FISCAL YEAR 2023 CARBON DIOXIDE REMOVAL PEER REVIEW

OVERVIEW REPORT

July 17, 2023

Disclaimer

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1 Introduction and Background

The National Energy Technology Laboratory's (NETL) Carbon Dioxide Removal (CDR) Program is advancing a diverse portfolio of CDR approaches that will aid in gigatonne-scale carbon dioxide (CO_2) removal from the atmosphere by mid-century. CDR is one method for carbon management that is part of a comprehensive multi-pronged approach that involves the coupling of carbon capture methods (i.e., CDR technologies co-located with low-carbon energy sources, and point source capture for fossil fuel-based power generation and industrial sources) with long-duration (at least 100 years) carbon storage in geologic, bio-based, and ocean reservoirs, or in long-lasting products (e.g., synthetic aggregates, biochar, concrete, durable carbon products). This diverse suite of technologies and solutions is integral to the goal of achieving a net-zero carbon economy in the United States by 2050. Furthermore, these efforts directly support the U.S. Department of Energy's (DOE) Carbon Negative Shot goal to remove CO_2 from the atmosphere and durably store it for less than $100/net tonne CO_2-equivalent (CO_2e).

Research and development (R&D) for CDR is focused on areas such as direct air capture (DAC), biomass carbon removal and storage (BiCRS) and bioenergy with carbon capture and storage (BECCS), enhanced mineralization, and direct ocean capture to remove CO_2 that has accumulated in the atmosphere or oceans and durably store it (i.e., geologic storage or subsurface mineralization) or convert it into durable products, such as low-carbon concrete. NETL supports the robust analysis of life cycle impacts of various CDR approaches and fosters a deep commitment to environmental justice throughout the research, development, and deployment process. The deployment of CDR methods can mitigate ongoing CO_2 emissions from difficult-to-decarbonize sectors (e.g., aviation, shipping, and agriculture) to reduce "net" emissions, as well as to address legacy CO_2 emissions to achieve net-negative emissions goals.

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

In compliance with requirements from the Office of Management and Budget (OMB) and in accordance with DOE's 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 2023 (FY 2023) CDR Peer Review Meeting with independent technical experts to offer recommendations to strengthen projects during the period of performance and assess each project's Technology Readiness Level (TRL) status and progression. KeyLogic, an NETL site-support contractor, convened a panel of four academic and industry experts[a] on June 6–9, 2023, to conduct a peer review of four CDR Program research projects (Exhibit 1-1).

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

Exhibit 1-1. FY 2023 CDR Peer Review—projects reviewed

Project Number	Title	Lead Organization	Total Funding		Project Duration	
			DOE	Cost Share	From	To
FE0031957	Demonstration of a Continuous Motion Direct Air Capture (DAC) System	Global Thermostat	$3,349,996	$850,000	01/01/2021	01/31/2024
FE0031959	Direct Air Capture Using Novel Structured Adsorbents	Electricore Inc.	$4,830,280	$1,731,698	10/01/2020	09/30/2023
FE0031970	A Combined Atmospheric Water Extraction and CO_2 Direct Air Capture System	IWVC LLC	$3,157,064	$672,000	10/01/2020	09/30/2023
FE0031961	Direct Air Capture Recovery of Energy for CCUS Partnership (DAC $RECO_2UP$)	Southern States Energy Board	$3,135,805	$635,805	10/01/2020	01/31/2024
TRL-Based Evaluation: During TRL-based evaluations, the independent Review Panel offers recommendations and assesses the technology readiness for work at the current TRL and the planned work to attain the next TRL.			**$14,473,145**	**$3,889,503**		
			$18,362,648			

2 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 OMB 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 four research projects supported by the CDR Program. Throughout the peer review meeting, these recognized technical experts offered recommendations to strengthen the projects during the remaining period of performance and assessed each project's TRL status and progression. KeyLogic selected an independent Review Panel, facilitated the peer review meeting, and prepared this report to summarize the results.

2.1 PRE-MEETING PREPARATION

Before the peer review meeting, each project team submitted a Project Technical Summary (PTS), project presentation, and Technology Maturation Plan (TMP). The Federal Project Manager (FPM)/Federal Point of Contact (FPOC) provided the Project Management Plan (PMP), the latest quarterly report, and supplemental technical papers as additional resources for the Review Panel. The Review Panel received these materials prior to the peer review meeting, which enabled the Review Panel to fully prepare for the meeting with the necessary background information.

To increase the efficiency of the peer review meeting, multiple pre-meeting orientation sessions were held with NETL, the project teams, the Review Panel, and KeyLogic to review the peer review process and procedures, roles and responsibilities, peer review evaluation criteria, and project documentation. The Technology Manager also offered an overview presentation of the program goals and objectives, as well as the rationale behind selecting the projects for peer review.

2.2 PEER REVIEW MEETING PROCEEDINGS

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

During the closed discussion sessions of the meeting, the Review Panel discussed each project (identified in Exhibit 1-1) to identify strengths, weaknesses, and recommendations in accordance with the NETL Peer Review Evaluation Criteria.[b] The Review Panel offered prioritized, actionable recommendations to strengthen the project during the remaining period

[b] Please see "Appendix A: Peer Review Evaluation Criteria" for more information.

of performance and an evaluation of current TRL status and progression toward achieving the planned end-of-project TRL.

3 SUMMARY OF KEY FINDINGS

This section summarizes the overall key findings of the projects evaluated at the FY 2023 CDR Peer Review Meeting. The Review 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 Review Panel to contribute to each project's development by identifying core issues and making constructive, actionable recommendations to improve project outcomes. The Review Panel generated 28 recommendations for NETL management to review and consider.

Several common themes were observed by the Review Panel during the peer review, ranging from the project teams' experience and expertise, system design, and testing plan/platform. Regarding experience and expertise, the panel noted the following:

- The teams' industrial experience, which is helpful for building a commercial pilot system.
- The individual expertise (e.g., process, adsorbent) of the respective team members, which results in a holistic view of the system tradeoffs.
- The teams' evaluation of potential near-term, commercial applications that could assist in quicker adaptation of DAC technology.

The panel also offered several comments related to the teams' system design, including:

- One project team's development of a novel system in terms of material and design by separating the water absorption from CO_2 absorption to reduce the energy requirement and combining the heat transfer and mass transfer from the same surface to reduce the size of the contactors.
- One project team basing its concept on proven, fully characterized, and widely applied adsorbent materials and monolith structure, which reduces the R&D timeline.

With respect to testing plan/platform, the panel stated that most of the projects are testing on a sufficient number of cycles to collect data and demonstrate durability (e.g., as many as 20,000 cycles). The panel noted that one project team's materials test plan is comprehensive, and the team understands there are many variables that need tracked and controlled to successfully implement in a real system.

The panel noted that some of the project teams should more frequently revisit their techno-economic analysis (TEA) and either update the analysis or include a sensitivity analysis (e.g., in one case, the panel recommended the project team address cost drivers as they relate to operating expenses [OPEX] and capital expenditures [CAPEX]).

Finally, the Review Panel noted that the National Carbon Capture Center (NCCC) serves as a resource for sorbent technology developers to progress from TRL 4 to TRL 5 (i.e., high-fidelity, integrated, and near-prototypic environment) and lower the cost and schedule burdens associated with development at their own test facility.

Evaluation of Technology Readiness Level Progression

The Review Panel assessed each project's current TRL and whether the project was on track to attain the planned end-of-project TRL based on the project strengths, weaknesses, issues, concerns, and recommendations identified during the peer review. The panel affirmed that the project teams are on track to attaining their respective planned end-of-project TRL and offered the following assessments.

- Project FE0031957 has attained TRL 4. Upon construction and operation of the complete continuous DAC (cDAC), the project will attain TRL 5.
- Project FE0031959 has attained TRL 4. Upon completion of the durability testing and analysis of the test, the project will attain TRL 5.
- Project FE0031970 has attained TRL 4. Upon completion of the construction and operation of the pilot to demonstrate the performance attributes and long-term stability, the project will attain TRL 6.
- Project FE0031961 has attained TRL 5. Upon completion of a long-term feasibility test at NCCC that shows acceptable sorbent degradation, the project will attain TRL 6.

4 Project Synopses

For more information on the CDR Program and project portfolio, please visit the NETL website: https://netl.doe.gov/carbon-dioxide-removal.

Project Number FE0031957

Project Title	Demonstration of a Continuous-Motion Direct Air Capture (DAC) System
Lead Organization	Global Thermostat LLC
Project Description	Global Thermostat LLC, in partnership with Zero Carbon Partners, VADA LLC, Georgia Tech, and the National Renewable Energy Laboratory (NREL), will develop a continuous motion direct air capture (DAC) system that will capture carbon dioxide (CO_2) from the air through an adsorption process and produce a greater than 95% purity CO_2 product. The process employs honeycomb monolith contactors with a solid amine sorbent incorporated into the pores of the monolith, resulting in high CO_2 adsorption capacities at very low CO_2 partial pressures. The project team will design and validate the mechanical components of the system and complete detailed engineering and sizing of the process equipment. In parallel, a phenomenological flow model and a systems-level Aspen model will be developed to refine process step development, monolith lifetime, and key performance tradeoffs. Global Thermostat will leverage the phenomenological model to inform experimental work while assessing the impacts on sorbent lifetime. The process equipment will be fabricated, delivered, and integrated with the mechanical system to form an integrated DAC system. The prototype DAC unit will be commissioned and operated at the Global Thermostat Technology Center to collect on-stream data that will inform the techno-economic and life cycle analyses (TEA/LCA).

PROJECT NUMBER FE0031959

Project Title	Direct Air Capture Using Novel Structured Adsorbents
Lead Organization	Electricore Inc.
Project Description	Electricore Inc. will advance a direct air capture (DAC) technology that combines a vacuum-temperature swing carbon dioxide (CO_2) adsorption process with structured adsorbent beds. The process employs Svante's novel solid sorbent laminate filter technology integrated with Climeworks' DAC technology in which CO_2 from air is chemically bound to a solid sorbent material and the sorbent is regenerated using vacuum- and temperature-swing desorption. The overall goals of the project are to construct and operate a 30-kilogram-per-day (kg/day) integrated field test unit capable of producing a concentrated CO_2 stream of at least 95% purity. A 12-month field test of the DAC system will be conducted at Wintec Energy's renewable energy facility to capture operational data on the novel process and material combination under real conditions. A full characterization of Svante's first-, second-, and third-generation sorbent materials will be performed after 1,000 hours of operation, with a goal of optimizing the sorbent structure geometry to reduce the amount of water uptake during adsorption and increase lifetime. Test data will be used to advise techno-economic and life cycle analyses (TEA/LCA) of the technology. The project will validate current state-of-the-art DAC systems and sorbent materials and will achieve cost reductions using advanced sorbents and energy optimization realized via reduced pressure drop in sorbent beds and innovative heat recovery techniques.

PROJECT NUMBER FE0031970

Project Title	A Combined Water and CO_2 Direct Air Capture System
Lead Organization	IWVC LLC
Project Description	IWVC LLC is developing a transformational hybrid direct air capture (HDAC) technology that simultaneously captures carbon dioxide (CO_2) and water from the air using an amine-functionalized solid sorbent developed by Pacific Northwest National Laboratory. In HDAC, a combination of high-performance desiccant and CO_2-selective sorbents are used to remove both the water vapor and CO_2 from the air in a single pass through the HDAC system. The atmospheric water extraction (AWE) section of the unit utilizes a novel isothermal pressure-swing regeneration cycle with desiccant beds thermally coupled by heat pipes that provide a passive heat transfer mechanism to minimize energy losses. The low relative humidity air stream is then passed over a CO_2-selective sorbent to remove 85% of the CO_2 from the air stream. Combining potable water generation and CO_2 capture in a single device with the unique energy conserving features of the design enables a competitive cost of capture to be achieved with much smaller plant capacities and capital costs than required by conventional DAC systems.

PROJECT NUMBER FE0031961

Project Title	**Direct Air Capture of Energy for Carbon Capture, Utilization, and Storage (CCUS) Partnership (DAC RECO$_2$UP)**
Lead Organization	**Southern States Energy Board**
Project Description	Southern States Energy Board is leading efforts to advance a solid amine sorbent-based carbon dioxide (CO_2) capture technology for direct air capture (DAC) through field testing in a commercially relevant environment. Carbon capture materials that have been developed by Global Thermostat and tested on DAC systems in the laboratory will be utilized in the project. The primary goal of the DAC RECO$_2$UP project is to decrease the cost of DAC through the testing of existing DAC materials in integrated field units that produce a concentrated CO_2 stream of at least 95% purity. Global Thermostat's technology employs a monolithic contactor impregnated with a solid polyethyleneimine polymer that forms agglomerations of polymeric amine capture sites within the mesopores of the contactor wherein CO_2 is adsorbed. The ultra-low, pressure drop monoliths maximize the efficiency of air flow, increasing mass transfer of CO_2 for adsorption. The project team will conduct an engineering design of an integrated DAC system utilizing energy recovery and support services at the National Carbon Capture Center (NCCC) and prepare a chemical process and energy utilization model on the design work. A DAC skid capable of adsorbing/desorbing CO_2 using Global Thermostat's solid-amine sorbent monolithic contactors and an energy recovery integration skid that uses process control and heat exchangers to produce the required steam for the DAC process will be constructed and installed at NCCC. Air Capture LLC will provide an existing third skid capable of compressing, liquifying, and purifying the CO_2. A three-phased testing campaign will be conducted in an integrated system environment at NCCC. Techno-economic and life cycle analyses (TEA/LCA) will be performed, in addition to a technology environmental health and safety assessment to determine the environmental sustainability and economic viability of the integrated DAC system.

APPENDIX A: PEER REVIEW EVALUATION CRITERIA

Peer reviews consist of a formal evaluation of selected National Energy Technology Laboratory (NETL) projects by an independent panel of subject matter experts (SMEs) and are conducted to ensure that the Office of Fossil Energy and Carbon Management's (FECM) research program, implemented by NETL, is compliant with Office of Management and Budget (OMB) guidance, the U.S. Department of Energy (DOE) Strategic Plan, and DOE guidance. Peer reviews reduce project risk (e.g., cost, schedule, technology development) and 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. NETL uses the peer review findings to guide and redirect projects, as appropriate, underscoring NETL's commitment to funding and managing a portfolio of high-quality research.

NETL PEER REVIEW—TECHNOLOGY READINESS LEVEL-BASED EVALUATION

At the meeting, the peer review facilitator leads the Review Panel in assessing a project's readiness to start work toward the next Technology Readiness Level (TRL) based on a project's strengths[c]; weaknesses[d], issues, and/or concerns; and recommendations.

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.

[c] A strength is an aspect of the project that, when compared to the evaluation criterion, reflects positively on the probability of successful accomplishment of the project's goal(s) and objectives.

[d] A weakness is an aspect of the project that, when compared to the evaluation criterion, reflects negatively on the probability of successful accomplishment of the project's goal(s) and objectives.

Exhibit A-1. NETL Peer Review evaluation criteria

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.
6. The project Technology Maturation Plan (TMP) represents a viable path for technology development beyond the end of the current project, with respect to scope, timeline, and cost.

[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.

APPENDIX B: DOE TECHNOLOGY READINESS LEVELS

Exhibit B-1. Description of DOE 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.
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.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
	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

FY 2023 Carbon Dioxide Removal Peer Review
June 6–9, 2023
Virtual Meeting

Tuesday, June 6, 2023

Project FE0031957 – Demonstration of a Continuous-Motion Direct Air Capture (DAC) System

** All times Eastern **

12:00–12:30 p.m.	**Peer Review Panel Kickoff Session** *DOE HQ/NETL, KeyLogic Peer Review Support, and Review Panel Attend* • Facilitator Opening, Review Panel Introductions, NETL Welcome, Peer Review Process and Meeting Logistics
12:30–1:15 p.m.	**Project FE0031957 – Demonstration of a Continuous-Motion Direct Air Capture (DAC) System** *Eric W. Ping* – Global Thermostat Operations LLC
1:15–2:00 p.m.	**Question-and-Answer Session**
2:00-2:15 p.m.	BREAK
2:15–3:45 p.m.	**Closed Discussion (TRL-Based Evaluation; Review Panel)** • *DOE HQ/NETL and KeyLogic Peer Review Support Attend as Observers*
3:45 p.m.	Adjourn

Wednesday, June 7, 2023

Project FE0031959 – Direct Air Capture Using Novel Structured Adsorbents

** All times Eastern **

12:00–12:10 p.m.	**Kickoff Session**
12:10–12:55 p.m.	**Project FE0031959 – Direct Air Capture Using Novel Structured Adsorbents** *Deborah Jelen* – Electricore Inc.
12:55–1:40 p.m.	**Question-and-Answer Session**
1:40-2:00 p.m.	BREAK
2:00–3:30 p.m.	**Closed Discussion (TRL-Based Evaluation; Review Panel)** • *DOE HQ/NETL and KeyLogic Peer Review Support Attend as Observers*
3:30 p.m.	Adjourn

THURSDAY, JUNE 8, 2023

PROJECT FE0031970 – A COMBINED WATER AND CO_2 DIRECT AIR CAPTURE SYSTEM

**** All times Eastern ****

12:00–12:10 p.m.	**Kickoff Session**
12:10–12:55 p.m.	**Project FE0031970 – A Combined Water and CO_2 Direct Air Capture System** *Will Kain* – IWVC LLC
12:55–1:40 p.m.	**Question-and-Answer Session**
1:40-2:00 p.m.	**BREAK**
2:00–3:30 p.m.	**Closed Discussion (TRL-Based Evaluation; Review Panel)** • *DOE HQ/NETL and KeyLogic Peer Review Support Attend as Observers*
3:30-4:15 p.m.	**Peer Review Panel Discussion** • *DOE/NETL and KeyLogic Peer Review Staff Attend*
4:15 p.m.	**Adjourn**

FRIDAY, JUNE 9, 2023

PROJECT FE0031961 – DIRECT AIR CAPTURE OF ENERGY FOR CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS) PARTNERSHIP (DAC RECO$_2$UP)

**** All times Eastern ****

12:00–12:10 p.m.	**Kickoff Session**
12:10–12:55 p.m.	**Project FE0031961 – Direct Air Capture of Energy for Carbon Capture, Utilization, and Storage (CCUS) Partnership (DAC RECO$_2$UP)** *Matt Atwood* – Air Capture Inc.
12:55–1:40 p.m.	**Question-and-Answer Session**
1:40-2:00 p.m.	**BREAK**
2:00–3:30 p.m.	**Closed Discussion (TRL-Based Evaluation; Review Panel)** • *DOE HQ/NETL and KeyLogic Peer Review Support Attend as Observers*
3:30-4:00 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*
4:00 p.m.	**Adjourn**

Appendix D: Peer Review Panel Members

FY 2023 Carbon Dioxide Removal Peer Review
June 6–9, 2023
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. in materials science and engineering from the University of Washington.

Santosh Gangwal, Ph.D.

Dr. Santosh Gangwal has more than 44 years of experience in coal/biomass gasification/pyrolysis, syngas conditioning/conversion, fuel desulfurization, combined-cycle power systems, fuel cells, carbon capture, solar energy storage, and techno-economic evaluation. He is a recognized expert in gas-solid reactions, catalyst/sorbent preparation, and production scale-up, and has managed complex, multimillion dollar, multiple team member research programs totaling more than $60 million from the U.S. Department of Energy (DOE), U.S. Department of Defense (DOD), U.S. Environmental Protection Agency (EPA), and private industry. He has published 14 patents and more than 225 peer-reviewed publications and conference proceedings.

Dr. Gangwal provides technical expertise and assistance in the development of novel energy-related chemical processes as the Vice President of SKG Process Development Inc. He is presently engaged in projects related to clean fuel production from syngas, hydrogen production, carbon dioxide (CO_2) capture, catalyst design and manufacture, and contaminant removal from fuels. He recently retired from Southern Research Institute, where he was a Director of Business Development in the Energy and Environment Division for more than eight years. Prior to Southern Research, he was the Senior Program Director and Senior Research Chemical Engineer at Research Technical Institute (RTI), where he was employed for more than 22 years. While at RTI, he procured and successfully managed projects totaling more than $30 million. He was responsible for developing and managing projects in cleanup and conversion of biomass- and coal-derived syngas to fuels and alcohols and spearheaded the development of an internationally recognized syngas desulfurization program at RTI that grew into the Center for Energy Technology. Dr. Gangwal has a Ph.D. and an M.S. in chemical engineering from the University of Waterloo, as well as a B.S. in chemical engineering from the Indian Institute of Technology in New Delhi, India.

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 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.

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