NATIONAL ENERGY TECHNOLOGY LABORATORY

FY22 CARBON CAPTURE PEER REVIEW OVERVIEW REPORT

November 17, 2021

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

DISCLAIMER

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INTRODUCTION AND BACKGROUND

The National Energy Technology Laboratory's (NETL's) Carbon Capture Program aims to develop the next generation of advanced carbon dioxide (CO_2) capture concepts. The U.S. Department of Energy (DOE) has adopted a comprehensive, multi-pronged approach for the research and development (R&D) of advanced CO_2 capture technologies that have the potential to provide step-change reductions in both cost and energy requirements as compared to currently available technologies. The success of this research enables cost-effective implementation of carbon capture and storage (CCS) technologies that can be applied to the existing fleet of fossil fuel-fired power plants, new power plants, industrial facilities, and the removal of CO_2 from the atmosphere. Cost-competitive carbon capture technologies have the potential to support the fossil sector while advancing U.S. leadership in high-efficiency, low-emission (HELE) generation technologies.

NETL's Carbon Capture Program includes two core research areas—Post-Combustion Capture and Pre-Combustion Capture—comprised of projects ranging from conceptual engineering and materials design to 10 megawatt electrical (MWe) equivalent pilot testing. Additionally, the program advances technologies in two emerging research areas: Capture from Industrial Sources and Negative Emissions Technologies.

- Post-combustion capture systems separate CO_2 from the flue gas stream produced by conventional fossil fuel-fired power plants after fuel combustion. In this approach, CO_2 is separated from nitrogen (N_2), the primary constituent of the flue gas. R&D is underway to develop technologies based on advanced solvents, sorbents, membranes, hybrid systems, and other novel concepts in post-combustion capture.
- Pre-combustion capture systems are designed to separate CO_2 and hydrogen (H_2) from the syngas stream produced by the gasifier in integrated gasification combined cycle (IGCC) power plants. R&D is underway to develop technologies based on advanced solvents, sorbents, membranes, hybrid systems, and other novel concepts in pre-combustion capture.

Office of Management and Budget and U.S. Department of Energy Requirements

In compliance with requirements from the Office of Management and Budget and in accordance with the DOE Strategic Plan, DOE and NETL are fully committed to improving the quality of research projects in their programs by conducting rigorous peer reviews. DOE and NETL conducted a Fiscal Year 2022 (FY22) Carbon Capture Peer Review Meeting with independent technical experts to offer recommendations to strengthen projects during the period of performance. KeyLogic, an NETL site-support contractor, convened a panel of four academic and industry experts[*] on October 26–28, 2021, to conduct a peer review of three Carbon Capture Program research projects.

[*] Please see "Appendix D: Peer Review Panel Members" for detailed panel member biographies.

TABLE 1. CARBON CAPTURE PEER REVIEW – PROJECTS REVIEWED

Project Number	Title	Lead Organization	Total Funding		Project Duration	
			DOE	Cost Share	From	To
FE0031944	Chevron Natural Gas Carbon Capture Technology Testing Project	Chevron	$13,000,000	$3,272,126	10/01/2020	04/30/2023
FE0031588	Engineering-Scale Demonstration of the Mixed-Salt Process for CO_2 Capture	SRI International	$15,002,571	$3,751,272	07/01/2018	03/31/2025
FE0031950	Engineering-Scale Demonstration of Transformational Solvent on NGCC Flue Gas	ION Clean Energy, Inc.	$13,000,000	$3,906,839	10/01/2020	10/31/2023
Recommendations-Based Evaluation: During recommendations-based evaluations, the independent panel provides recommendations to strengthen the performance of projects during the period of performance.			$41,002,571	$10,930,237		
			$51,932,808			

OVERVIEW OF THE PEER REVIEW PROCESS

Peer reviews are conducted to help ensure that the Office of Fossil Energy and Carbon Management's (FECM) research program, implemented by NETL, is in compliance with requirements from the Office of Management and Budget and in accordance with the DOE Strategic Plan and DOE guidance. Peer reviews improve the overall quality of the technical aspects of R&D activities, as well as overall project-related activities, such as utilization of resources, project and financial management, and commercialization.

KeyLogic convened a panel of four academic and industry experts to conduct a peer review of three research projects supported by the Carbon Capture Program. Throughout the peer review meeting, these recognized technical experts offered recommendations to strengthen the projects during the remaining period of performance. KeyLogic selected an independent Peer Review Panel, facilitated the peer review meeting, and prepared this report to summarize the results.

Pre-Meeting Preparation

Before the peer review, each project team submitted a Project Technical Summary (PTS) and project presentation. The Federal Project Manager (FPM) provided the Project Management Plan (PMP), the latest quarterly report, and supplemental technical papers as additional resources for the panel. The panel received these materials prior to the peer review meeting, which enabled the panel members to fully prepare for the meeting with the necessary background information to thoroughly evaluate the projects.

To increase the efficiency of the peer review meeting, multiple pre-meeting orientation teleconference calls were held with NETL, the Peer Review Panel, and KeyLogic staff to review the peer review process and procedures, evaluation criteria, and project documentation, as well as to allow for the Technology Manager to provide an overview of the program goals and objectives.

Peer Review Meeting Proceedings

At the meeting, each project performer gave a presentation describing the project. The presentation was followed by a question-and-answer session with the panel and a closed panel discussion and evaluation. The time allotted for the presentation, the question-and-answer session, and the closed panel discussion was dependent on the project's complexity, duration, and breadth of scope.

During the closed sessions of the peer review meeting, the panel discussed each project (identified in Table 1) to identify strengths, weaknesses, and recommendations in accordance with the Peer Review Evaluation Criteria. The panel offered prioritized recommendations to strengthen the projects during the remaining period of performance.

SUMMARY OF KEY FINDINGS

This section summarizes the overall key findings of the projects evaluated at the FY22 Carbon Capture Peer Review Meeting. The panel concluded that the peer review provided an excellent opportunity to comment on the relative strengths and weaknesses of each project. The presentations and question-and-answer sessions provided additional clarity to complement the pre-meeting documentation. The peer review also provided insight into the range of technology development and the relative progress that has been made by the project teams. The technical discussion enabled the panel to contribute to each project's development by identifying core issues and making constructive, actionable recommendations to improve project outcomes. The panel generated 15 recommendations for NETL management to review and consider.

The panel stated that the project teams are pursuing promising processes; the status of technology development was evident from the discussions during the peer review. The project teams were well-rounded, with a strong understanding of the science (e.g., physics) needed to execute their respective project scope. The panel indicated that the project teams' efforts would benefit from additional evaluation of the functional requirements (e.g., responsiveness, lifetime). It was also noted that some teams are working to address mechanical issues. The composition of the project teams and carefully considered project plans led the panel to believe that these teams can achieve their goals and objectives. The panel confirmed that the projects are aligned with DOE's near- and/or long-term goals and demonstrated noteworthy progress and accomplishments within their respective work scope and budgets. Several common observations and recommendations were offered to the project teams, such as:

- Using the techno-economic analysis (TEA) as a tool to guide the testing protocol and design of experiments (e.g., process dynamic, controls, startups and shutdown, load following capabilities, other industrial sources of CO_2).
- Incorporating recent advances in their modeling capability (e.g., stochastic modeling with NETL's Framework for Optimization, Quantification of Uncertainty, and Surrogates [FOQUS] toolset to enable sequential design of experiments and uncertainty quantification and reduction and the Institute for the Design of Advanced Energy Systems [IDAES] equation-oriented simulation system that enables true process design optimization).
- Creating ongoing links to potential commercial end users to provide market-back data.
- Identifying a group of potential commercial applications and the organizations and individuals associated with these applications to provide ongoing feedback to the development of the technology.
- Establishing a mechanism for regular interaction with these potential commercialization partners and a plan to integrate their guidance into further development plans.
- Utilizing the complete data available from prior pilot and bench experiments and advanced process models to create an optimum operating plan for the program.

The panel also indicated that an additional item for consideration/evaluation is the need for a consistent set of rules for technology comparisons. This was highlighted by the differences in these processes in the outlet CO_2 pressures that were cited as either an advantage or disadvantage (if not considering the downstream costs of bringing the CO_2 product to pipeline quality and pressure). These technologies could also be expected to have significant differences in upstream integration, particularly for steam requirements and the ability to respond to operational variations. A consistent means of evaluating and comparing processes that accounts for upstream and downstream considerations should also be pursued. Finally, the panel advised that the project teams should remain cognizant of current supply chain challenges to ensure they can lock in the price and quantity of material(s) needed.

PROJECT SYNOPSES

For more information on the Carbon Capture Program and project portfolio, please visit the NETL website: https://netl.doe.gov/coal/carbon-capture.

FE0031944

CHEVRON NATURAL GAS CARBON CAPTURE TECHNOLOGY TESTING PROJECT

CHEVRON

Project Description: Chevron is partnering with Svante, Inc.; Electricore, Inc.; Kiewit Engineering Group Inc.; Kiewit Power Constructors; and Offshore Technical Services to validate the transformational VeloxoTherm™ solid sorbent carbon capture technology at engineering scale under indicative natural gas flue gas conditions and continuous long-term operation at Chevron's Kern River oil field. The VeloxoTherm technology uses proprietary CALgary Framework-20 (CALF-20) metal-organic framework (MOF) sorbent materials and is comprised of a rotary adsorption machine for rapid-cycle thermal swing adsorption (RC-TSA) using structured adsorbent beds. The team will design, construct, and test an engineering-scale plant of approximately 30 metric tons per day under steady-state conditions at varying flue gas carbon dioxide (CO_2) concentrations (approximately 4 to 14%). Chevron will also conduct a techno-economic analysis (TEA) on the VeloxoTherm technology integrated into a full-scale natural gas combined cycle (NGCC) power plant, as well as a comprehensive gap analysis.

FE0031588

ENGINEERING-SCALE DEMONSTRATION OF THE MIXED-SALT PROCESS FOR CO_2 CAPTURE

SRI INTERNATIONAL

Project Description: SRI International, in partnership with OLI Systems, Inc., the University of Illinois, Trimeric Corporation, and Baker Hughes, will test their advanced mixed-salt post-combustion carbon dioxide (CO_2) absorption technology at engineering scale (0.5 megawatt electric [MWe]) to address concerns related to scale-up and integration of the technology in fossil fuel-based power plants. The process uses a non-degradable solvent that combines readily available, inexpensive potassium and ammonium salt solutions, operates without solvent chilling, and employs a novel flow configuration that has been optimized to improve absorption kinetics, minimize ammonia emissions, and reduce water use compared to state-of-the-art ammonia-based and amine technologies. The objectives of the research project are to (1) perform integrated mixed-salt process (MSP) testing at engineering scale for long-term periods under dynamic and continuous steady-state conditions with a real flue gas stream to address concerns relating to scale-up and integration of the technology to coal-based power plants; (2) operate the MSP with advanced heat integration to demonstrate advantages in process efficiencies; (3) study the solvent and water management strategies; and (4) collect critically important data for a detailed techno-economic analysis (TEA).

FE0031950

ENGINEERING-SCALE DEMONSTRATION OF TRANSFORMATIONAL SOLVENT ON NGCC FLUE GAS

ION CLEAN ENERGY, INC.

Project Description: ION Clean Energy, Inc. (ION) will partner with Koch Modular Process Systems, Sargent & Lundy, Calpine Corporation, and Hellman & Associates to advance their transformational post-combustion carbon dioxide (CO_2) capture technology through engineering-scale (1 megawatt electric [MWe]) testing on a slipstream of flue gas from Calpine's Los Medanos Energy Center (LMEC)—a commercially dispatched natural gas combined cycle (NGCC) power plant. The project team will design, construct, and operate a CO_2 capture pilot system using ION's water-lean, amine-based, third-generation ICE-31 solvent that will capture 10 metric tons of CO_2 per day and yield a CO_2 product flow with greater than 95% purity that is suitable for compression and dehydration into a CO_2 pipeline. The project will leverage ION's process expertise gained through testing their second-generation, state-of-the-art solvent, ICE-21, at bench- and pilot-scale with coal-fired flue gases. The CO_2 capture process will be optimized to take full advantage of the benefits provided by ION's ICE-31 solvent in combination with other process improvements, all of which are derived through a process-intensification design philosophy focused on NGCC flue gas. The benefits of this holistic approach include a smaller physical plant, reduced energy requirements, improved CO_2 product quality, less solvent degradation, lower emissions, lower water usage, less maintenance, and lower capital costs.

APPENDIX A: PEER REVIEW EVALUATION CRITERIA

Peer reviews are conducted to ensure that the Office of Fossil Energy and Carbon Management's (FECM) research program, implemented by the National Energy Technology Laboratory (NETL), is compliant with the U.S. Department of Energy (DOE) Strategic Plan and DOE guidance. Peer reviews improve the overall quality of the technical aspects of research and development (R&D) activities, as well as overall project-related activities, such as utilization of resources, project and financial management, and commercialization.

In the upcoming NETL peer review, a significant amount of information about the projects is covered in a short period. For that reason, NETL has established a set of guidelines for governing the meeting.

The following pages contain the criteria used to evaluate each project. Each criterion is accompanied by multiple characteristics to further define the topic. Each reviewer is expected to independently assess all the provided material for each project prior to the meeting and engage in discussion to generate feedback for each project during the meeting.

NETL Peer Review – Recommendations-Based Evaluation

At the meeting, the Facilitator leads the Peer Review Panel in identifying strengths, weaknesses, prioritized recommendations, and overall score for each project. The strengths and weaknesses serve as a basis for the determination of the overall project score in accordance with the Rating Definitions and Scoring Plan.

Under a recommendation-based evaluation, strengths and weaknesses are characterized as either "major" or "minor" during the Review Panel's discussion at the meeting. For example, a weakness that presents a significant threat to the likelihood of achieving the project's stated technical goal(s) and supporting objectives is considered "major," whereas relatively less significant opportunities for improvement are considered "minor."

A recommendation emphasizes an action that is considered by the project team and/or DOE to correct or mitigate the impact of weaknesses, expand upon a project's strengths, or progress along the technology maturation path. A recommendation has as its basis one or more strengths or weaknesses. Recommendations are ranked from most important to least, based on the major/minor strengths/weaknesses.

NETL Peer Review Evaluation Criteria
1. Degree to which the project, if successful, supports the U.S. Department of Energy (DOE) Program's near- and/or long-term goals.
• Program goals are clearly and accurately stated. • Performance requirements[1] support the program goals. • The intended commercial application is clearly defined. • The technology is ultimately technically and economically viable for the intended commercial application.
2. Degree to which there are sufficient resources to successfully complete the project.
• There is adequate funding, facilities, and equipment. • Project team includes personnel with the needed technical and project management expertise. • The project team is engaged in effective teaming and collaborative efforts, as appropriate.
3. Degree of project plan technical feasibility.
• Technical gaps, barriers, and risks to achieving the performance requirements are clearly identified. • Scientific/engineering approaches have been designed to overcome the identified technical gaps, barriers, and risks to achieve the performance requirements. • Remaining technical work planned is appropriate considering progress to date and remaining schedule and budget. • Appropriate risk mitigation plans exist, including Decision Points when applicable.
4. Degree to which progress has been made towards achieving the stated performance requirements.
• The project has tested (or is testing) those attributes appropriate for the next Technology Readiness Level (TRL). The level of technology integration and nature of the test environment are consistent with the aforementioned TRL definition. • Project progress, with emphasis on experimental results, shows that the technology has, or is likely to, achieve the stated performance requirements for the next TRL (including those pertaining to capital cost, if applicable). • Milestones and reports effectively enable progress to be tracked. • Reasonable progress has been made relative to the established project schedule and budget.
5. Degree to which an appropriate basis exists for the technology's performance attributes and requirements.
• The TRL to be achieved by the end of the project is clearly stated[2]. • Performance attributes for the technology are defined[2]. • Performance requirements for each performance attribute are, to the maximum extent practical, quantitative, clearly defined, and appropriate for and consistent with the DOE goals as well as technical and economic viability in the intended commercial application.
[1] If it is appropriate for a project to not have cost/economic-related performance requirements, then the project is evaluated on technical performance requirements only. [2] Supported by systems analyses appropriate to the targeted TRL.

NETL Peer Review – Rating Definitions and Scoring Plan

The Review Panel assigns an overall score to the project after strengths, weaknesses, and prioritized recommendations are generated at the meeting. Intermediate whole number scores are acceptable if the Review Panel feels it is appropriate. The overall project score must be justified by, and consistent with, the identified strengths and weaknesses.

NETL Peer Review Rating Definitions and Scoring Plan	
10	**Excellent -** Several major strengths; no major weaknesses; few, if any, minor weaknesses. Strengths are apparent and documented.
8	**Highly Successful -** Some major strengths; few (if any) major weaknesses; few minor weaknesses. Strengths are apparent and documented, and outweigh identified weaknesses.
5	**Adequate -** Strengths and weaknesses are about equal in significance.
2	**Weak -** Some major weaknesses; many minor weaknesses; few (if any) major strengths; few minor strengths. Weaknesses are apparent and documented, and outweigh strengths identified.
0	**Unacceptable -** No major strengths; many major weaknesses. Significant weaknesses/deficiencies exist that are largely insurmountable.

APPENDIX B: DOE TECHNOLOGY READINESS LEVELS

The following is a description of U.S. Department of Energy (DOE) Technology Readiness Levels (TRLs).

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	**TRL 9**	Actual system operated over the full range of expected mission conditions	The technology is in its final form and operated under the full range of operating mission conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	**TRL 8**	Actual system completed and qualified through test and demonstration	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this Technology Readiness Level (TRL) represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has been successfully completed prior to the start of hot testing.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning (1). Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.
Technology Demonstration	**TRL 6**	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering-scale prototypical system with a range of simulants (1). Supporting information includes results from the engineering-scale testing and analysis of the differences between the engineering-scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step-up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Technology Development	**TRL 5**	Laboratory-scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants (1) and actual waste (2). Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.
Technology Development	**TRL 4**	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small-scale tests on actual waste (2). Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4–6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Research to Prove Feasibility	**TRL 3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative tested with simulants (1). Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
	TRL 2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
Basic Technology Research	**TRL 1**	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

[1] Simulants should match relevant chemical and physical properties.

[2] Testing with as wide a range of actual waste as practicable and consistent with waste availability, safety, as low as reasonably achievable (ALARA), cost, and project risk is highly desirable.

Source: U.S. Department of Energy, "Technology Readiness Assessment Guide." Office of Management. 2011.

APPENDIX C: MEETING AGENDA

FY22 Carbon Capture Peer Review
October 26–28, 2021
Virtual Meeting

**** All times Eastern ****

Day 1–Tuesday, October 26, 2021

12:00–12:30 p.m. Peer Review Panel Kickoff Session
DOE HQ/NETL, KeyLogic Peer Review Support Staff, and Panel Members Attend
- Facilitator Opening, Review Panel Introductions, NETL Welcome,
  Peer Review Process and Meeting Logistics

12:30–1:30 p.m. Project FE0031944 – Chevron Natural Gas Carbon Capture Technology Testing Project
Justin Freeman – Chevron

1:30–2:30 p.m. Question-and-Answer Session

2:30–2:45 p.m. BREAK

2:45–4:15 p.m. Closed Discussion (Peer Review Panel Evaluation – Recommendations-Based)
DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers

4:15 p.m. Adjourn

**** All times Eastern ****

Day 2–Wednesday, October 27, 2021

12:00–12:15 p.m.	Kickoff Session
12:15–1:15 p.m.	Project FE0031588 – Engineering-Scale Demonstration of the Mixed-Salt Process for CO_2 Capture *Indira Jayaweera* – SRI International
1:15–2:15 p.m.	Question-and-Answer Session
2:15–2:30 p.m.	BREAK
2:30–4:00 p.m.	Closed Discussion (Peer Review Panel Evaluation – Recommendations-Based) *DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers*
4:00–4:45 p.m.	Peer Review Panel Discussion *DOE/NETL and KeyLogic Peer Review Staff Attend*
4:45 p.m.	Adjourn

**** All times Eastern ****

Day 3–Thursday, October 28, 2021

12:00–12:15 p.m.	Kickoff Session
12:15–1:45 p.m.	Project FE0031950 – Engineering-Scale Demonstration of Transformational Solvent on NGCC Flue Gas *Andrew Awtry* – ION Clean Energy, Inc.
1:45–2:45 p.m.	Question-and-Answer Session
2:45–3:00 p.m.	BREAK
3:00–4:30 p.m.	Closed Discussion (Peer Review Panel Evaluation – Recommendations-Based) *DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers*
4:30–5:00 p.m.	Peer Review Panel Wrap-Up Session (Common Themes & Logistics/Process Feedback) *DOE HQ/NETL, KeyLogic Peer Review Support Staff, and Panel Members Attend*
5:00 p.m.	Adjourn

APPENDIX D: PEER REVIEW PANEL MEMBERS

FY22 Carbon Capture Peer Review
October 26-28, 2021
Virtual Meeting

Dane Boysen, Ph.D.

Dane Boysen founded Modular Chemical Inc. in October 2017. Prior to this, Dr. Boysen was the chief technologist at Cyclotron Road. He has many years of experience developing and commercializing hard energy technology. Before Cyclotron Road, he was Executive Director of Research Operations at the Gas Technology Institute (GTI). Prior to GTI, Dr. Boysen served as a Program Director at the Advanced Research Projects Agency-Energy (ARPA-E), where he managed more than $100 million spread across more than 30 of the nation's most cutting-edge energy technology research and development (R&D) projects. Prior to joining ARPA-E, Dr. Boysen led an $11 million project to develop liquid metal batteries for grid-scale energy storage under Professor Don Sadoway at the Massachusetts Institute of Technology (MIT). This work led to the founding of the venture-backed start-up Ambri. In 2004, Dr. Boysen co-founded Superprotonic Inc., a venture capital-backed start-up developing solid acid electrolyte-based fuel cells. Dr. Boysen received his M.S. and Ph.D. in materials science from Caltech and his B.S. from the University of Washington in materials science and engineering.

Bhadra Grover

Bhadra Grover is a retired chemical engineer with more than 45 years of industrial experience in process design and R&D. He is an expert in various technologies for chemical production and gas purification, including hydrogen and syngas production by steam reforming and gasification, and carbon dioxide (CO_2) capture, purification, compression, and transportation. Mr. Grover has industrial experience in engineering, R&D, business development, application development, and operation of following processes and plants. He is a member of the American Institute of Chemical Engineers (AIChE) and a member of the Compressed Gas Association (CGA) Task Force on Combustion Safety Guidelines for Steam Reformer Operation. He has also received 12 U.S. Patents; more than 15 other patent applications are in various stages and four papers have been published or presented at professional conferences. Past work includes the development of high-temperature (300°C+) sorbents for CO_2 capture from syngas, a metallic and ceramic membrane reactor for steam reforming and shift reactors, burners for steam methane reforming (SMR) furnaces, and chemical looping for combustion and hydrogen production. Mr. Grover holds an M.S. in chemical engineering from Manhattan College in New York and a B.Tech in chemical engineering from the Indian Institute of Technology in New Delhi, India.

Norman Z. Shilling, Ph.D.

Before entering private consulting practice, Dr. Norman Shilling was the senior product manager for General Electric (GE) Energy's gasification product line, responsible for developing policy and regulatory strategies and providing advocacy in Washington and international forums on solutions for greenhouse gases.

Dr. Shilling's experience in environmental and utility power generation includes serving as product line leader for gas turbines, focusing on applications involving unconventional fuels, integrated gasification combined cycle (IGCC), and the integration of power production with chemical refinery plants and steel mills. He previously served as program manager for low-emissions locomotive diesel development and as environmental systems engineering manager at GE's Research Center, collaborating with many GE businesses on pollution prevention and energy efficiency initiatives. Dr. Shilling was also an advanced engineering manager at GE's Environmental Systems, where he was responsible for the development of advanced scrubbers and particulate controls for utility power plants. Prior to the start of his GE career, Dr. Shilling worked in nuclear steam generator development and advanced automotive power plant development. In addition, he has provided testimony to many regulatory and legislative bodies and is a member of several coal forums and workgroups. Dr. Shilling holds an M.S. degree from MIT and B.S. and D.Sc. degrees from the New Jersey Institute of Technology. He has taught in the graduate engineering school at Penn State University (PSU) and is a licensed professional engineer.

John Shinn, Ph.D.

Dr. John Shinn holds a Ph.D. in chemical engineering from University of California, Berkeley and has spent his career dedicated to improving the world's energy systems from an environmental and social perspective. Dr. Shinn served 35 years guiding Chevron and the oil industry, helping develop new environmentally improved process technologies, as well as effective approaches to improve the environmental and social value of their operations. He formed his own private advisory group (SynPatEco LLC), advising clients that include the World Bank, U.S. Department of Energy (DOE), Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory (LBNL), and others on the environmentally and socially effective use of fossil fuels and biofuels, and has been involved in several venture capital startups. Dr. Shinn has served on numerous advisory boards and held similar roles in engineering, environmental, and social institutes at MIT, Caltech, Stanford, Sandia, Kyushu University, PSU, and others. He served on the Governing Board of Engineers Without Borders USA for 10 years during its key formative development period.