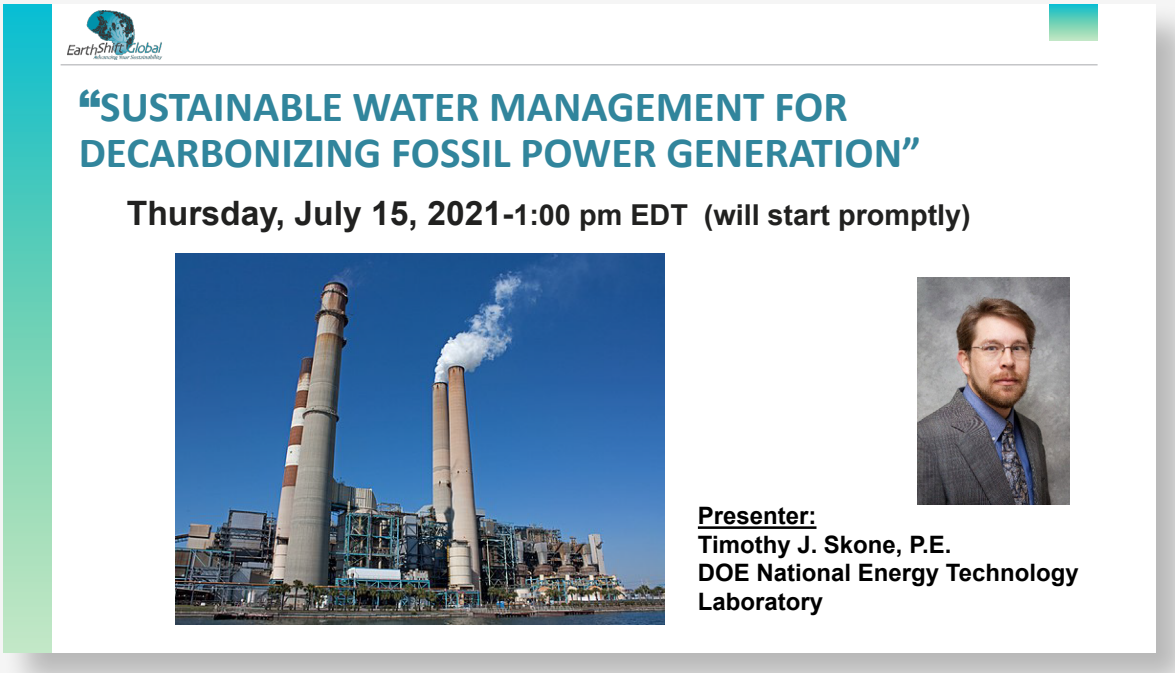
Smart Grid Observer Hosts NETL Experts on Decarbonization

Peter Balash, associate director of Strategic Systems Analysis and Engineering (SSAE), will join NETL Director Brian Anderson, and other NETL experts as a featured speaker at Smart Grid Observer's Carbon Capture, Storage & Utilization Virtual Forum on Tuesday, July 27.

Balash's presentation, scheduled for 11:30 a.m. (CDT), will focus on "Economic Analysis & Modeling; CCUS: Competitive, Reliable And Essential" highlighting the critical roles carbon capture, utilization, and storage (CCUS) plays in several areas including creating credible decarbonization scenarios and contributing competitive and reliable electricity. Learn more.

Topics to be covered by Director Anderson and NETL experts are:

- An Introduction to Carbon Capture, Utilization and Storage — Director Brian Anderson
- High Performance Polymer Blend Membranes for CO_2 Capture — Research Scientist Lingxiang Zhu
- Progress Towards Decarbonization of Natural Gas Power Generation — Carbon Capture Technology Manager Dan Hancu
- DOE's Geologic Carbon Storage Program Overview — Carbon Storage Technology Manager Mark McKoy
- Estimating Storage Capacity and Risk for Geologic Carbon Storage in the U.S. — Research Engineer Dustin Crandall



// PERSPECTIVES

SSAE to Make Significant Contributions in Transition to Carbon-Neutral World

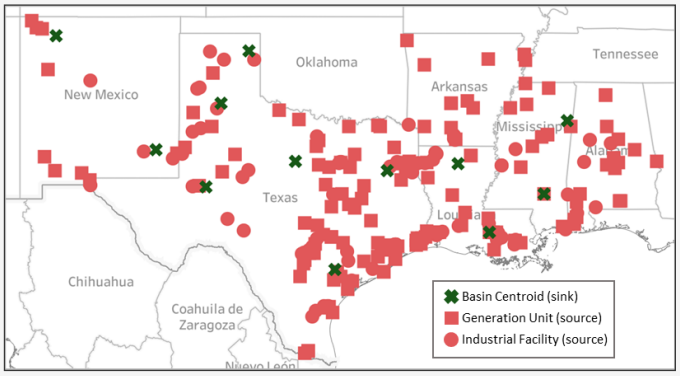
Deployment of large-scale CCUS projects represents an essential undertaking to establish a carbon-constrained or carbon-neutral world. To understand how workable carbon management projects may be developed, it is important to understand the technical and economic aspects of the CCUS ecosystem.

SSAE has expertise in all aspects of CCUS (i.e., CO_2 capture, CO_2 transport via pipelines and CO_2 storage, either using saline aquifers or CO_2 EOR, and possible alternate downstream uses of captured CO_2). To this end, SSAE has developed techno-economic resources and models for each facet of CCUS. These include the:

- Carbon capture retrofit databases to estimate the cost of retrofitting CO_2 capture technology at fossil-fuel power plants (pulverized coal and natural gas combined cycle) and large industrial point-source CO_2 emitters.
- FE/NETL CO_2 Transport Cost Model to assess the expense of transporting CO_2 by pipeline.
- FE/NETL CO_2 Saline Storage Cost Model to generate estimates for storing CO_2 in geologic formations in the contiguous 48 states.
- FE/NETL Onshore CO_2 EOR Evaluation System, a system of models (including FE/NETL CO_2 Prophet Model and FE/NETL Onshore CO_2 EOR Cost Model), to estimate the cost of implementing CO_2 for enhanced oil recovery (EOR).

To date, SSAE has used these resources and models primarily to assess CCUS opportunities for a single fossil-fuel power plant or several fossil-fuel power plants transporting CO_2 to a single CO_2 saline storage site or oil field implementing CO_2 EOR.

SSAE recently performed a project in which multiple CO_2 sources (fossil-fuel power generators and industrial point sources of CO_2) and CO_2 sinks (both saline storage geologic formations and oil fields that could implement CO_2 EOR) were identified in the southcentral United States. In this study, the cost of capture was estimated for each source, the cost of saline storage was calculated for each formation, and the maximum CO_2 price each oil field could pay for CO_2 EOR was determined. The cost of a dedicated point-to-point pipeline was calculated for each source to the nearest saline storage site or the nearest oil field that could implement CO_2 EOR. However, no attempt was made to develop a pipeline network featuring large diameter pipelines with high CO_2 flow capacity that could connect multiple sources to multiple sinks. Such a network could offer lower costs for transporting CO_2 than a dedicated point-to-point pipeline.



CO_2 Sources and Geologic Basins with CO_2 Storage Opportunities in South Central States

SSAE is initiating a project to develop pipeline networking software that can estimate an optimal or near-optimal pipeline network for connecting CO_2 sources to CO_2 sinks. Such a network would feature large diameter trunklines with smaller diameter pipelines collecting CO_2 from CO_2 sources and separate small diameter pipelines distributing CO_2 to CO_2 sinks. This effort will begin by developing datasets of all large point source emitters of CO_2 (power plants and industrial sources), CO_2 storage formations and oil fields that could implement CO_2 EOR. These datasets will include spatial data so sources and sinks can be mapped with geographical information system (GIS) software. Existing CO_2, natural gas and oil pipelines will be included in the GIS data so that existing pipeline rights of way can be identified. Also, the location of areas that should be avoided by trunklines, such as large urban areas and lakes, will be placed in the GIS data. Existing pipeline networking software packages will be reviewed for use on this project and one package will be selected for this effort.

In a carbon-constrained world, variable renewable energy (VRE) sources (wind and photovoltaic solar) may be preferentially dispatched to the grid, relegating fossil-fuel power plants to backup or peak-load supporting roles. Nonetheless, fossil-fuel power plants would have to operate at maximum capacity at certain times to make up for the lack of power provided by VRE sources. The combination of low-capacity factors, maximum capacity operation for short periods of time and the added burden of CO_2 capture will drive up the price these power plants will need to charge when they dispatch electricity to the grid. Potential strategies and recommendations to address this issue will be developed by SSAE.

It also is clear that CCUS will not be deployed on a large scale without significant government intervention. SSAE has completed studies examining how the 45Q tax credit could affect the economics of CCUS. SSAE will use its expertise to examine how other incentives or disincentives (for example, carbon taxes) may affect the deployment of CCUS. – Contributed by **David Morgan**, NETL SSAE Energy Systems Analysis Team.

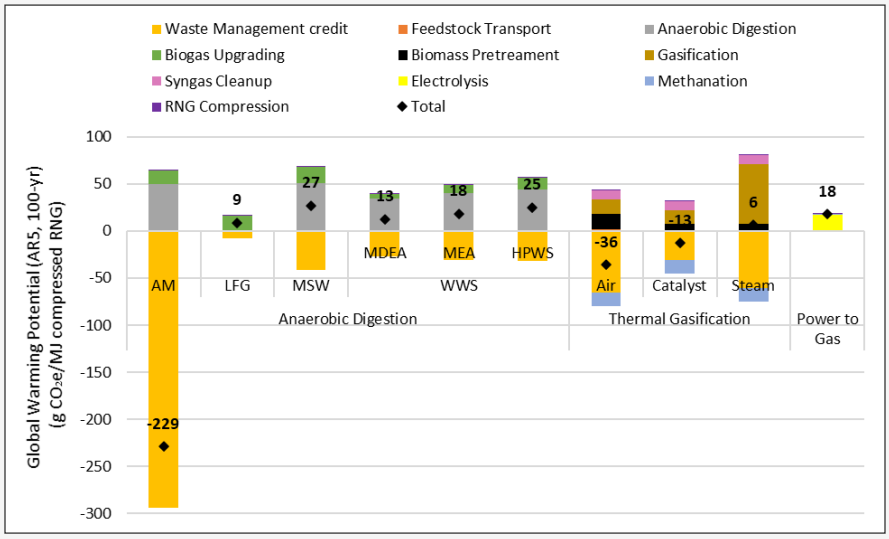
// PERSPECTIVES (cont'd)

SSAE's Energy Systems Analysis Team Provides LCA Evaluation of the GWP Impacts of RNG Production Pathways

Tackling the climate crisis requires deep decarbonization across all sectors of our economy, including power generation. Renewable natural gas (RNG) resources coupled with carbon capture and permanent sequestration have the potential to provide net negative greenhouse gas emissions over plant life cycles, enabling the United States to transition to less carbon-intensive power generation to support variable renewable generation by wind, solar, etc.

SSAE initiated research into RNG options in 2020 to inform potential decarbonization strategies for the natural gas sector. This early research is now serving as a foundation for evaluating a broad range of electricity and hydrogen production research in blending fossil resources with RNG to reduce carbon intensity while minimizing impacts to the cost of production. This research is helping DOE to understand the differences between environmental footprints of various RNG resources. Proper accounting of the energy and resources to convert waste streams into economic value deals with an environmental burden, while eliminating the need for existing waste processing (i.e., end-of-life management) expresses an environmental advantage. This research answers the question on a life cycle basis whether the burdens or advantages are greater—and by how much.

SSAE models three RNG pathways with multiple feedstocks and technologies: anaerobic digestion (AD), thermal gasification (TG) and power to gas (P2G). AD generates biogas by breaking down organic matter in the absence of oxygen. Feedstocks in the AD pathway include animal manure (AM), landfill gas (LFG), municipal solid waste (MSW) and wastewater sludge (WWS), within which the biogas from wastewater sludge can be upgraded to RNG by using methyldiethanolamine (MDEA) scrubbing, monoethanolamine (MEA) scrubbing or high-pressure water scrubbing (HPWS). The TG pathway uses a wood waste feedstock and represents gasification technologies wherein a controlled amount of air, steam, or catalyst reacts with available carbon in the biomass in a gasifier at high temperatures to generate syngas, which is then cleaned, upgraded and passed through methanation to produce RNG. The P2G pathway uses renewable electricity to produce hydrogen from water electrolysis, which is then reacted with CO_2 to produce RNG.



We compare RNG scenarios to corresponding business-as-usual (BAU) scenarios employing a functional unit of 1 MJ compressed RNG or compressed fossil natural gas before it enters the transmission network, also accounting for waste management of the feedstock needed to produce the RNG. We model the pathways using three analytical approaches: (1) attributional LCA of RNG pathways, (2) attributional LCA of BAU scenarios compared to corresponding RNG scenarios and (3) consequential LCA of RNG pathways.

The graphic shows the global warming potential (GWP) impacts of all the RNG pathways from a consequential perspective, and it demonstrates that not all pathways of RNG production are carbon neutral or carbon negative. RNG production via anaerobic digestion of animal manure and thermal digestion of wood wastes via air and catalyst gasification technologies lead to net negative GHG emissions ranging from -228.8 to -13.0 g CO_2e/MJ of compressed RNG. The landfill gas pathway and thermal gasification of wood wastes via steam gasification have net positive GHG emissions ranging from 6.2 to 9.0 g CO_2e/MJ compressed RNG. However, these pathways are still preferable to fossil natural gas as they have a smaller GWP impact compared to compressed fossil natural gas (fossil natural gas has a 100-yr GWP of 10.1 g CO_2e/MJ). The anaerobic digestion of municipal solid waste and wastewater sludge and the power-to-gas pathways have higher GWP impacts than fossil natural gas.

The results of this research are being used to inform natural gas sector decarbonization strategies under the Oil and Gas Program (FE-30) and power and hydrogen production decarbonization strategies under the Fossil Energy Carbon Management Program (FE-20). The findings of this research are preliminary and planned for submission to the Journal of Cleaner Production. – Contributed by **Srijana Rai**, NETL Support Contractor

Additional information on NETL's LCA capability, analyses and life cycle inventory data and models can be publicly accessed at www.netl.doe.gov/LCA.

Attributional life cycle assessments estimate the share of the global environmental burdens attributed to a product. **Consequential LCAs** estimate the effects of products' production and use on the global environmental burdens.

// 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 and August 2021:

Timothy Skone (presenter)
EarthShift Global Webinar
Webinar, July 15, 2021

Gregory Hackett (participant)
17th International Symposium on Solid Oxide Fuel Cells (SOFC-XVII)
Digital Meeting, July 18–23, 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 Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26-29, 2021

Eric Lewis (participant)
45th International Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Robert Stevens (participant)
45th International Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Thomas Tarka (presenter)
45th International Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Walter Shelton (participant)
45th International Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Stephen Zitney (presenter)
45th International Technical Conference on Clean Energy – Clearwater Clean Energy Conference
Virtual, July 26–29, 2021

Peter Balash (presenter)
Carbon Capture, Storage & Utilization Virtual Forum
Virtual, July 27, 2021

Luciane Cunha (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Tim Fout (presenter)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Timothy Grant (presenter)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Gregory Hackett (presenter)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Sydney Hughes (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Donald Remson (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Thomas Schmitt (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Robert Stevens (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

Alexander Zoelle (participant)
DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
Virtual, August 2021

// CONFERENCES AND EVENTS

- The Next Chapter in the Bakken - Learning from the Past and Opportunities for the Future
  Virtual Forum, June 22–July 1, 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
- bp Statistical Review of World Energy 2021
  Zoom Webinar, July 12, 2021
- 2021 Global Coal & Steel Raw Materials Forum
  Virtual, July 13–15, 2021
- Achieving Decarbonization with Power Purchase Agreements
  Greenbiz Webcast, July 13, 2021
- Haynesville Basin, the Next Chapter in Unconventionals - Learning from the Past and Opportunities for the Future
  Virtual Forum, July 13–22, 2021
- IEA: India Bioenergy Workshop –Current status in India and international experience in deploying biogas and MSW-to-energy
  Workshop, July 13, 2021
- Using Renewables to Operate a Low-Carbon Grid – Demonstration of Advanced Reliability Services from Utility-Scale Solar PV & Utility-Scale Wind Plants
  Webinar, July 13, 2021
- CONSENSUS: Indian Energy Minerals Forum 2021 Webinar Series #2, Webinar #5: Successful Tribal Energy Projects
  Webinar, July 14, 2021
- Intersolar North America and Energy Storage North America conference and trade show
  Digital Summit, July 14–15, 2021
- Nordic Power Markets in 2050: an energy transition in low-carbon markets
  Webinar, July 14, 2021
- EarthShift Global – Sustainable Water Management for Decarbonizing Fossil Power Generation
  Webinar, July 15, 2021
- Is Low Carbon Hydrogen the Panacea for Climate Change? What Can the US Learn from Early Adoption in Europe?
  Webinar, July 15, 2021
- Plotting the Journey to Net Zero for Investment Managers: The Steps, Opportunities, and Pitfalls
  Webinar, July 15, 2021
- 17th International Symposium on Solid Oxide Fuel Cells (SOFC-XVII)
  Digital Meeting, July 18–23, 2021
- CO_2 Recycling: Technology Limits, Opportunities, and Policies for a Circular Carbon Economy
  Zoom Webinar, July 19, 2021
- Global Hydrogen Safety Codes and Standards
  AIChE Webinar, July 21, 2021
- Unconventional Resources Technology Conference
  Hybrid (Virtual and Houston, TX), July 26–28, 2021
- 45th International Conference on Clean Energy – The Clearwater Clean Energy Conference
  Virtual, July 26–29, 2021
- Carbon Capture, Storage & Utilization Virtual Forum
  Virtual Forum, July 27, 2021
- Power & Renewables Conference: North America
  Virtual, July 27–28, 2021
- Verge: Net Zero – Accelerating the Transition to a Climate-Positive Future
  Virtual, July 27–28, 2021
- IEA Webinar on Evolving Energy Service Companies (ESCOs) in Emerging Economies
  Webinar, July 28, 2021
- How Flexible Energy Drives the Future of Clean Electrification
  Greenbiz Webcast, July 29, 2021
- Microgrid Planning: The SEPA Playbook and Lessons Learned in North Carolina
  Webinar, July 29, 2021
- Clean Energy Transitions in Sahel Countries Regional Dialogue
  Event, July 30, 2021
- DOE-NETL's 2021 Carbon Management and Oil and Gas Research Project Review Meeting
  Virtual, August 2–31, 2021
- NETL 2021 Workshop on Multiphase Flow Science
  Webinar, August 3–5, 2021
- AIChE 3rd Sustainable Waste Management Conference
  Virtual, August 4–6, 2021
- SPE Subsea Well Intervention - Virtual Symposium
  Virtual, August 10–12, 2021
- Thermal-Mechanical-Chemical Energy Workshop
  San Antonio, TX, August 10–11, 2021
- Offshore Technology Conference
  Hybrid (Virtual and Houston, TX), August 16–19, 2021

// RECENT PUBLICATIONS

Manuscripts

A. Lee, J. Ghouse, J. Eslick, C. Laird, J. Siirola, M. Zamarripa, D. Gunter, J. Shinn, A. Dowling, D. Bhattacharyya, L. Biegler, A. Burgard and D. Miller, "The IDAES Process Modeling Framework and Model Library – Flexibility for Process Simulation and Optimization," *Journal of Advanced Manufacturing and Processing*, e10095, 2021.

Reports

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

K. Labarbara, S. Lin, P. Shirley, R. Wallace and J. Brewer, "2021 Summer Resource Adequacy in the ERCOT Region," U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2021/2763, May 27, 2021.

R. Boswell, "Evaluation of Technically-recoverable Resources in the Marcellus and Utica Shale Gas Plays of the Appalachian Basin," U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2021/3213, Pittsburgh, PA, June 23, 2021.

Presentations

J. Brewer, "New Energy Infrastructure Outlook, Data as of December 31, 2020," U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2021/2759, 2021.

Conference Proceedings and Events

S. Can Uysal, D. Straub and J. Black, "Impact on Cycle Efficiency of Small Combined Heat and Power Plants From Increasing Firing Temperature Enabled by Additive Manufacturing of Turbine Blades and Vanes," paper presented at ASME 2021 Turbo Expo, Virtual, June 7, 2021.

S. Pidaparti, C. White and N. Weiland, "Impact of Plant Siting on Performance and Economics of Indirect Supercritical CO_2 Coal Fired Power Plants," paper presented at ASME 2021 Turbo Expo, Virtual, June 11, 2021.

S. Pidaparti, C. White and N. Weiland, "Optimized Performance and Cost Potential for Indirect Supercritical CO_2 Coal Fired Power Plants," paper presented at ASME 2021 Turbo Expo, Virtual, June 11, 2021.

// REFERENCE SECTION

Models / Tools

- FE/NETL CO_2 Transport Cost Model
- FE/NETL CO_2 Storage Cost Model
- FE/NETL CO_2 Prophet Model
- FE/NETL Onshore CO_2 EOR Cost Model
- Life Cycle Analysis Models
- IDAES Power Generation Model Library

Key Reports

- Baseline Studies for Fossil Energy Plants
- Quality Guidelines for Energy Systems Studies
- Life Cycle Analysis

- Search for other SSAE products
- Institute for the Design of Advanced Energy Systems webpage
- Life Cycle Analysis webpage

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Visit us: www.NETL.DOE.gov

@NationalEnergyTechnologyLaboratory

@netl_doe

@netl_doe

SSAE Newsletter