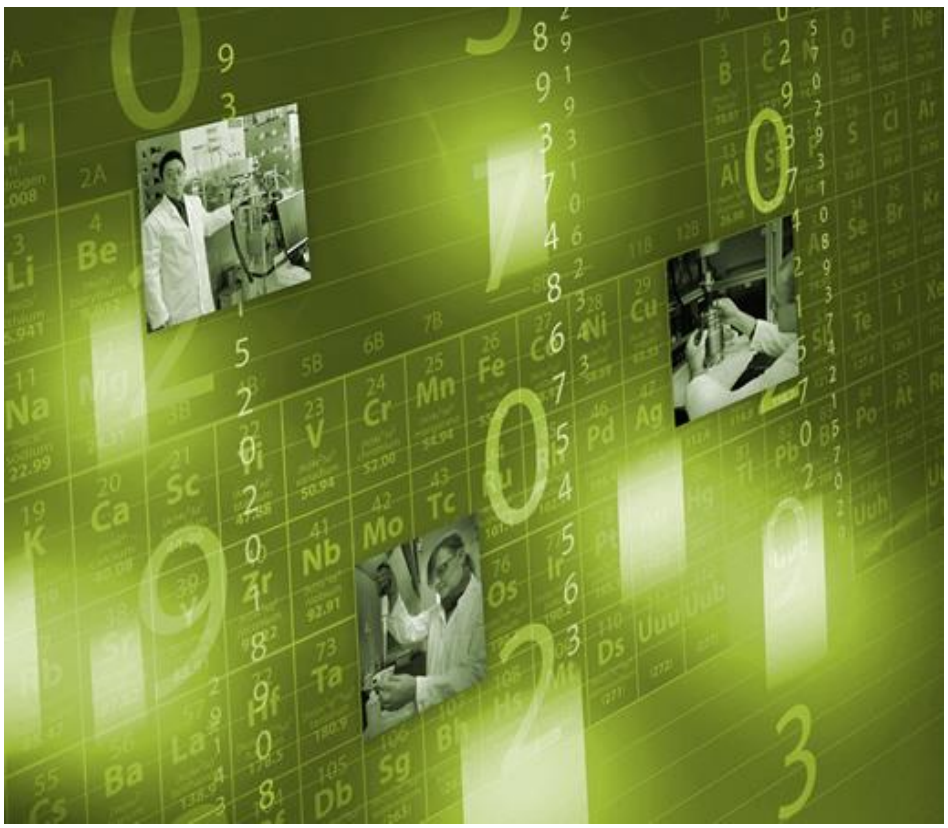
NATIONAL ENERGY TECHNOLOGY LABORATORY

FY20 SOLID OXIDE FUEL CELLS PEER REVIEW OVERVIEW REPORT



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

DISCLAIMER

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INTRODUCTION AND BACKGROUND

Solid oxide fuel cells (SOFCs) are electrochemical devices that convert chemical energy of a fuel and oxidant directly into electrical energy. Since SOFCs produce electricity through an electrochemical reaction and not through a combustion process, they are more efficient and environmentally benign than conventional electric power generation processes. Their inherent characteristics make them uniquely suitable to address the environmental and water concerns associated with fossil fuel-based electric power generation.

The National Energy Technology Laboratory's (NETL) SOFC Program maintains a portfolio of research and development (R&D) projects that address the technical issues facing the commercialization of SOFC technology and pilot-scale testing projects intended to validate the solutions to those issues. To successfully complete the maturation of the SOFC technology from its present state to the point of commercial readiness, the program's efforts are channeled through three key technologies: Cell Development, Core Technology, and Systems Development.

- **Cell Development**–This key technology focuses on the cell-related technologies critical to the commercialization of SOFC technology. The components of the SOFC—the anode, cathode, and electrolyte—are the primary research emphasis. The electrochemical performance, durability, and reliability of the SOFC are key determinants in establishing the technical and economic viability of SOFC power systems. The SOFC Program maintains a diversified portfolio of cell development projects that are focused on improving electrochemical performance and cell power density, reducing long-term degradation, developing more robust cells, and reducing cost. Additional research projects include the evaluation of contaminants, advanced materials, materials characterization, advanced manufacturing, and failure analysis. The portfolio maintains a mix of near-, mid-, and long-term R&D projects at the bench- and laboratory-scale.
- **Core Technology**–This key technology conducts applied R&D on technologies—exclusive of the cell components—that improve the cost, performance, robustness, reliability, and endurance of SOFC stack or balance-of-plant (BOP) technology. Projects in the Core Technology portfolio focus on interconnects and seals; identify and mitigate stack-related degradation; develop computational tools and models; and conduct laboratory- and bench-scale testing to improve the reliability, robustness, endurance, and cost of stacks and BOP components, respectively.
- **Systems Development**–This key technology maintains a portfolio of projects that focus on the research, development, and demonstration (RD&D) of SOFC power systems. Project participants (industry teams) are independently developing unique and proprietary SOFC technology suitable for either syngas- or natural gas-fueled applications. The industry teams are responsible for the design and manufacture of the fuel cells, integration of cells hardware development, manufacturing process development, commercialization of the technology, and market penetration. Additionally, the developers focus on the scaleup of cells and stacks for aggregation into fuel cell modules and the validation of technology. This key technology also supports laboratory-scale stack tests, proof-of-concept systems, and pilot-scale tests.

The Systems Development key technology also focuses on innovative concepts. These projects conduct bench-scale R&D on innovative SOFC stack technologies that have the potential to significantly decrease the cost of SOFC power systems by leveraging advancements in lower-cost materials, advanced manufacturing methods, and/or alternative architectures.

Office of Management and Budget Requirements

In compliance with requirements from the Office of Management and Budget and in accordance with the U.S. Department of Energy (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 2020 (FY20) SOFC Peer Review Meeting with independent technical experts to offer each project prioritized recommendations and to assess two projects' Technology Readiness Level (TRL) progression. KeyLogic (NETL site-support contractor) convened a panel of three academic and industry experts[*] on July 21-23, 2020, to conduct a peer review of three SOFC Program research projects.

TABLE 1. SOFC PEER REVIEW – PROJECTS REVIEWED

Project Number	Title	Lead Organization	Total Funding		Project Duration	
			DOE	Cost Share	From	To
FWP-1022411	Solid Oxide Fuel Cells*	National Energy Technology Laboratory	$16,172,833	$0	April 1, 2018	March 31, 2021
FE0027844	Metal-Supported Ceria Electrolyte-Based SOFC Stack for Scalable, Low Cost, High Efficiency and Robust Stationary Power Systems**	Cummins Power Generation, Inc.	$3,734,510	$984,782	October 1, 2016	December 31, 2020
FE0031653	Multi-Gas Sensors for Enhanced Reliability of Solid Oxide Fuel Cell Operation**	General Electric (GE) Company	$460,696	$153,865	August 17, 2018	August 16, 2020
			$20,368,039	$1,138,647		
			$21,506,686			

* Recommendations-Based Evaluation: During recommendations-based evaluations, the independent panel provides recommendations to strengthen the performance of projects during the period of performance.

** TRL-Based Evaluation: During TRL-based evaluations, the independent panel offers recommendations and assesses the projects' technology readiness for work at the current TRL and the planned work to attain the next TRL.

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

OVERVIEW OF THE PEER REVIEW PROCESS

Peer reviews are conducted to help ensure that the Office of Fossil Energy's (FE) 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 three academic and industry experts to conduct a peer review of three research projects supported by the SOFC Program. Throughout the peer review meeting, these recognized technical experts offered recommendations and provided feedback on two projects' technology readiness for work at the current TRL and the planned work to attain the next TRL. In consultation with NETL representatives, who chose the projects for review, 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 projects subject to a TRL-based evaluation also shared a Technology Maturation Plan (TMP) to facilitate TRL evaluation from the Peer Review Panel (reference Table 1). The Federal Project Manager (FPM) provided the Project Management Plan (PMP) or Field Work Proposal (FWP), the latest quarterly report, and supplemental technical papers as additional resources for the panel (as applicable). 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[†]. For one project, the panel offered prioritized recommendations to strengthen the project during the remaining period of performance. For the remaining two projects, the panel offered prioritized recommendations and an evaluation of TRL progression.

† Please see "Appendix A: Peer Review Evaluation Criteria" for more information.

SUMMARY OF KEY FINDINGS

This section summarizes the overall key findings of the projects evaluated at the FY20 SOFC 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 an 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 by making constructive recommendations to improve project outcomes. The panel generated 10 recommendations for NETL management to review and consider.

The panel offered several common strengths among the projects reviewed. The panel stated that the Principal Investigators (PIs) and the project team members were all knowledgeable and possessed the necessary expertise to execute the work as planned. The projects are well managed by the project performers and NETL; the project documentation and reporting were both informative and timely. It was clear to the panel how all three projects align with DOE's near- and long-term goals. Finally, the panel was impressed with the project teams' commitment to knowledge sharing through the dissemination of information via journal articles, presentations, and publications.

The panel also noted several areas for improvement among the projects reviewed. The panel noted that the project teams should evaluate their contribution to key SOFC technology issues rather than simply progress a technology along the development pathway to commercialization. The panel also indicated that the projects would benefit from performing long-term testing (i.e., more than 10,000 hours) on the SOFC systems to validate durability.

Evaluation of Technology Readiness Level Progression

At the meeting, the panel assessed two projects' readiness to start work towards the next TRL based on a project's strengths, weaknesses, recommendations, issues, and concerns. For the various projects subject to review, the panel found that all were on track to attaining their respective planned end-of-project TRL based on achievement of the project goals as planned and addressing the panel recommendations.

- Project FE0027844 has attained TRL 4. Upon successful completion of the planned system test and the recommended long-term testing (more than 10,000 hours), and resolution of any technical issues identified during testing, Project FE0027844 will attain TRL 5.
- Project FE0031653 has attained TRL 4. Upon identifying requisite temperature stability range (e.g., 250 to 350°C) to achieve performance, demonstrating stability out to 10,000 hours, completing the interface design between the sensor and the SOFC system, demonstrating reproducibility of the sensor, and achieving an acceptable cost of the system, Project FE0031653 will attain TRL 5.

PROJECT SYNOPSES

For more information on the SOFC Program and project portfolio, please visit the NETL website: https://netl.doe.gov/coal/fuel-cells.

FWP-1022411

SOLID OXIDE FUEL CELLS

NATIONAL ENERGY TECHNOLOGY LABORATORY

Project Description: The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Solid Oxide Fuel Cell (SOFC) Program is responsible for coordinating efforts to facilitate development of a commercially relevant and robust SOFC system. Specific program objectives include achieving an efficiency of more than 60% (without carbon capture and storage [CCS]), meeting a stack cost target of $225/kilowatt (kW), and demonstrating lifetime performance degradation of less than 0.2% per 1,000 hours over an operating lifetime of 40,000 hours.

FE0027844

METAL-SUPPORTED CERIA ELECTROLYTE-BASED SOFC STACK FOR SCALABLE, LOW COST, HIGH EFFICIENCY AND ROBUST STATIONARY POWER SYSTEMS

CUMMINS POWER GENERATION, INC.

Project Description: This project will advance the development of a metal-supported cell technology with complete internal fuel reforming that operates from approximately 600 to 630°C. It leverages Ceres Power's novel and highly differentiated technology based upon the use of thick-film ceramics deposited on a ferritic stainless-steel substrate, using doped ceria as the predominant oxygen ion conducting ceramic within the cell. Ceres' technology has been demonstrated to perform high levels of internal methane reforming, with a path to complete internal reforming through further development. The scope of this project includes advancing the internal reforming capability of the cell, including improving robustness, to anode and cathode contaminants through testing to understand poisoning mechanisms and rates and implementation of system mitigations. The scope also includes scaling-up the cell active area fivefold from the current 1-kilowatt (kW) format to enable an integrated stack module with power output of 5 kW, which is in turn scalable to higher power levels through replication of the 5-kW, modular-stack platform.

FE0031653

MULTI-GAS SENSORS FOR ENHANCED RELIABILITY OF SOLID OXIDE FUEL CELL OPERATION

GENERAL ELECTRIC

Project Description: General Electric (GE) Global Research will build and field-test gas sensors for monitoring hydrogen (H_2) and carbon monoxide (CO) anode tail gases produced in situ via onsite steam reforming in solid oxide fuel cell (SOFC) systems. Knowledge of the H_2/CO ratio of these tail gases will help accurately determine and control the efficiency of the reforming process in the SOFC system and deliver a lower operating cost for SOFC customers. The project objectives are to achieve a multi-gas monitoring capability with a single multivariable sensor and to sustain this performance between maintenance cycles of the SOFC system. The team will optimize a previously developed concept for detecting multiple gases with a single high-temperature sensor by monitoring H_2 and CO in precise lab experiments followed by field validation in SOFCs at GE-Fuel Cells, LLC. The team expects to achieve, at most, ±10% error in sensor accuracy in side-by-side comparisons against the benchmark instrument utilized on existing GE SOFC systems.

APPENDIX A: PEER REVIEW EVALUATION CRITERIA

PEER REVIEW EVALUATION CRITERIA AND GUIDELINES

Peer reviews are conducted to ensure that the Office of Fossil Energy's (FE) 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.

Technology Readiness Level-Based Evaluation

At the meeting, the Facilitator and/or Panel Chairperson leads the Peer Review Panel in assessing a project's readiness to start work towards the next Technology Readiness Level (TRL) based on a project's strengths[‡], weaknesses[§], recommendations, issues, and concerns.

Recommendations-Based Evaluation

At the meeting, the Facilitator and/or Panel Chairperson leads the Peer Review Panel in identifying strengths, weaknesses, overall score, and prioritized recommendations 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 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.

§ 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.

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 (TRL-based evaluation). 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.
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. *(This criterion is not applicable to a recommendations-based evaluation)*
[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

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.

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.
	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, ALARA, cost and project risk is highly desirable.

APPENDIX C: MEETING AGENDA

FY20 Solid Oxide Fuel Cells Peer Review
July 21-23, 2020
Virtual Meeting

Day 1 – Tuesday, July 21, 2020

10:00 – 10:30 a.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
10:30 – 11:30 a.m.	Project FWP-1022411 – Solid Oxide Fuel Cells *Gregory Hackett* – National Energy Technology Laboratory
11:30 – 12:30 p.m.	Question-and-Answer Session
12:30 – 1:15 p.m.	LUNCH/BREAK
1:15 – 3:00 p.m.	Closed Discussion (Peer Review Panel Evaluation – Recommendations-Based) *DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers*
3:00 – 3:20 p.m.	Peer Review Panel Wrap-Up Session (Logistics/Process Feedback) *DOE HQ/NETL, KeyLogic Peer Review Support Staff, and Panel Members Attend*
3:20 p.m.	Adjourn

Day 2 – Wednesday, July 22, 2020

10:00 – 10:10 a.m.	Kickoff Session
10:10 – 11:10 a.m.	Project FE0027844 – Metal-Supported Ceria Electrolyte-Based SOFC Stack for Scalable, Low Cost, High Efficiency and Robust Stationary Power Systems *Charles Vesely* – Cummins Power Generation, Inc.
11:10 – 12:10 p.m.	Question-and-Answer Session
12:10 – 12:55 p.m.	LUNCH/BREAK
12:55 – 2:40 p.m.	Closed Discussion (Peer Review Panel Evaluation – TRL-Based) *DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers*
2:40 – 3:00 p.m.	Peer Review Panel Wrap-Up Session (Logistics/Process Feedback) *DOE HQ/NETL, KeyLogic Peer Review Support Staff, and Panel Members Attend*
3:00 p.m.	Adjourn

Day 3 – Thursday, July 23, 2020

10:00 – 10:10 a.m.	Kickoff Session
10:10 – 11:10 a.m.	Project FE0031653 – Multi-Gas Sensors for Enhanced Reliability of Solid Oxide Fuel Cell Operation *Radislav Potyrailo* – General Electric (GE) Company
11:10 – 12:10 p.m.	Question-and-Answer Session
12:10 – 12:55 p.m.	LUNCH/BREAK
12:55 – 2:40 p.m.	Closed Discussion (Peer Review Panel Evaluation – TRL-Based) *DOE HQ/NETL and KeyLogic Peer Review Support Staff Attend as Observers*
2:40 – 3:25 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*
3:25 p.m.	Adjourn

APPENDIX D: PEER REVIEW PANEL MEMBERS

FY20 Solid Oxide Fuel Cells Peer Review
July 21-23, 2020
Virtual Meeting

Raymond George

Raymond George has more than 40 years of industry experience in the nuclear power and solid oxide fuel cell (SOFC) power generation fields. His experience at Westinghouse Commercial Nuclear Power included managing the Nuclear Fuel Division Advanced Pressurized Water Reactor Development Program and plant marketing. He also served as Engineering Manager of the SOFC Development Program at the Westinghouse Research and Development (R&D) Center. Mr. George served as Manager of both Engineering and Manufacturing for SOFC Power Generation (sold to Siemens in 1998) and Chief Technology Officer of Stationary Fuel Cells for Siemens Power Generation. Following his time as Chief Technology Officer, Mr. George offered consulting support to Siemens. Mr. George also offered consulting support to Israeli Company on solid oxide electrolysis.

Mr. George studied nuclear engineering at Carnegie Mellon University and holds an M.E. and B.S. in nuclear engineering from Rensselaer Polytechnic Institute.

Wayne Huebner, Ph.D.

Dr. Wayne Huebner is the Materials Science and Engineering Department Chairman and a Professor of Ceramic Engineering at the Missouri University of Science and Technology. Dr. Huebner's research interests include the preparation, characterization, and theoretical understanding of electronic ceramics (i.e., ferroelectrics, piezoelectrics, varistors, thermistors, superionic conductors, and solid oxide electrolytes), fuel cells, and oxygen separation membranes.

Dr. Huebner was recognized by the American Ceramic Society in 1995 with the Karl Schwartzwalder Professional Achievement in Ceramic Engineering Award, the Missouri Science and Technology Outstanding Teaching Award, the Dr. Edward F. Tuck Excellence Award, and the McDonnell Douglas Faculty Excellence Award. Dr. Huebner holds a patent for Method of Manufacture of Multiple-Element Piezoelectric Transducer and has published numerous articles in peer-reviewed academic journals.

Dr. Huebner received his B.S. and Ph.D. in ceramic engineering from the University of Missouri-Rolla.

Subhash Singhal, Ph.D.

Dr. Subhash Singhal worked as a Battelle Fellow and Director, Fuel Cells, at the U.S. Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) from 2000 to 2013 and provided senior technical, managerial, and commercialization leadership to the laboratory's extensive fuel cell and clean energy programs. Prior to joining PNNL in 2000, Dr. Singhal led fuel cell development at Siemens Power Generation (formerly Westinghouse Electric Corporation) for nearly 30 years, conducting and/or managing major research, development, and demonstration programs in the field of advanced materials for various energy conversion systems, including steam and gas turbines, coal gasification, and fuel cells. While at Siemens, Dr. Singhal served as the Manager of Fuel Cell

Technology from 1984 to 2000, during which he was responsible for the development of high-temperature SOFCs for stationary power generation and led an internationally recognized group that brought SOFC technology from a few-watt laboratory curiosity to a fully integrated, 200-kilowatt (kW)-size power generation system.

Dr. Singhal has also served as an Adjunct Professor in the Department of Materials Science and Engineering at the University of Utah, and a Visiting Professor at the China University of Mining and Technology-Beijing and the Kyushu University-Japan. He serves on the Advisory Boards of the Department of Materials Science and Engineering at the University of Florida, Florida Institute for Sustainable Energy, Division of Materials Science and Engineering at Boston University, Materials Research Science and Engineering Center at the University of Maryland, Center on Nanostructuring for Efficient Energy Conversion at Stanford University, and the Fuel Cell Institute at the National University of Malaysia. Dr. Singhal has authored more than 75 scientific publications; edited 13 books; received 13 patents; and given more than 240 plenary, keynote, and other invited presentations worldwide. A member of the National Academy of Engineering and a fellow of four professional societies (American Association for the Advancement of Science, American Ceramic Society, ASM International, and Electrochemical Society), Dr. Singhal has a bachelor's degree in metallurgy from the Indian Institute of Science; a bachelor's degree in physics, chemistry, and mathematics from Agra University, India; an MBA from the University of Pittsburgh; and a Ph.D. in materials science engineering from the University of Pennsylvania.