PROLOGUE

Dear Colleague:

This document summarizes the comments provided by peer reviewers on hydrogen and fuel cell projects presented at the FY 2010 U.S. Department of Energy (DOE) Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting (AMR), held June 7–11 in Washington, D.C. In response to direction from various stakeholders, including the National Academies, this review process provides evaluations of the Program's projects in applied research, development, demonstration, and analysis of hydrogen, fuel cells, and infrastructure technologies. The plenary session included overview presentations from the Office of Energy Efficiency & Renewable Energy (EERE), the Hydrogen Program, the Vehicle Technologies Program, and the Office of Basic Energy Sciences. In addition, the plenary session included information about American Recovery and Reinvestment Act projects and commentary from project principal investigators (PIs).

The recommendations of the reviewers are taken into consideration by DOE technology development managers in generating future work plans. The table below lists the projects presented at the review, evaluation scores, and the major actions to be taken during the upcoming fiscal year (October 1, 2010, to September 30, 2011). The projects have been grouped according to sub-program (Production and Delivery; Hydrogen Storage; Fuel Cells; Manufacturing R&D; Technology Validation; Safety, Codes & Standards; Education; and Systems Analysis) and reviewed according to the five evaluation criteria. For the first time, a session was dedicated to projects initiated under the American Recovery and Reinvestment Act (ARRA), with projects reviewed according to an appropriate set of criteria. The weighted scores for all projects are based on a four-point scale. To furnish PIs with direct feedback, all evaluations and comments are provided to each presenter; however, the authors of the individual comments remain anonymous. The PI of each project is instructed by DOE to fully consider these summary evaluation comments, as appropriate, in their fiscal year (FY) 2011 plans.

In addition to thanking all participants of the AMR, I would like to express my sincere appreciation to the reviewers. You make this report possible, and we rely on your comments, along with other management processes, to help make project decisions for the new fiscal year. We look forward to your participation in the FY 2011 Annual Merit Review, which is presently scheduled for May 9–13, 2011, at the Crystal Gateway Marriott and the Crystal City Marriott in Arlington, Virginia. Thank you for participating in the FY 2010 AMR.

Sincerely,

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Hydrogen Production and Delivery

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
PD-02	Biomass-derived Liquids Distributed (Aqueous Phase) Reforming *Yong Wang; Pacific Northwest National Laboratory (PNNL)*	2.8		X		The reviewers noted that much progress has been made in characterization of catalysts, addressing conversion and selectivity barriers and in understanding of reaction pathways. Selectivity improvements should be emphasized in the work scope. Reviewers also recommended that the project address screening of other catalyst variables, catalyst synthesis and long term testing of catalysts. Recommendations include identifying future R&D plans and focus (e.g., either syngas for SOFCs or hydrogen production) and strengthening collaborations with other researchers and potential end-users.
PD-03	Hydrogen from Glycerol: A Feasibility Study *Shabbir Ahmed; Argonne National Laboratory (ANL)*	3.1			X	Reviewers noted that good progress was made in establishing the range of associated costs for glycerol reforming needed to achieve DOE goals for production. Although the project was completed in FY 2010, the reviewers identified additional areas for further investigation of this topic if work continues at a later date. These include incorporation of new and emerging reactions (e.g., a water gas shift membrane reactor) and separation technologies into the flow chart to examine their economic validity, and investigation of glycerol as a fuel additive for fuel-flexible reformers.
PD-04	Distributed Bio-Oil Reforming *Stefan Czernik; National Renewable Energy Laboratory (NREL)*	3.0	X			The reviewers pointed out that there are still a number of issues and topics that remain to be addressed at bench scale, including the investigation of bio-oils of different qualities and types and an alternative means for bio-oil stabilization other than alcohols. Also, long term bench scale testing is needed to observe and characterize poisoning effects.
PD-05	High-Performance, Durable Palladium Alloy Membrane for Hydrogen Separation and Purification *Ashok Damle; Pall Corporation*	3.0	X			According to reviewers, good progress has been made in membrane development and fabrication, in long-term evaluation of the hydrogen flux in WGS environments, in determining effects of impurities, and in characterizing the effect of hydrogen recovery on costs. Reviewers recommended that the project should consider the impact of pressure loss and include a comparison with PSA technology in the techno-economic analysis. A test protocol for achieving simultaneous target performance levels should be established and documented, and extensive testing of the membranes in the presence of hydrogen sulfide is needed.
PD-06	A Novel Slurry Based Biomass Reforming Process *Thomas Vanderspurt; United Technologies Research Center (UTRC)*	3.3			X	According to reviewers, future funding in this area should depend on results of economic evaluation. A cost comparison with PSA technology was recommended. Next steps should include investigation of effects of variations in feedstock composition and impurities on catalyst performance, use of non-wood flower feedstock, and scale-up to system pilot testing.

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PD-07	Composite Pd and Alloy Porous Stainless Steel Membranes for Hydrogen Production and Process Intensification (Office of Fossil Energy) *Yi Hua (Ed) Ma; Worcester Polytechnic Institute*	2.9	X			Reviewers commented that the technical work plan for the project is well-designed, comprehensive, and considers all of the relevant issues to test the feasibility of the concept at the laboratory scale. Reviewers expressed some concerns with the membranes' lack of tolerance to sulfur and carbon monoxide impurities and suggested that future work focus on economics and partnerships with industrial developers and/or a coal gasification facility to perform tests at larger scale and under real-world conditions.
PD-08	Development of Robust Hydrogen Separation Membranes (Office of Fossil Energy) *Bryan D. Morreale; National Energy Technology Laboratory (NETL)-Office of Research and Development*	2.9	X			According to reviewers, the project team has a good understanding of engineering principles, membrane technology, and conversion processes. The capability to conduct unbiased verification testing of membranes was considered a strength. Additionally, the project team has developed a good understanding of sulfur poisoning of palladium and palladium-copper alloys, which should provide important clues to increasing sulfur tolerance. Reviewers commented that the project may benefit from a "user industry" team to obtain direct commercial guidance and to gain consensus on process and process economic considerations, and they recommend the addition of a partner from the coal gasification industry.
PD-09	Scale-Up of Hydrogen Transport Membranes for IGCC and FutureGen Plants (Office of Fossil Energy) *Carl Evenson; Eltron Research Inc.*	3.1	X			Reviewers commented that some parts of this project were difficult to evaluate due to intellectual property concerns. Otherwise, reviewers viewed the teaming with an industrial partner (Eastman Chemicals) as a strength, and considered the proposed future work plan systematic and logical. It was suggested that additional laboratory work be performed to better understand performance losses prior to the testing with Eastman. Additionally, a better economic assessment of membrane module costs was recommended, since the module cost may be significantly more than the materials cost.
PD-10	Amorphous Alloy Membranes for High Temperature Hydrogen Separations (Office of Fossil Energy) *Kent Coulter; Southwest Research Institute®*	2.8	X			Reviewers thought the project was innovative and exploratory, and the systematic approach using combinational screening techniques and computational modeling could lead to some very useful results. It was recommended that the project first demonstrate the feasibility of developing a stable glassy metal alloy, and then offer a compelling plan to achieve success with respect to applying a catalytically active protective coating. It was recognized by the reviewers that the project will eventually perform tests at the Western Research Institute gasification facility but an industrial partner should also be considered. An additional task to perform a preliminary economic analysis was suggested.

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PD-11	Experimental Demonstration of Advanced Palladium Membrane Separators for Central High-Purity Hydrogen Production (Office of Fossil Energy) *Sean Emerson; UTRC*	2.6			X	Overall, most reviewers thought the approach was reasonable and that the ternary alloys in the body-centered cubic (BCC) phase warranted further investigation. However, the reviewers felt that significant additional work was needed at the laboratory scale in fabricating defect-free membranes to overcome deficiencies in achieving flux, durability, and stability. Reviewers recommended that the manufacturability issue be resolved and that the project team select a ternary metal that avoids oxide segregation.
PD-12	Supported Molten-Metal Membrane (SMMM) for Hydrogen Separation (Office of Fossil Energy) *Ravindra Datta; Worcester Polytechnic Institute*	2.3		X		In general, the concept and approach were considered innovative by reviewers. However, it was felt that significant additional efforts were needed in the prioritization of key challenges and in establishing focus and direction. Reviewers recommended that the project team seek collaborators such as a metals or materials expert and others that could assist with modularization, economics, and commercialization aspects of SMMMs. Due to the low score, project scope will be modified.
PD-13	R&D Status for the Cu-Cl Thermochemical Cycle-2010 *Michele Lewis; ANL*	2.9	X			According to reviewers, good progress has been made and the team has established excellent collaborations with domestic and international partners. Reviewers commented that the primary focus should be on solving critical path issues before scale-up is attempted. Key challenges identified include materials compatibility, corrosion, copper cross-over, and electrolyzer development for improved efficiency. They also identified the membrane as a critical challenge and suggested that the project team consider including membrane development in their research plan.
PD-14	Hydrogen Delivery Infrastructure Analysis *Marianne Mintz; ANL*	3.5	X			The reviewers commented that this project successfully takes into account most of the important variables involved in determining delivery cost and is therefore a good assessment for focusing research. It was suggested that more short-term projection and industry input would be beneficial.
PD-15	H2A Delivery Analysis and H2A Delivery Components Model *Olga Sozinova; NREL*	3.4	X			The reviewers noted that the project is very inclusive and thorough, and they commended the team on their competency and ability to analyze diverse delivery pathways. It was suggested that the model needs more accurate and representative data for calibration and for more reliable predictions. The project team should also clarify the current hydrogen delivery baseline cost.

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PD-16	Oil-Free Centrifugal Hydrogen Compression Technology Demonstration *Hooshang Heshmat; Mohawk Innovative Technologies*	3.0	X			The reviewers praised the team for their approach and noted that the project is novel, yet solid in its design and in covering all variables. The reviewers recommended that further work is needed to provide single-stage testing data and noted that performance projections based on the current design may be overly optimistic. Furthermore, it was suggested that the project should currently be at a more advanced stage. For example, single-stage compressors should already be in the manufacturing stage.
PD-17	Development of a Centrifugal Hydrogen Pipeline Gas Compressor *Frank Di Bella; Concepts NREC*	3.3	X			The reviewers noted that results appear to be reliable and that an effective design for large-scale hydrogen production has been achieved for meeting most of the DOE targets. According to reviewers, although an excellent mix of industry, academic, and national laboratory partners has been established, the project is missing some important industry input and relies too heavily on assumptions from project collaborators.
PD-18	Advanced Hydrogen Liquefaction Process *Joe Schwartz; Praxair*	2.4		X		The reviewers noted that Praxair has extensive experience in hydrogen liquefaction, currently the highest-density delivery option. However, reviewers felt that important details were lacking throughout the project, especially in the verification of process efficiency numbers. Furthermore, it was observed that the project does not appear to be able to meet the objectives of the DOE EERE mission due to cost considerations.
PD-19	Active Magnetic Regenerative Liquefier *John Barclay; Prometheus Energy*	2.7		X		The reviewers noted that the project is based on a sound plan and has good potential to dramatically reduce energy use for liquefaction. The sound theoretical background used to support the development of the active magnetic regenerative liquefier (AMRL) technology was commended. However, it was strongly recommended that the project provide test data for a complete system.
PD-20	Inexpensive Delivery of Cold Hydrogen in Glass Fiber Composite Pressure Vessels *Andrew Weisberg; Lawrence Livermore National Laboratory (LLNL)*	3.2	X			The project objective is to demonstrate a novel application of materials and composites to pressure vessels for the delivery of cold hydrogen. The reviewers called the project plans and processes sound and praised the team's strong technical knowledge and coordination with industrial partners. It was felt that the project team has demonstrated continual improvements of the technology and evolution from concept to real devices. It was observed, however, that more work is needed in assuring the safety of the technology and that the expected life cycle of the full-scale vessels needs to be addressed further.

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PD-21	Development of High Pressure Hydrogen Storage Tank for Storage and Gaseous Truck Delivery *Don Baldwin; Lincoln Composites*	2.9	X			The reviewers noted the team's competency in designing, manufacturing, and qualifying hydrogen vessel technology, and recognized the near-term application of the tank-trucks. However, it was recommended that cost-performance tradeoff studies should be done prior to a demonstration, and it was suggested that the project would benefit from the establishment of collaborations in key areas. It was specifically recommended that failure modes and effects analysis and other robustness tools be included in the project scope.
PD-22	Fiber Reinforced Composite Pipelines *Thad Adams; Savannah River National Laboratory (SRNL)*	2.9	X			Reviewers noted that the project has developed strong collaborations with manufacturers and with ASME. It was noted that the strong practical approach for evaluating FRPs for hydrogen piping should yield new insight into this potential substitute for hydrogen service. However, it was felt that many questions remain unanswered at this late stage of the four-year project period. It was noted that the project should be addressing the cost of FRP, cyclic pressure responses, joints, and effects of trenchless installation.
PD-23	A Combined Materials Science/Mechanics Approach to the Study of Hydrogen Embrittlement of Pipeline Steels *Petros Sofronis; University of Illinois*	3.2	X			The reviewers felt that the project successfully provides the basic knowledge required for understanding the effect of embrittlement on hydrogen infrastructure. It was specifically noted that the project's approach for subcritical crack growth experiments using sound engineering practices is important in the development of a useful thermodynamic model of de-cohesion. However, it was noted that more work is needed to define real-world problems, and that slow progress has been made on the actual determination of failure modes, failure rates, and the dependence on various operating conditions.
PD-24	Composite Technology for Hydrogen Pipelines *Barton Smith; Oak Ridge National Laboratory (ORNL)*	2.9	X			The reviewers noted that the project is developing useful data for evaluating the status and potential of composite pipelines for hydrogen, and that relevant materials and information for cost modeling are being provided by project collaborators (it was specifically highlighted that the team uses a good and balanced approach in utilizing existing oil and gas industry experience in composite pipelines). It was felt, however, that additional work is needed in expanding the scope of the project. The project may benefit from studies of long-term pressure and temperature cycling of the composite pipe, as well as investigations on connectors and well-health system monitoring tools.

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PD-25	Hydrogen Embrittlement of Structural Steels *Brian Somerday; Sandia National Laboratories (SNL)*	3.3	X			The reviewers commended the collaborations with NIST, component manufacturers, and ASME as strengths in this project. It was specifically pointed out that the project has developed a sound understanding for material effects of hydrogen toward the long-term safety and integrity of steels. As a recommendation, reviewers noted that further examination of pressure cycling effects on steel pipelines in hydrogen operation is needed.
PD-26	Innovative Hydrogen Liquefaction Cycle *Martin Shimko; Gas Equipment Engineering Corporation*	3.3	X			The reviewers commended the project for successfully demonstrating the potential of using modifications to existing technology (such as helium expanders) to significantly reduce the energy and cost for hydrogen liquefaction, while improving reliability. Continuous catalytic heat exchangers, however, were considered a possible project weakness. It was recommended that the team include evaluations for both the capital cost of the system and the resulting liquid hydrogen cost (per kg).
PD-27	Solar High-Temperature Water Splitting Cycle with Quantum Boost *Robin Taylor; SAIC/FSEC*	3.1	X			According to reviewers, the project is well-planned, well-organized, and focused on the key deliverables. Good progress has been made in lowering the electrolytic cell potential. The complexity of the cycle, potentially high capital and maintenance costs, and the need for design for 24/7 operation remain issues. Reviewers suggested that future work include durability testing and thermal cycling, and that attention should be given to the sulfur trioxide decomposition step, particularly on discerning the need for its integration into the overall process.
PD-28	Solar-Thermal ALD Ferrite-Based Water Splitting Cycles *Al Weimer; University of Colorado*	2.9	X			As noted by reviewers, the project team has demonstrated rapid-cycle hydrogen generation and good material durability. The project team has done a good job in addressing AMR 2009 reviewer concerns on earlier project weaknesses. Reviewers suggested extending the economic analyses of ferrite-based water splitting cycles to include materials fabrication costs, the use of solar flux to heat the carrier materials and more realistic operating and maintenance costs for the cycle. A longer-term cycling test added to the R&D plan would be valuable to demonstrate long cycle life of the materials.
PD-29	High-Capacity, High Pressure Electrolysis System with Renewable Power Sources *Martin Shimko; Avalence LLC*	2.9	X			According to reviewers, progress is being made, including a successful demonstration of 6500-psi operation in single-cell testing. Reviewers were not convinced that this approach would reduce system cost. A cost study is needed when the multi-cell high pressure system is designed. Additionally, there are concerns with the gas purity and potential resulting safety risks on a larger system. Remaining issues with the membrane also need to be resolved.

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PD-30	PEM Electrolyzer Incorporating an Advanced Low Cost Membrane *Monjid Hamdan; Giner, Inc.*	3.4	X			According to reviewers, the project has demonstrated good progress toward the goals and has a defined a clear path forward for scale-up. The highly effective and coordinated team approach was specifically highlighted. Also commended were the titanium separator work and the life test studies and accelerated testing experiments. It was recommended by reviewers that longer-term testing be included to determine lifetime/failure modes, and suggested that high-pressure operations could be explored.
PD-31	Renewable Electrolysis Integrated System Development and Testing *Kevin Harrison; NREL*	3.2	X			Reviewers noted that the real-world demonstration of the closely coupled system is informing the technology by generating invaluable data including long-duration, unattended system operations. The analysis work was viewed as appropriate and informative and the collaborations are considered strong. It was felt, though, that project focus could be improved. It was also recommended that the project continue independent testing of electrolyzer systems and further expand its analysis scenario.
PD-32	Photoelectrochemical Hydrogen Production: DOE PEC Working Group Overview *Eric L. Miller; University of Hawaii at Manoa*	3.2	X			Reviewers note that PEC technology is highly relevant to DOE production targets, but is at a relatively low technology readiness level. The extensive Working Group collaborations among project teams are a notable strength, and the projects have demonstrated significant recent progress in a range of materials systems under investigation. Reviewers noted that more work is needed in evaluating a broader class of materials systems, and more effort is needed in advancing technology readiness and in demonstrating technology viability and scalability to large-scale systems.
PD-33	Nanostructured MoS2 and WS2 for the Solar Production of Hydrogen *Thomas Jaramillo; Stanford University*	3.4	X			Reviewers see this project as an excellent example of nanoscience applied to the problem of PEC hydrogen production. Specific research strengths include the focus of approach, as well as the good scientific methods developed in evaluating nanostructured materials properties and viability. Reviewers noted that additional work is needed in the broader evaluation of technology viability and scalability to manufacturing systems.
PD-34	Development and Optimization of Cost Effective Material Systems for Photoelectrochemical Hydrogen Production *Eric McFarland; University of California, Santa Barbara*	3.0	X			Reviewers noted that this project did well in its out-of-the-box technical approaches to the material stability issue. Strengths include characterization and synthesis abilities in formulating and creating targeted compositions, high-throughput screening capabilities enabling rapid screening of compositional variations, and collaborative efforts with the DOE PEC Working Group. It was suggested, though, that further work is needed in evaluating specific passivation schemes, formulating cost projections, and addressing technology viability and scalability.

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PD-35	Semiconductor Materials for Photoelectrolysis *John Turner; NREL*	3.1	X			Reviewers commented favorably on the project's success in bringing leaders in the PEC community into the DOE program. Specific project strengths cited include the efforts in establishing efficiency standards, the work in addressing important stabilization strategies, and the focus on evaluating the potential viability of given materials systems. According to reviewers, further work is needed in addressing technology viability and scalability issues. More emphasis is also needed to accelerate the anticipated synergism between PEC Working Group theorists and experimentalists for facilitating the development of viable PEC materials and systems.
PD-36	Maximizing Light Utilization Efficiency and Hydrogen Production in Microalgal Cultures *Tasios Melis; University of California, Berkeley*	3.4	X			Reviewers highlighted the systematic manner in which mutants have been developed, characterized and shown to behave in predictable ways as a particular strength of this impressive work. It was commented that in addition to its relevance in photobiological hydrogen production, the results of this study will have very clear relevance in considerations of algal systems for other forms of bioenergy production. Establishing partnerships with groups more focused on photobioreactor design and evaluation was a specific reviewer recommendation.
PD-37	Biological Systems for Hydrogen Photoproduction *Maria Ghiradi; NREL*	3.2	X			Reviewers noted that the project team has demonstrated a strong record of accomplishments, publications, invitations, and scholarship, and is doing a good job in exploring the fundamental understanding of hydrogenase structure and function, particularly with regard to oxygen tolerance. Concern was expressed, however, that the project's tasks and subtasks, although individually interesting and appropriate, in many cases seem scattered, with a wide range of goals and objectives. Project focus and prioritization efforts are recommended by reviewers.
PD-38	Fermentation and Electrohydrogenic Approaches to Hydrogen Production *Pin-Ching Maness; NREL*	3.6	X			The good combination of novel fermentation with microbial electrolysis cell (MEC) technology was considered a project strength, and the project results in terms of molar yields were considered quite impressive. It was also felt that good progress has been made towards improving hydrogen per hexose ratios. Reviewers expressed some concern that this approach requires a relatively expensive feedstock and that maintaining the feed mixtures could be a significant challenge. Additional work is needed in the economic assessment of the proposed process.

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PD-39	Hydrogen from Water in a Novel Recombinant Oxygen-Tolerant Cyanobacterial System *Qing Xu; J. Craig Venter Institute*	3.4	X			Reviewers observed that the project team has strong expertise in metabolic engineering of this type, and that the team's ability to effectively leverage metagenomic libraries is a significant advantage. It was noted that the project has made consistent progress in transferring oxygen-tolerant hydrogenases from several sources into cyanobacteria and demonstrating activity. Reviewers expressed some concerns that the parallel nature of the collaborations seems to be a weakness. A clearer demonstration of the integrative effort was recommended. It was also suggested that localization of introduced hydrogenases within the cell could prove very informative.
PD-42	Catalytic Solubilization and Conversion of Lignocellulosic Feedstocks *Troy Semelsberger;Los Alamos National Laboratory (LANL)*	2.8		X		Reviewers noted that the proposed low-temperature catalytic aqueous phase reforming (APR) system in this study is extremely challenging but, if successful, would be a viable alternative to the traditional pyrolysis or high-temperature gasification methods. The reviewers expressed concerns that limited results have been achieved to date despite the team's solid vision. Revisiting some of the original tests and checking for an insoluble phase in the product was specifically suggested. Expanding collaborative efforts was a further recommendation.
PD-45	Distributed Reforming of Renewable Liquids using Oxygen Transport Membranes *Balu Balachandran; ANL*	2.7		X		Reviewers noted the strong focus on improving the ethanol reforming process in the work. Additional strengths include the project team's expertise and experience in synthesizing and testing oxygen transport membrane materials. It was felt by reviewers, however, that substantial additional work is needed in establishing clear project objectives, targets, and milestones; in clearly demonstrating the advantage of oxidative reforming over steam reforming; and in performing engineering analyses to verify the viability of an industrial process.
PD-46	Reversible Liquid Carriers for an Integrated Production, Storage and Delivery of Hydrogen *Alan Cooper; Air Products*	2.8		X		The reviewers noted that the concept is sound and incorporates good safety aspects. The delivery simplification of hydrogen-to-vehicle from a production facility was also commended. It was felt, however, that more work is needed in defining the infrastructure details required to implement the project. Reviewers suggested that the project would benefit from more OEM involvement.
PD-47	Materials Solutions for Hydrogen Delivery in Pipelines *Todd Boggess; Secat, Inc.*	3.5	X			The reviewers commended the project for its clear, direct applied-science approach, and they emphasized the invaluable insight into the effect of hydrogen on pipeline steels provided by the work. Additional work is recommended to further consider the effects of hydrogen at weld points, as these are often the weakest points of a pipeline. It was also recommended that the project should continue with fracture toughness testing and fatigue crack growth testing.

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PD-48	Development of Highly Efficient Solid State Electrochemical Hydrogen Compressor (EHC) *Ludwig Lipp; FuelCell Energy, Inc.*	3.2	X			Reviewers observed that the project is novel, promising and technically elegant. This compressor has no moving parts to degrade performance and durability, and still promises to be able to separate non-reactive compounds like nitrogen, argon, and helium. Additional work is needed to increase capacity beyond two pounds per day. Reviewers also commented that the clarity of the milestone comparison table could be improved, that future cost estimates are needed, and that collaboration could be improved with the addition of an end-user partner.
PD-51	Characterization of Materials for Photoelectrochemical Hydrogen Production (PEC) *Clemens Heske; University of Nevada, Las Vegas*	3.4	X			As highlighted by reviewers, the project provides important data to guide the design of the new PEC materials, in both synthetic and theoretical approaches. Specific project strengths cited include the technical approaches, the excellent materials characterization capabilities, strong collaborations with other research labs in the DOE PEC Working Group, and a focus on materials stability. It was noted that further work is needed in producing larger active area cells and in evaluating the viability and feasibility of supported PEC technologies.
PD-52	PEC Materials: Theory and Modeling *Yanfa Yan; NREL*	3.2	X			According to reviewers, the strong theory and calculation competency of this work is important in guiding promising areas of PEC research. A particular project strength cited was the consideration of important physical properties in material dopants, such as the formation of different phases and incorporation at different possible sites. Further work is needed in developing the theory tools to give predictions regarding the final phase of the materials and dopants. Reviewers also felt the project needs to take a stronger direction-setting role on the synthesis of materials from other DOE PEC Working Group teams and in evaluating viability and scalability of supported PEC technologies.
PD-53	Photoelectrochemical Hydrogen Production: Progress in the Study of Amorphous Silicon Carbide as a Photoelectrode in Photoelectrochemical Cells *Arun Madan; MVSystems*	3.2	X			According to reviewers, this work successfully leverages the existing knowledge base in photovoltaics to supplement the PEC knowledge base. Reviewers stated that strengths include the project team's focus on a single material class, their elegant solution to the problem of band mismatch for water splitting, and the good materials characterization capability of project partners. It was recommended, though, that the cost of this approach compared to other options be further addressed, along with technology viability, scalability, and manufacturing in large scale.

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PD-54	Photoelectrochemical Hydrogen Production: Progress in the Study of Tungsten Oxide Compounds as Photoelectrodes in Photoelectrochemical Cells *Nicolas Gaillard; Hawaii Natural Energy Institute*	2.8		X		Reviewers noted the focus on a single material class as a good approach. Cited strengths include the project team's good scientific methods in materials synthesis and characterization, their collaboration across many groups in the DOE PEC Working Group, and their work with economic viability studies. Reviewers stated that further work is needed in considering the cost of this approach compared to other options, in optimization of counter electrode designs, in improvement in efficiency, and in establishing technology viability and scalability.
PD-55	Photoelectrochemical Hydrogen Production: Progress in the Study of Copper Chalcopyrite as Photoelectrodes in Photoelectrochemical Cells *Jess Kaneshiro; Hawaii Natural Energy Inst.*	3.0	X			Reviewers commended the project for its focus on a single material class and leveraging of the high photocurrents observed in this material class toward developing highly efficient water splitting devices. A project strength is the novel approach to system challenges based on theory and correlation to known photovoltaic systems. Reviewers commented that further work is needed in considering the cost of this approach compared to other options, in development of surface treatments and optimized back contacts, and in establishing technology viability and scalability. It was recommended that the team consider separating silverization efforts into a separate project if segregation cannot be easily overcome.
PD-56	Critical Research for Cost-Effective Photoelectrochemical Production of Hydrogen *Liwei Xu; Midwest Optoelectronics, LLC*	2.8		X		Reviewers noted the project's focus on identifying additional PEC materials systems and evaluating their potentials and viability as a strength. According to reviewer recommendations, however, more work is needed in leveraging substantial industry knowledge in alkaline electrolysis in relation to the different substrate and immersion system schemes under investigation. Further work is also needed in the reevaluation of technology viability, scalability, and overall manufacturing potential.
PD-58	Characterization and Optimization of Photoelectrode Surfaces for Solar-to-Chemical Fuel Conversion *Tadashi Ogitsu; LLNL*	3.2	X			Reviewers note that the project is developing a potentially powerful method for understanding catalysis of the water-splitting/hydrogen-evolving reaction, and can be important in guiding promising areas of PEC research. The focus on modeling surface corrosion characteristics is seen as particularly relevant, and is filling a hole in the overall DOE PEC Working Group research portfolio. According to reviewer recommendations, more work is needed in developing models to extend below the surface, in applying models to alternative less-expensive model material systems, in modeling possible surface modification, and in developing models to evaluate photoanode in addition to photocathode systems.

Hydrogen Storage

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ST-01	System Level Analysis of Hydrogen Storage Options *Rajesh Ahluwalia; ANL*	3.5	X			Reviewers commented that this project should continue to perform system analysis in support of hydrogen storage technology development. The team should document project results and increase coordination of analysis work with the Hydrogen Storage Engineering CoE.
ST-02	Analyses of Hydrogen Storage Materials and On-Board Systems *Stephen Lasher; TIAX, LLC*	3.4			X	Funding for this project ends as the project concluded in FY 2010 with extension of schedule to complete reports into second quarter of FY 2011. TIAX will provide cost analysis report as well as a final project report.
ST-03	Compact (L)H_2 Storage with Extended Dormancy in Cryogenic Pressure Vessels *Gene Berry; LLNL*	3.3	X			The project team should focus on developing a thorough understanding of para-ortho hydrogen conversion and the factors that affect it, implications of using composite pressure vessels in cryogenic applications including degassing into the vacuum insulation space, and the robustness of vacuum insulation systems in automotive applications.
ST-04	Hydrogen Storage Engineering Center of Excellence *Don Anton; SRNL*	3.2	X			While it is still early in the overall Engineering CoE effort, the reviewers considered the coordination and progress good; however, they expressed concern over the potential impact that the ending of the three materials CoEs may have. SRNL should continue to ensure efficient coordination of the Engineering CoE partners, prepare a current state-of-the-art assessment of on-board storage systems for the three material classes for a go/no-go decision point in mid-FY 2011, and ensure system engineering gaps have been identified and appropriate engineering R&D is being carried out within the Engineering CoE.
ST-05	Systems Engineering of Chemical Hydride, Pressure Vessel, and Balance of Plant for On-Board Hydrogen Storage *Darrell Herling; PNNL*	2.9	X			Reviewers found that PNNL has made good progress; however, they expressed concerns regarding the number of areas within the Engineering CoE that PNNL is involved in and regarding their extensive involvement with solid AB, which is considered a high-risk approach for the use of chemical hydrogen materials. In coordination with Engineering CoE partners, PNNL should prepare a current state-of-the-art assessment of the use of solid AB in an on-board hydrogen storage system for a mid-FY 2011 go/no-go decision and should continue to support the Engineering CoE in its other center roles.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-06	Advancement of Systems Designs and Key Engineering Technologies for Materials Based Hydrogen Storage *Dan Mosher; UTRC*	3.2	X			The UTRC effort was found to be well-organized and well-planned and to play a vital role within the Engineering CoE. Reviewers raised concerns that there needs to be good coordination and collaboration with other center partners (e.g., LANL on purification strategies) to avoid duplication of efforts. UTRC should complete model integration and focus on material packing (e.g., metal hydride and sorbents), balance of plant optimization, and qualitative risk assessments in coordination with their Engineering CoE partners.
ST-07	Chemical Hydride Rate Modeling, Validation, and System Demonstration *Troy Semelsberger; LANL*	3.5	X			The LANL team was considered to be well organized and their efforts critical to the Engineering CoE. The development of the acoustic fuel gauge was lauded by the reviewers. LANL should continue their Engineering CoE efforts including development of a fuel gauge sensor and reactor development for hydrogen release from chemical hydrogen storage materials. They should prepare a current state-of-the-art assessment for the go/no-go decision in mid-FY 2011.
ST-08	System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage *Matthew Thornton; NREL*	2.9	X			NREL's modeling efforts are considered an important function of the Engineering CoE, and the reviewers considered the team to be well qualified. However, they expressed concern regarding whether sufficient auto OEM input is included in the vehicle modeling. There were also questions concerning the "viability index" modeling effort, which they said needs better clarity. NREL should continue to provide guidance to the Engineering CoE on system design trade-offs through their vehicle-level modeling efforts, including prioritization of targets, and they should continue to assist in the selection and characterization of adsorbent materials.
ST-09	System Design and Media Structuring for On-Board Hydrogen Storage Technologies *Darsh Kumar; General Motors*	3.0	X			The reviewers consider the GM team to be strong and their collaborations to be important within the Engineering CoE; however, concern was raised over potential redundancy. GM should continue to collaborate with and support the Engineering CoE on the modeling and design of metal hydride and sorbent-based storage systems.
ST-10	Ford/BASF-SE/UM Activities in Support of the Hydrogen Storage Engineering Center of Excellence *Andrea Sudik; Ford Motor Company*	3.1	X			The reviewers consider the Ford team to be strong and their collaborations to be important within the Engineering CoE, especially their effort investigating the impact of compaction of sorbent materials on their performance. Ford should continue to support the Engineering CoE on adsorbent material engineering and vehicle, cost, and manufacturing modeling.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-11	Fundamental Reactivity Testing and Analysis of Hydrogen Storage Materials *Don Anton; SRNL*	3.1			X	This project is scheduled to end at the end of FY 2010. A final report is being prepared.
ST-12	Quantifying & Addressing the DOE Material Reactivity Requirements with Analysis & Testing of Hydrogen Storage Materials and Systems *John Khalil; UTRC*	2.8			X	This project is scheduled to end during FY 2011. During the remaining time, UTRC will complete its risk assessment activities and carry out additional dust cloud and blow-down characterizations.
ST-13	The Reactivity Properties of Hydrogen Storage Materials in the Context of Systems *Daniel Dedrick; SNL*	3.1			X	This project is schedule to end at the end of FY 2010. A final report is being prepared.
ST-18	A Biomimetic Approach to Metal-Organic Frameworks with High H_2 Uptake *Hong-Cai Zhou; Texas A&M University*	3.0	X			This project, started in FY 2007, was part of the Hydrogen Sorption CoE that is ending in FY 2010. The project will continue its phase 2 work as an independent project. Reviewers recommend emphasizing experiments demonstrating the impact of the open metal sites on hydrogen adsorption kinetics and thermodynamics. Materials should emphasize high volumetric capacity (high surface area per volume), not just exclusively high surface area. External validation of results is also recommended.
ST-19	Multiply Surface-Functionalized Nanoporous Carbon for Vehicular Hydrogen Storage *Peter Pfeifer; University of Missouri-Columbia*	2.9	X			This project, started in FY 2008, was part of the Hydrogen Sorption CoE that is ending in FY 2010. The project will continue its phase 1 work as an independent project. Reviewers recommend that further validation of experimental results be shown through external collaborations, particularly on the measurements of excess capacity hydrogen isotherms and isosteric heats of adsorption.
ST-21	NREL Research as Part of the Hydrogen Sorption Center of Excellence *Lin Simpson; NREL*	3.1			X	This project is part of the Hydrogen Sorption CoE that is ending in FY 2010. A final report will be issued summarizing the overall work accomplished during the past five years of the project. DOE will also maintain a storage material database that will include data from this project.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-22	A Joint Theory and Experimental Project in the Synthesis and Testing of Porous COFs for On-Board Vehicular Hydrogen Storage *Omar Yaghi; UCLA*	2.8	X			Closer internal coordination is needed between the synthesis and theory pieces of the project for theory validation. It is recommended that the group attempt to synthesize at least one composition that was predicted by theory to have high capacity at room temperature. The team should consider using infrared and/or NMR tools to determine the sorption locations and thermodynamics relative to the covalent organic framework structure for the most promising samples, for model validation.
ST-23	New Carbon-Based Porous Materials with Increased Heats of Adsorption for Hydrogen Storage *Randall Snurr; Northwestern University*	3.1	X			Reviewers recommend that further validation of experimental results be shown through external collaborations, particularly on the measurements of excess capacity hydrogen isotherms and isosteric heats of adsorption. Closer internal coordination is needed between the synthesis and theory pieces of the project for theory validation. The project team should increase material characterization to validate sorption locations (for model validation) and performance at both low (<10 bar) and higher pressure (~70-100 bar).
ST-24	Hydrogen Trapping through Designer Hydrogen Spillover Molecules with Reversible Temperature and Pressure-Induced Switching *Angela Lueking; Penn State University*	2.6	X			Reviewers recommend that further validation of experimental results be shown through external collaborations, particularly on the measurements of excess capacity isotherms and kinetics. Efforts should stress a systematic study (e.g., statistical design of experiments) in determining the controlling factors for weak chemisorption (spillover) and additional work on identifying the barriers to improving the uptake and desorption kinetics. The hydrogen trapping work should be of lower priority.
ST-25	Polymer-Based Activated Carbon Nanostructures for H_2 Storage *Israel Cabasso; State University of New York-ESF at Syracuse*	2.3		X		A go/no-go decision point process is underway. Significant improvement is needed on the project plan. A more systematic study is needed to (1) use modeling to identify promising materials, (2) develop those materials, and (3) test the hydrogen storage properties. Improved characterization of the doping material is necessary. Reviewers recommend that further validation of experimental results be shown through external collaborations, particularly on the measurements of excess capacity isotherms and isosteric heat of adsorption.
ST-26	Capacitive Hydrogen Storage Systems: Molecular Design of Structured Dielectrics *Robert Currier; LANL*	1.8		X		This project has been discontinued, and a final report is being prepared.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-27	Tunable Thermodynamics and Kinetics for Hydrogen Storage: Nanoparticle Synthesis Using Ordered Polymer Templates *Mark Allendorf; SNL*	3.2	X			The reviewers found this project to be very relevant and to address critical areas related to hydrogen storage materials—e.g., thermodynamics and kinetics. While there was a general feeling that considerable progress has been made, current results do not clearly demonstrate if thermodynamics can be "tuned" through control of particle size. To address this, the project team should carry out further experimental work to characterize materials and validate the computational predictions so that a definitive conclusion can be drawn.
ST-28	Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage *Christopher Wolverton; Northwestern University*	3.3	X			The approach of using computational modeling to direct experimental efforts was highly praised by the reviewers. The project should continue according to its research plan, with a greater emphasis on obtaining experimental validation of the computational predictions. However, it was recommended that kinetics be included, and significant emphasis be given to this area.
ST-31	Advanced, High-Capacity Reversible Metal Hydrides *Craig Jensen; University of Hawaii*	3.6	X			This project is scheduled to be completed in FY 2011. During the remaining time, the project should finish its investigations on the extent of reversibility of metal borohydrides under moderate temperature and pressure and the regeneration of $LiAlH_4$ in non-conventional solvents.
ST-32	Lightweight Metal Hydrides for Hydrogen Storage *J.-C. Zhao; Ohio State University*	3.3	X			The project should continue to follow its research plan on the investigation of the reversibility and release kinetics of novel aluminoborane compounds and ammoniated boron-hydrogen compounds.
ST-38	Hydrogen Storage by Novel CBN Heterocycle Materials *Shih-Yuan Liu; University of Oregon*	3.0	X			Reviewers suggested that the project continue and complete demonstrating low energy requirements for the overall dehydrogenation and hydrogenation reactions. They observed that progress has been made on hydrogen release experiments emphasizing hydrogen release kinetics and impact of impurities. Reviewers recommend investigating release mechanisms to understand hydrogen storage capacity that can be realized at given T/P window.
ST-40	Chemical Hydrogen Storage R&D at Los Alamos National Laboratory *Anthony Burrell; LANL*	3.9			X	This project is part of the Chemical Hydrogen Storage CoE that is ending in FY 2010. A final report will be issued summarizing the overall work accomplished during the past five years of the project. DOE will also maintain a storage material database that will include data from this project.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-41	PNNL Progress as Part of the Chemical Hydrogen Storage Center of Excellence *Jamie Holladay; PNNL*	3.2			X	This project is part of the Chemical Hydrogen Storage CoE that is ending in FY 2010. A final report will be issued summarizing the overall work accomplished during the past five years of the project. DOE will also maintain a storage material database that will include data from this project.
ST-44	SRNL Technical Work Scope for the Hydrogen Storage Engineering Center of Excellence: Design and Testing of Metal Hydride and Adsorbent Systems *Ted Motyka; SRNL*	2.9	X			The SRNL technical effort was found by the reviewers to be well coordinated with strong collaborations; however, some reviewers would like to see an increased effort in experimental validation of the modeling. The project should continue to support the Engineering CoE through completion of the "Acceptability Envelope" development and material assessment, completion of system scoping models and materials and system design and characterization efforts. Current state-of-the-art assessments will be completed for a go/no-go decision in mid-FY 2011.
ST-45	Key Technologies, Thermal Management, and Prototype Testing for Advanced Solid-State Hydrogen Storage Systems *Joseph W. Reiter; NASA-JPL*	2.6	X			The reviewers expect that the internal knowledge at JPL, from its space programs and previous hydrogen system experience, will be important to the Engineering CoE; however, they found less progress to date than had been expected. The project should continue to support the Engineering CoE through completion of development of an insulation database and leading the adsorbent system design efforts. Current state-of-the-art assessments will be completed for a go/no-go decision in mid-FY 2011. Efforts should be made to achieve greater accomplishments for the next year than have been demonstrated over the past year.
ST-46	Microscale Enhancement of Heat and Mass Transfer for Hydrogen Energy Storage *Kevin Drost; Oregon State University*	2.9	X			The Microproducts Breakthrough Institute at OSU was thought by the reviewers to have innovative technology to bring to the Engineering CoE; however, the reviewers did not clearly understand how the microchannel heat exchanger inserts could benefit the storage systems. Also, the extent of OSU's collaborations was not clear. The project should continue to support the Engineering CoE through development of microchannel heat exchangers and combustors. Efforts should be made to identify key applications for the technology and focus on those specific areas. Collaborations should be strengthened.
ST-47	Development of Improved Composite Pressure Vessels for Hydrogen Storage *Norman Newhouse; Lincoln Composites*	2.5	X			While the reviewers know the background of Lincoln Composites and feel their experience can benefit the Engineering CoE, the project approach and progress to date were not as strong as the reviewers expected. The project should continue to support the Engineering CoE through development, testing and validation of lower-cost and improved pressure vessels for hydrogen storage systems. Lincoln Composites should strengthen their collaborations and be a better contributing partner in the Engineering CoE.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-48	Hydrogen Storage Materials for Fuel Cell Powered Vehicles *Andrew Goudy; Delaware State University*	2.7			X	This is a Congressionally Directed Project. The project team should focus on more promising material systems, ensure appropriate baseline model systems are selected, and minimize replication/duplication of work that has been previously carried out or is being carried out by other groups.
ST-49	Hydrogen Storage in Metal-Organic Frameworks *Omar Yaghi; UCLA*	3.3			X	This project has been completed. A final project report will be submitted.
ST-50	Hydrogen Storage through Nanostructured Porous Organic Polymers (POPs) *D.J. Liu; ANL*	3.2			X	A go/no-go decision process is underway. Reviewers recommend that further validation of experimental results be shown through external collaborations, particularly on the measurements of excess capacity hydrogen isotherms and isosteric heats of adsorption. The project team should increase material characterization to validate sorption locations (for model validation) and also performance at low (<10 bar) and higher pressure (~70-100 bar).
ST-51	Electron-Charged Hydrogen Storage Materials *Chinbay Fan; Gas Technology Inst.*	2.1		X		This project will be subjected to a go/no-go decision before the end of calendar year 2010 based on demonstration of a 25% increase in sorption capacity with an applied electric field versus without a field.
ST-53	Life-cycle Verification of Polymeric Storage Liners *Barton Smith; ORNL*	3.1	X			Reviewers found the project approach to be adequate but thought it could be strengthened by inclusion of model validation. Reviewers also questioned if the results will be made publicly available if proprietary materials are being tested. This project should continue according to its research plan on the permeation and lifecycle verification testing of liner materials, and results should be made publicly available.
ST-54	Standardized Testing Program for Solid-State Hydrogen Storage Technologies *Michael Miller; Southwest Research Inst.®*	3.2	X			This project should continue according to its research plan and test and provide results of hydrogen storage materials. Coordination should be strengthened with other DOE-led efforts on material storage characterization and method standardization.
ST-55	NaSi and Na-SG Powder Hydrogen Fuel Cells *Michael Lefenfeld; SiGNa*	3.1	X			This is a Congressionally Directed Project. Reviewers recommend that the project continue to improve hydrogen yield while reducing water requirements and explore waste/canister disposition options with cost and environmental considerations.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ST-92	SRNL Technical Work Scope for the Hydrogen Storage Engineering Center of Excellence Design and Testing of Metal Hydride and Adsorbent Systems *Ted Motyka; SRNL*	3.1	X			The SRNL technical effort was found by the reviewers to be well coordinated with strong collaborations; however, some reviewers would like to see an increased effort in experimental validation to the modeling. The project should continue to support the Engineering CoE through completion of the "Acceptability Envelope" development and material assessment, completion of system scoping models and materials and system design and characterization efforts. Current state-of-the-art assessments should be completed for a go/no-go decision in mid-FY 2011.
ST-93	High Strength Carbon Fibers *Felix Paulauskas; ORNL*	3.6	X			The reviewers found this project to be highly relevant, with a strong approach and good results to date. Stronger industrial collaborations were recommended. This project should continue, according to its research plan, to work on developing lower-cost precursor material for the production of high-strength carbon fibers.

Fuel Cells

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-01	Advanced Cathode Catalysts and Supports for PEM Fuel Cells *Mark Debe; 3M*	3.6	X			Reviewers regarded this project as one of the most relevant projects in the Program's portfolio. Work remains concerning water management solutions. It was recommended that the next phase of the project involve large scale customer and developer testing.
FC-02	Highly Dispersed Alloy Catalyst for Durability *Vivek Murthi; UTC Power*	3.1	X			Reviewers suggest that the PI test the most stable catalyst with the most stable support before the project ends in April 2011 and demonstrate durability of the MEAs.
FC-03	Development of Alternative and Durable High Performance Cathode Supports for PEM Fuel Cells *Yong Wang; PNNL*	2.8	X			Reviewers suggest that this project continue with enhanced collaborations with industry partners. Durability measurements should rely on MEA testing rather than rotating disk electrode testing.
FC-04	Non-Platinum Bimetallic Cathode Electrocatalysts *Deborah Myers; ANL*	2.9	X			Reviewers commented that the PI should demonstrate how surface structure might affect oxygen reduction reaction and address the stability of Pd-transition metal alloys in acid media.
FC-05	Advanced Cathode Catalysts *Piotr Zelenay; LANL*	3.3	X			Reviewers thought that there were very good performance results for the non-PGM catalysts. Future work should focus on the *in situ* durability of the catalysts (both PGM and non-PGM).
FC-06	Durable Catalysts for Fuel Cell Protection during Transient Conditions *Radoslav Atanasoski; 3M*	3.3	X			Reviewers commented that this project team uses novel concepts of oxygen evolution reaction at the cathode and oxygen reduction reaction at the anode to address durability under start/stop conditions. Future work should include proof that the mitigation strategy works under these conditions with dispersed carbon catalysts.
FC-07	Extended, Continuous Pt Nanostructures in Thick, Dispersed Electrodes *Brian Pivovar; NREL*	2.9	X			Reviewers noted that this project is less than a year old, but that the effort to understand substrate materials and novel material production method is evident. Down-selection over time is encouraged to narrow the focus of the project and demonstrate a significant breakthrough.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-08	Nanosegregated Cathode Catalysts with Ultra-Low Platinum Loading *Nenad Markovic; ANL*	3.5	X			Reviewers thought that this new project was very relevant to DOE objectives, addressing high activity electrocatalysts and ultra-low PGM loading. Accelerated MEA testing is recommended to validate results shown in *ex situ* testing.
FC-09	Contiguous Platinum Monolayer Oxygen Reduction Electrocatalysts on High-Stability-Low-Cost Supports *Radoslav Adzic; BNL*	2.9	X			This project was rated highly by reviewers regarding relevance to DOE objectives, and it was noted for having a strong team, good collaborations, and solid fundamental concepts. It was suggested that the team analyze materials to identify the most promising materials for future R&D emphasis.
FC-10	The Science and Engineering of Durable Ultralow PGM Catalysts *Fernando Garzon; LANL*	2.7	X			Reviewers encouraged the team to partner with a fuel cell company capable of making state-of-the-art electrodes. Reviewers are interested in how flooding will be addressed in future plans.
FC-11	Molecular-scale, Three-dimensional Non-Platinum Group Metal Electrodes for Catalysis of Fuel Cell Reactions *John Kerr; LBNL*	1.9		X		LBNL's approach is new and very high risk, but, considering the talent of the team, reviewers think that the potential exists for a breakthrough in catalysis. Early go/no-go decisions should be made, and work should only continue on materials that demonstrate feasibility.
FC-12	Polymer Electrolyte Fuel Cell Lifetime Limitations: The Role of Electrocatalyst Degradation *Deborah Myers; ANL*	3.3	X			Reviewers think that this new project may answer some key fundamental questions about fuel cell degradation mechanisms. The PI should study the effects of sulfate contamination on low-loaded novel electrode materials.
FC-13	Durability Improvements through Degradation Mechanism Studies *Rod Borup; LANL*	3.3	X			The reviewers noted that this team has world class scientists with complementary specialties and has already identified the impact of electrode ink solvent and durability. Reviewers suggested streamlining and consolidating some of the tasks.
FC-14	Durability of Low Pt Fuel Cells Operating at High Power Density *Scott Blanchet; Nuvera Fuel Cells*	3.0	X			Reviewers noted that the work of this project is balanced between modeling and experimentation. The PI is encouraged to investigate materials that can enable operation at higher temperatures.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-15	Improved Accelerated Stress Tests (ASTs) Based on Real World FCV Data *Tom Madden; UTC Power*	2.7	X			Reviewers commended the focus and approach of the team and stated the importance of connecting laboratory findings to real-world data. The PI is encouraged to reconsider including performance recovery cycles, since they can help keep low-Pt materials from being unnecessarily eliminated from consideration.
FC-16	Accelerated Testing Validation *Rangachary Mukundan; LANL*	3.4	X			Reviewers noted that fuel cell systems for buses may have significantly different stressors compared to those for light-duty vehicles. The PI should perform additional diagnostics to obtain insight into sources of performance losses.
FC-17	Fuel Cells Systems Analysis *Rajesh Ahluwalia; ANL*	3.6	X			The PI has developed a model that addresses performance targets, such as cost, thermal and water management, start-up and shut-down time, and transient operation. Reviewers encourage collaborations with more OEMs (including forklift manufacturers) to deepen understanding of components.
FC-18	Mass-Production Cost Estimation for Automotive Fuel Cell Systems *Brian James; Directed Technologies, Inc.*	3.3	X			This project received exceptionally high scores from the reviewers regarding its relevance to DOE objectives, as it provides essential benchmarks for the current state of the Program. The addition of workshops was suggested, to allow OEMs to interact with and better understand the model. Project ends in the 2nd quarter of FY 2011.
FC-19	Direct Hydrogen PEMFC Manufacturing Cost Estimation for Automotive Applications *Jayanti Sinha; TIAX, LLC*	3.2	X			Reviewers noted that this highly detailed research is essential for informing overall policy on the realistic prospect that fuel cell systems will be an affordable alternative to other technologies. The analysis highlights which areas need attention to further reduce cost. A sensitivity analysis of membrane thickness is recommended. Project ends in the 2nd quarter of FY 2011.
FC-20	Microstructural Characterization of PEM Fuel Cell Materials *Karren More; ORNL*	3.0	X			Reviewers noted that this team has exceptional skills and equipment to explore the microstructural information from the MEAs. Work to characterize the carbon corrosion and catalyst particle changes around polymer electrolyte ionomers in the MEA catalyst layers is recommended.
FC-21	Neutron Imaging Study of the Water Transport in Operating Fuel Cells *David Jacobson; NIST*	3.5	X			Reviewers thought that the approach of the PI is very effective and efficient and the project is highly relevant to DOE objectives. The PI should address water transport and distribution in the fuel cell stacks to diagnose the failure mechanism of individual cells in stacks.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-22	Nitrided Metallic Bipolar Plates *Peter Tortorelli; ORNL*	3.1	X			Reviewers commented that improved metallic bipolar plates will help overcome the cost and durability barriers that inhibit fuel cell commercialization. The PI should examine more complicated flow fields over larger plates and perform *ex situ* evaluations before and after cycling. Project ends in the 2nd quarter of FY 2011.
FC-23	Low Cost PEM Fuel Cell Metal Bipolar Plates *Conghua Wang; TreadStone*	2.7	X			Reviewers noted the PI's endeavors to produce a low cost bipolar plate base material to meet the DOE 2015 cost target. They commented that the project should demonstrate performance and corrosion resistance under real-world conditions and for greater lengths of time.
FC-24	Metallic Bipolar Plates with Composite Coatings *Jennifer Mawdsley; ANL*	3.2	X			The reviewers noted that the approach of using highly conductive and ductile aluminum as a new material is new and innovative. The PI should conduct high temperature testing and contact-resistance testing, and a dopant should be identified as soon as possible.
FC-25	Air-Cooled Stack Freeze Tolerance *Dave Hancock; Plug Power, Inc.*	1.9		X		Reviewers regarded this approach as focusing too much on a specific niche market instead of advancing scientific understanding of underlying freeze issues and proposed mitigation strategies. A lack of focus was noted by reviewers. Project will undergo a go/no-go decision process in December 2010.
FC-26	Fuel-Cell Fundamentals at Low and Subzero Temperatures *Adam Weber; LBNL*	3.1	X			Reviewers noted that start-up and operation in subzero temperatures is vitally important for fuel cells in automotive applications. The PI should focus on the effect of water and freezing within the thin catalyst layer structure.
FC-27	Development and Validation of a Two-phase, Three-dimensional Model for PEM Fuel Cells *Ken Chen; SNL*	2.7	X			Reviewers commented that this project is in its early stages, but it is not clear how the model's predictive capabilities will address the cost and durability goals. The PI should compare the simulation results with other simulation groups based on a more commonly used flow field design.
FC-28	Transport Studies Enabling Efficiency Optimization of Cost-Competitive Fuel Cell Stacks *James Cross; Nuvera Fuel Cells*	3.3	X			Operating at high current densities is essential to the practical application of fuel cells in vehicles, said reviewers. The PI should place greater emphasis on fundamentals of mass transport.
FC-29	Water Transport Exploratory Studies *Rod Borup; LANL*	3.2	X			Reviewers noted that the understanding of water management in cells and stacks will lead to enhanced fuel cell performance. It is recommended that the PI conduct *ex situ* measurements of transport properties of porous materials and relate them to improvements in the cell.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-30	Water Transport in PEM Fuel Cells: Advanced Modeling, Material Selection, Testing, and Design Optimization *Vernon Cole; CFD Research Corp.*	2.6		X		Reviewers noted that the PI's approach focuses on using computational fluid dynamics to model water transport with emphasis on gathering experimental data and modeling water transport in MEAs. Reviewers suggest revisiting fundamental material parameters as part of two-phase model validation efforts.
FC-31	Development and Demonstration of a New Generation High Efficiency 10kW Stationary PEM Fuel Cell System *Durai Swamy; Intelligent Energy*	2.4		X		Reviewers noted that to date, the demonstrated lifetime, durability, and efficiency metrics are well below DOE targets. System optimization and redesign are recommended to accommodate future plug-in absorption-enhanced reformer in order to increase system efficiency.
FC-32	Development of a Low Cost 3-10kW Tubular SOFC Power System *Norman Bessette; Acumentrics Corporation*	3.1	X			While this project focuses on non-renewable fuels, reviewers noted that it also is leveraging niche markets to further develop fuel cell technology. Future work should include assuring cell stability, demonstrating stability over thermal cycles, focusing on efficiency enhancement, resolving thermal issues, and continuing cell manufacturing automation.
FC-33	New Polyelectrolyte Materials for High Temperature Fuel Cells *John Kerr; LBNL*	2.7	X			Reviewers scored this project exceptionally high for its relevance to DOE objectives; however, high MEA performance has yet to be demonstrated. Reviewers recommended focusing on imidizoles attached to perfluorosulfonic acid (PFSA) and measuring conductivity versus relative humidity at various temperatures.
FC-34	Membranes and MEAs for Dry, Hot Operating Conditions *Steven Hamrock; 3M*	3.6	X			Reviewers noted that building on proven PFSA chemistry has allowed the PI to improve conductivity and durability while maintaining manufacturability. It was recommended that the PI de-emphasize the model compound polymer degradation work and the competitive kinetics work.
FC-35	Lead Research and Development Activity for DOE's High Temperature, Low Relative Humidity Membrane Program *James Fenton; University of Central Florida*	2.4		X		Reviewers commented that this project strives to provide a standardized MEA fabrication and testing service for membrane fabricators as part of the High Temperature Membrane Working Group. *In situ* tests need to focus on hydrogen crossover, electrical insulation mechanisms, and high frequency resistance to cover the ideal function of the membrane.

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FC-36	Dimensionally Stable Membranes *Cortney Mittelsteadt; Giner Electrochemical Systems, LLC*	3.2	X			Reviewers commented that the development of robust, high temperature, low RH membranes is vital for the successful commercialization of fuel cells, especially for automotive applications. The PI builds understanding of low equivalent weight (EW) material performance and durability and has produced low EW ionomers that meet conductivity and resistance targets. Further characterization and optimization are required.
FC-37	Rigid Rod Polyelectrolytes: Effect on Physical Properties Frozen-in Free Volume: High Conductivity at low RH *Morton Litt; Case Western Reserve University*	2.6		X		Reviewers noted that novel polymer chemistry is being developed to produce materials that are thermally stable and have enhanced conductivity at low relative humidity, but they question the ability of the project to develop a membrane with desired stability. Industrial collaboration to bring different perspectives is suggested.
FC-38	NanoCapillary Network Proton Conducting Membranes for High Temperature Hydrogen/Air Fuel Cells *Peter Pintauro: Vanderbilt University*	2.9	X			Reviewers noted that the team used a novel materials engineering approach to create improved composite membranes. The PI has shown the capability of creating materials that are highly conductive at 120^{o}C, 50%RH. Reviewers recommend including a cost study to prove that an electrospun membrane can be consistent with DOE cost targets.
FC-39	Novel Approaches to Immobilized Heteropoly Acid (HPA) Systems for High Temperature, Low Relative Humidity Polymer-Type Membranes *Andrew Herring; Colorado School of Mines*	3.3	X			Reviewers commented that this project addresses the need to provide conductivity in the absence of water. The project uses materials that are inherently conductive, so its full upside potential is very large. Adding a stack developer for outside testing and validation, when a stable membrane is made, is recommended.
FC-40	High Temperature Membrane with Humidification-Independent Cluster Structure *Ludwig Lipp; FuelCell Energy, Inc.*	1.9		X		Reviewers thought that this project had a lack of disclosure on technical details of approach and results data. Conflicting priorities of protecting intellectual property and sharing information from a publicly funded project made it difficult for reviewers to assess progress.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-41	Novel Approach to Advanced Direct Methanol Fuel Cell Anode Catalysts *Huyen Dinh; NREL*	2.7	X			Reviewers noted that this project addresses stabilizing the dispersion and chemical composition of the platinum/ruthenium catalyst on a support to stabilize catalysis of methanol oxidation. The most relevant objective of this project would be to demonstrate the first stable and possible high-activity catalyst for methanol electro-oxidation.
FC-42	Advanced Materials for RSOFC Dual Operation with Low Degradation *Randy Petri; Versa Power*	2.9	X			Reviewers noted that reversible solid oxide fuel cells can integrate renewable production of electricity and hydrogen when power generation and steam electrolysis are coupled in a system – thus converting intermittent solar and wind energy into "firm power." Project targets are too low and should be increased to prove the project's relevance to the DOE portfolio.
FC-43	Resonance-Stabilized Anion Exchange Polymer Electrolytes *Yu Seung Kim; LANL*	2.6		X		Reviewers commented that the PI presents an innovative concept—to discern if stable alkaline membranes can be obtained while achieving DOE targets. The PI should increase MEA testing and increase the involvement of collaborators.
FC-44	Engineered Nano-scale Ceramic Supports for PEM Fuel Cells *Eric Brosha; LANL*	3.1	X			Reviewers commented that the project's evaluation of alternatives to carbon-supported catalysts is highly relevant, because a new catalyst support that is more corrosion-resistant than carbon-supported catalysts—while maintaining hydrophobicity—should result in a more durable cell. The PI should add thermogravimetric analysis in the presence of catalysts to determine mass loss and degradation of catalysts in a humidified air atmosphere.
FC-45	Effects of Fuel and Air Impurities on PEM Fuel Cell Performance *Fernando Garzon; LANL*	3.2	X			Reviewers said that understanding impurity effects on the rates of fuel cell reactions is very important to improving the performance and increasing the lifetime of fuel cells. The PI should include more work on mitigation strategies for impurities to improve durability.
FC-46	Effects of Impurities on Fuel Cell Performance and Durability *James Goodwin; Clemson University*	3.1	X			Reviewers thought that even though a limited set of impurities has been selected, those impurities studied have been well characterized and provided useful information. The PI should add airborne impurities to the scope of the project.
FC-47	The Effects of Impurities on Fuel Cell Performance and Durability *Trent Molter; University of Connecticut*	2.7	X			Reviewers noted that the team observed little effect from many of their experiments, probably due to testing at 100% RH (which would likely flush the contaminant from the system) and at 800 mA/cm^2 (likely leading to oxidation of the contaminants). The PI should consider testing at different operating conditions.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-48	Effect of System and Air Contaminants on PEMFC Performance and Durability *Huyen Dinh; NREL*	3.2	X			Reviewers praised this project for receiving the highest score of the impurities projects in the category of relevance to DOE objectives. The project has a relatively broad scope, as it attempts to identify, model, and catalog system contaminants and to disseminate this knowledge to the fuel cell community. Electrochemical and fuel cell testing should start as soon as possible.
FC-50	Economic Analysis of Stationary PEM Fuel Cell Systems *Kathya Mahadevan; Battelle*	3.2			X	Reviewers commented that this project is highly relevant to the DOE, as stationary and early market applications have become a larger part of the Program's portfolio. Collaboration was widespread, including 60 partners and 400 current or candidate users. The project has been completed.
FC-51	Fuel Cell Testing at the Argonne Fuel Cell Test Facility *Ira Bloom; ANL*	3.5	X			Reviewers rated this project as one of the highest ranking in terms of relevance to overall DOE objectives, as it is quite important to have standardized test procedures so that informed decisions based on validated data can be made in the marketplace. The PI is commended for leading a well-planned and well-executed project. Protocol verification tests are recommended for dynamic cycling tests.
FC-52	Technical Assistance to Developers *Tommy Rockward; LANL*	3.0	X			Reviewers noted that this project has the potential to make very valuable contributions to the Program as it leverages the DOE investment to provide organizations with answers to their technical questions. The PI should develop a strategic test plan that targets clients, rather than operate on a first-come, first-served basis.
FC-59	Improved, Low-Cost, Durable Fuel Cell Membranes *James Goldbach; Arkema*	2.6			X	Reviewers commented that blending a highly conductive, low-cost ionomer with a stable non-conductive polymer is a solid approach. However, when the blends fail to reach conductivity targets, the approach becomes questionable. Reviewers recommend providing a cost estimate to justify the basis for the low cost claim. Project has been completed.
FC-60	Protic Salt Polymer Membranes: High-Temperature Water-Free Proton-Conducting Membranes *Dominic Gervasio; Arizona State University*	2.3		X		Reviewers thought that the development of an anhydrous proton conductor could enable significant system simplification and cost reduction of PEMFC systems. Reviewers suggest PI pause testing fuel cells until conductivity and stability are proven. Project was deemed a 'no-go' during go/no-go process.
FC-76	Biomass Fuel Cell Systems *Neal Sullivan; Colorado School of Mines*	3.1	X			This is a Congressionally Directed Project. Reviewers noted that this project supports the biomass-to-hydrogen pathway, which is deemed a very important pathway. Reviewers recommended that the PI address the impurities in biogas reforming and how the gas will be cleaned.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed/ Other*	Summary Comments
FC-77	Fuel Cell Coolant Optimization and Scale-up *Satish Mohapatra; Dynalene*	2.6		X		This is a Congressionally Directed Project. Reviewers noted that the product being developed is a potentially valuable coolant that will be compatible with small fuel cells. Coolant is close to production. Independent validation by a national lab is recommended.

Manufacturing R&D

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
MN-01	Fuel Cell MEA Manufacturing R&D *Michael Ulsh; NREL*	3.3	X			The reviewers noted a good collaborative effort; however, there is a need to integrate modeling with hardware diagnostics and to create an overall plan to provide feedback.
MN-02	Reduction in Fabrication Costs of Gas Diffusion Layers *Jason Morgan; Ballard Material Products*	3.1	X			The reviewers noted good progress; however, there is a need for more collaborative efforts. The addition of at least one outside customer to evaluate product quality and performance would add significantly to the credibility of the project's results.
MN-03	Modular, High-Volume Fuel Cell Leak-Test Suite and Process *Ian Kaye; UltraCell Corp.*	3.3	X			There is a Go/No-Go decision pending complete prototype validation. UltraCell should assess the transferability of this process to other products and technologies.
MN-04	Manufacturing of Low-Cost, Durable Membrane Electrode Assemblies Engineered for Rapid Conditioning *Colin Busby; W.L. Gore*	3.3	X			Reviewers asked for more data on the cost reductions. This project needs to move quickly to achieve DOE target loadings for FY 2010 and FY 2015.
MN-05	Adaptive Process Controls and Ultrasonics for High Temperature PEM MEA Manufacture *Raymond Puffer; Rensselaer Polytechnic Inst.*	3.6	X			Reviewers noted good progress in developing adaptive real-time process controls. RPI has demonstrated the feasibility of ultrasonic welding with a cycle time of less than one second as compared to about one minute for thermal bonding.
MN-06	Metrology for Fuel Cell Manufacturing *Eric Stanfield; NIST*	3.0	X			Reviewers noted a need for more industry input on flow field plate manufacturing variability. Informal interactions seem widespread; however, it is not clear how deep the interactions are, how beneficial to the project they are, and whether feedback exists.
MN-07	High Speed, Low Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies *Emory De Castro; BASF*	3.2	X			The XRF application is progressing well; however, reviewers noted that more attention needs to be shown on adaptability to low temperature PEM fuel cells and other technologies.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
MN-08	Development of Advanced Manufacturing Technologies for Low Cost Hydrogen Storage Vessels *Mark Leavitt; Quantum Fuel Systems Technologies Worldwide, Inc.*	2.7			X	The project did not receive high scores from reviewers regarding relevance to proposed future research. The reviewers noted that the approach (even if fully successful) will have a low impact on reducing the storage system manufactured cost. An increased focus on reducing the need for expensive materials, such as carbon fiber, was recommended.

Technology Validation

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
TV-01	Controlled Hydrogen Fleet and Infrastructure Analysis *Keith Wipke; NREL*	3.6	X			It was observed that this work is very relevant to DOE fuel cell objectives of conducting independent assessment and dissemination of fuel cell vehicle (FCV) information and providing real-world feedback to researchers and partners to improve technology. The information gathered will help improve technology readiness for FCVs and lead to successful market introduction. This project validated DOE targets in real-world conditions. Reviewers commented that there should be an expanded presentation of results from primarily fuel cell events to broader auto events and government conferences.
TV-04	Hydrogen to the Highways *Ron Grasman; Daimler*	3.3	X			Reviewers noted that the project addresses DOE goals for technology validation and aligns well with Daimler's internal program goals. They are moving the technology toward greater commercial readiness. They are addressing not only vehicle technology goals, but also associated issues such as maintenance and codes and standards. Real-world vehicle operation has been shown for Generation I vehicles but not much yet for Generation II. It was recommended that a plan be developed for continued operation and testing of the Generation II vehicles and refueling stations after completion of the present project.
TV-05	Hydrogen Vehicle and Infrastructure Demonstration and Validation *Gary Stottler; General Motors*	3.7	X			Reviewers observed that this project involves real-life vehicle demonstration and performance validation, making it quite relevant to the goals and objectives of the Program. In particular, Project Driveway, a meaningful test and evaluation by a sample representing consumers, is especially relevant because self-serve refueling is also a part of the project. The project exhibits tremendous progress of the fuel cell system in terms of performance, volume, weight, and cost. Reviewers stated that another technology validation phase is needed beyond September 2011.
TV-06	Validation of an Integrated Hydrogen Energy Station *Ed Heydorn; Air Products*	2.8	X			Reviewers noted that the project concept is very relevant to DOE objectives to improve the availability and reduce the cost of hydrogen for vehicle refueling as a co-product of economic power generation. The project had very slow progress in meeting objectives. No system economic analysis has been presented for the OCSD, Fountain Valley station. Reviewers encouraged Air Products to speed up the OCSD demonstration.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
TV-07	California Hydrogen Infrastructure Project *Ed Heydorn; Air Products*	3.0	X			Reviewers suggested that plans be made to continue operation, data collection, and analysis (including economic evaluation) following completion on the project. Station operators should be identified, and a smooth transition to these new operators should be initiated as soon as possible. They further recommended that Air Products investigate and compare the economics of different station concepts (liquid hydrogen station versus pipeline station), evaluate challenges of different technologies, and give cost breakeven points dependent on demand.
TV-08	Technology Validation: Fuel Cell Bus Evaluations *Leslie Eudy; NREL*	3.2	X			Reviewers commented that this project should continue for as long as the bus demonstration projects are providing meaningful data to be collected and analyzed. By assimilating results across a range of environmental conditions and from different manufacturers and operators, a much clearer picture of the status of fuel cell bus technology should emerge.
TV-09	Hawaii Hydrogen Power Park *Richard Rocheleau; Hawaii Natural Energy Inst.*	3.1	X			Reviewers stated that this is a good, broad project that should generate useful, real-world information on systems performance versus key technical targets. The project has encountered significant delays to its schedule due to delays in processing agency approvals. Reviewers recommended that the project integrate with renewable energy storage efforts on the Big Island and that the project accelerate its activities.
TV-10	Tanadgusix (TDX) Foundation Hydrogen Project/PEV Project *Connie Fredenberg; Tanadgusix Foundation*	2.5			X	Reviewers commented that this Congressionally directed project should be moved to the Vehicle Technologies Program as it is no longer considering the use of fuel cells. It is still relevant to DOE objectives, but not the Hydrogen Program objectives.
TV-11	Texas Hydrogen Highway—Fuel Cell Hybrid Bus and Fueling Infrastructure Technology Showcase *David Hitchcock; Texas Hydrogen Highway*	2.9	X			Reviewers stated that this Congressionally directed project should ensure that operational data is shared with NREL. They observed that the team was able to perform the key duties necessary to procure and operate a fuel cell bus and fueling infrastructure in a large state where fuel cells and hydrogen have little presence, and that the project has provided public exposure to an operational hydrogen-powered bus and fueling station.
TV-12	Florida Hydrogen Initiative *David Block; University of Central Florida*	2.2	X			Reviewers commented that this Congressionally directed project, as initially conceived, had some degree of relevance to DOE research, development, and demonstration objectives. However the significant changes over time have made it less relevant.

Safety, Codes and Standards

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
SCS-01	National Codes and Standards Templates *Carl Rivkin; NREL*	3.3	X			Reviewers thought this was a solid project and noted that the National Templates demonstrate a comprehensive coordination to bring stakeholders together to develop data-driven codes and standards to address critical gaps. Reviewers suggested expanding the level of detail of this project to provide a useful tool for experts, and to include balance-of-plant-related impurities for fuel quality standards. Reviewers noted that the project does an excellent job of synthesizing and compiling codes and standards into one resource.
SCS-02	Component Standard Research & Development *Robert Burgess; NREL*	3.3	X			Reviewers appreciated the project's well-coordinated alignment of its test program with industry and SDOs such as the Society for Automotive Engineers (SAE), CSA Standards, and the American Society of Mechanical Engineers (ASME). Reviewers also praised the round-robin safety sensor testing and international collaboration. Reviewers suggested additional outreach to industry stakeholders to better understand industry needs and increased funding to continue sensor and composite overwrap pressure vessel testing. The reviewers also suggested that the project complete a comprehensive list of components under consideration to identify and prioritize gaps in component needs.
SCS-03	Codes and Standards Training and Outreach and Education for Emerging Fuel Cell Technologies *Carl Rivkin; NREL*	3.5	X			Reviewers noted the project's critical role in implementing hydrogen and fuel cell technologies including the focus on forklift and backup power—two examples of early market commercialization. Reviewers also recognized the excellent collaboration with the California Fuel Cell Partnership and local fire departments, holding workshops at locations where hydrogen and fuel cell technologies are deployed, and they noted the coverage given to a variety of projects (such as stationary power, forklifts, etc.). Reviewers suggested increasing project funding to allow for additional training sessions. Recommended actions include outreach programs to regional training and outreach to volunteer first-responder centers.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
SCS-04	Hydrogen Safety Sensors *Eric Brosha; LANL*	3.1	X			The reviewers appreciated the integrated technical approach to R&D and especially the collaboration between the two national laboratories—LANL and LLNL. Reviewers also supported including an industry partner, ESL, into the sensor testing process. Reviewers recognized the project's technical accomplishments such as a stable sensor response time, long-term testing and evaluation of sensor materials, and designs to improve long-term stability. Reviewers recommended stronger coordination with the industry partner, ESL, to better define ESL's role, competencies and contributions. Some reviewers were also concerned about the project's approach to commercialization in regard to cost goals, performance, and calibration requirements.
SCS-05	Materials and Components Compatibility *Daniel Dedrick; SNL*	3.3	X			Reviewers thought this was a solid project that enables the early market deployment of hydrogen and fuel cell technologies such as forklifts. Most of the reviewers commended the test facilities, general collaboration, and thorough engineering-based data collection and test methodology, which are critical to the development of codes and standards. However, some reviewers expressed concern that there is insufficient industry collaboration. Reviewers thought that progress has been slow on material system evaluations and the application of the fatigue crack growth law. One reviewer noted that the fatigue crack growth law is based on the hypothesis of "leak before break" and that it is unclear how the testing program will incorporate the hypothesis into its testing procedures.
SCS-06	Hydrogen Safety Knowledge Tools *Linda Fassbender; PNNL*	3.7	X			Reviewers praised the project's depth and breadth of resources related to hydrogen safety. One reviewer noted that the Hydrogen Safety Best Practices Online Manual and the H2 Incident Reporting and Lessons Learned Database are a "go-to information source" for the successful implementation of hydrogen infrastructure technologies. Reviewers also praised the applied expertise and input from the Hydrogen Safety Panel. However, some reviewers noted that these Web sites need more distribution and increased involvement with energy companies. Specific recommendations include improving the Web site layout and creating better metrics to show who is using the Web site.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
SCS-07	Hydrogen Fuel Quality *Tommy Rockward; LANL*	3.5	X			Reviewers commended the rigorous technical R&D approach for determining levels of constituents in hydrogen. The reviewers also recognized the project's contribution of critical data to the development of an international standard for hydrogen fuel quality—International Organization for Standardization (ISO) Technical Committee 197 Working Group 12. Most reviewers noted the strong collaboration between investigators and stated that this should be considered a model on how to approach such tasks. Reviewers did note the project will need to go more in-depth on durability testing at the cell level and should enhance stack-level testing and system-validation. Reviewers encouraged stronger international collaboration with fuel providers.
SCS-08	Hydrogen Safety Panel *Steven Weiner; PNNL*	3.5	X			Reviewers agreed the Hydrogen Safety Panel (HSP) provides critical expertise for the safety of hydrogen and fuel cell projects. Reviewers recognized the extensive experience and background (NASA, industry partners, etc.) of each panel member as a strength. Also, reviewers identified the safety recommendations, which are based on incident reviews, as an excellent resource. Reviewers expressed concerns for how the HSP is evaluated in terms of its effectiveness and stated that no metric exists to show how much work the HSP has accomplished. Reviewers also expressed concern that the HSP might be overfunded.
SCS-10	Hydrogen Release Behavior *Daniel Dedrick; SNL*	3.4	X			Most reviewers recognized the strength of the project's defensible and traceable research basis for codes and standards development. In particular, reviewers commended the outstanding transformation of scientific analysis into actual safety guidance. Some reviewers also praised the work done on tunnel release and the good data that came out of the project. Reviewers thought the weak collaboration for indoor refueling was a weakness. In addition, some reviewers thought the tunnel release work could benefit from additional clarity and direction.
SCS-13	International Energy Agency Hydrogen Implementing Agreement Task 19 Hydrogen Safety *William Hoagland; SNL*	3.0	X			Reviewers recognized the importance of the project's commitment and role in the international collaboration. Reviewers observed that the project does a good job with data collaboration and has a strong link for input into www.h2incidents.org. However, most reviewers stated that the project focus is vague and Task 19 goals need more clarity. Some reviewers noted that collaboration needs to increase with SDOs such as ISO and the International Electrotechnical Committee (IEC).

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
SCS-14	Safe Detector System for Hydrogen Leaks *Robert Lieberman; Intelligent Optical Systems, Inc.*	3.2	X			Reviewers recognized the project's successful R&D efforts toward a commercially available sensor. Reviewers thought the project was well executed and has fostered good collaboration with potential customers. Reviewers also praised the sensor development process and sensor testing, including collaboration with NREL. Reviewers noted the project has yet to address significant technological barriers including cross interference, humidity, and carbon monoxide poisoning. Also, reviewers noted the project should not suggest to the public to install sensors in residential garages. Reviewers suggested the project needs to complete a more thorough cost analysis and clearly identify the size of the end-user market.
SCS-15	Hydrogen Safety Training for First Responders *Linda Fassbender; PNNL*	3.8	X			Reviewers praised the project's relevance and its important role in advancing the safe deployment of hydrogen and fuel cell technologies. Reviewers identified a number of important strengths, including the project's focus on real-time training, accurate targeting of relevant audiences, the well-designed curriculum, the hands-on training afforded by the fuel cell prop, and the ability to move the course to a variety of locations. Some reviewers stated that the project should consider increased collaboration with the DOD, onsite training on the East Coast, training specific to forklift operation, and greater outreach to more audiences and locations.
SCS-17	Hydrogen Safety Training for Researchers *Salvador Aceves; LLNL*	3.6	X			Reviewers praised the relevance of the course and its sound technical approach. Reviewers noted the Web-based course has an excellent graphical layout and the course reaches out to the correct audiences. Reviewers also recognized the technical expertise and facilities at LLNL that were used to develop the training. Some reviewers thought that it might be useful for the course to be tailored to specific laboratory settings. Also, the course might need to be modified for audiences with different education levels (i.e., those with associate degrees and those with doctoral degrees).
SCS-18	Optically Read MEMS Hydrogen Sensor *Barton Smith; ORNL*	3.3	X			Reviewers recognized good coordination and technology transfer as strengths of this project. In particular, reviewers identified excellent cooperation between the government and industry. Reviewers suggested improving collaboration during the testing process with nationally recognized testing laboratories such as Underwriters Laboratories (UL).

Education

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ED-03	Hydrogen and Fuel Cell Education at California State University, Los Angeles *David Blekhman; Cal State-LA*	3.6			X	This project is fully funded. Reviewers stated, "This is a much-needed, well-thought-out undergraduate curriculum for hydrogen technologies. The coursework is combined with substantial laboratory work, which is excellent." Comments suggest increased collaboration with other universities, particularly Humboldt State University (another Education project) and formalized student feedback (information retention and opinion) on coursework.
ED-04	Hydrogen Energy in Engineering Education (H2E3) *Peter Lehman; Humboldt State University Sponsored Programs Foundation*	3.4			X	This project is fully funded. Reviewers appreciated the multi-element, hands-on, generalized approach that allowed the project to reach a larger group of students in a meaningful and relevant way through lab kits, internships, and general engineering curriculum modules. Suggestions include increased collaboration with other universities to increase the number of students reached, formalized feedback to measure student information retention and opinion, and additional industry partnerships to support a stronger internship program.
ED-05	Hydrogen Education Curriculum Path at Michigan Technological University *Jason Keith; Michigan Technological University*	3.5			X	This project is fully funded. Reviewers commended the project's module approach, citing the potential for education programs to easily incorporate the materials into their curriculum. The rigorous collaboration and external review process were also identified as key to creating a comprehensive curriculum. Reviewers encouraged the project to proactively promote the course for broad dissemination at other education institutions.
ED-06	Hydrogen and Fuel Cell Education Program Concentration *David Block; University of Central Florida/University of North Carolina-Charlotte*	2.7			X	This project is fully funded. Reviewers recognized the challenges faced by the project move from the University of Central Florida to the University of North Carolina-Charlotte and thought that the project contributed to the Program's education goals in a limited way. They suggested that the PI develop more substantive collaborations by offering the coursework through remote teaching or at additional educational institutions.
ED-07	Development of a Renewable Hydrogen Production and Fuel Cell Education Program *Michael Mann; University of North Dakota*	2.7			X	This project is fully funded. Reviewers viewed this as a solid project with a comprehensive outreach to general and advanced engineering students at the University of North Dakota and saw potential in promoting hydrogen as an energy storage medium for intermittent renewables in this wind-rich state. They encouraged the development of a national dissemination plan.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
ED-08	Dedicated to the Continued Education, Training and Demonstration of PEM Fuel Cell Powered Lift Trucks In Real-World Applications *Tom Dever; Carolina Tractor & Equipment Co. Inc.*	3.4			X	This project is fully funded. This education project with concurrent hands-on demonstration experience was very well received by reviewers. The educators, a respected forklift distributor, were ideally situated to reach out to potential adopters as a trusted spokesperson in the industry. Reviewers would have liked to see more interaction with material-handling trade associations and a better developed data collection effort; they encouraged similar follow-on projects.
ED-09	Hydrogen Education in Texas *David Hitchcock; Houston Advanced Research Center*	3.0			X	This project is fully funded. Reviewers thought that this project was a solid state-education effort, reaching out to a diverse and comprehensive audience throughout Texas. The project adopted appropriate performance measurement efforts following last year's suggestions. Reviewers encouraged wider reach by moving beyond the "green" community.
ED-10	Development of Hydrogen Education Programs for Government Officials *Shannon Baxter-Clemmons; The South Carolina Hydrogen and Fuel Cell Alliance*	3.5			X	This project is fully funded. Reviewers were impressed with this multi-pronged outreach effort targeting state leaders through in-person interaction and traditional and new media. They commended the group for exceeding goals for the number of outreach events. The suite of information materials, including case studies and payback evaluations, helped to strengthen the case for adopting hydrogen and fuel cells. Suggestions included expanded collaboration and documentation of best practices to serve as a guide for other state outreach efforts.
ED-11	VA-MD-DC Hydrogen Education for Decision Makers *Chelsea Jenkins; Commonwealth of Virginia*	3.4			X	This project is fully funded. Reviewers praised the extensive collaboration and real-world experience (actual and virtual) imparted through ride-and-drives and nationally broadcast videos. Partnerships with the surrounding area, other states, industry, a national laboratory, and a television show provided a broad network to disseminate newsletters, video segments, and other education materials. It is recommended that remaining videos focus on early markets and fuel cell vehicles.
ED-12	State and Local Government Partnership *Joel Rinebold; Connecticut Center for Advanced Technology, Inc.*	3.3			X	This project is fully funded. As a state with an existing fuel cell presence, Connecticut was viewed as a good candidate for education efforts. Reviewers observed that the feasibility and financial models balanced real-world considerations with potential benefits and provided a realistic basis for recommending fuel cells, without overselling the technology. However, some reviewers were concerned with the potential misuse of the simple analyses. It was recommended that best-practices be rolled out in New England, New York, and New Jersey.

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ED-13	Raising H2 and Fuel Cell Awareness in Ohio *Pat Valente; Ohio Fuel Cell Coalition*	3.5			X	This project is fully funded. Reviewers commented on the strength of developing audience-specific forums to reach out with targeted and relevant information. Databases, forums, and other networking resources linking state funding, project developers, fuel cell manufacturers, and end-users have been particularly successful and useful. Sharing best-practices with neighboring state organizations and other renewable energy and energy efficiency organizations in Ohio was recommended.
ED-14	H2L3: Hydrogen Learning for Local Leaders *Patrick Serfass; Technology Transition Corporation*	3.4			X	This project is fully funded. Reviewers commended the project's commitment to working *with* local leaders, rather than talking *at* them. These efforts were aided by using peer presenters and informal networking and by implementing train-the-trainer education through collaboration with the Public Technology Institute and National Association of State Energy Officials. Reviewers suggested additional outreach meetings at state and local official meetings beyond hydrogen, fuel cell, or energy focused events where they were "preaching to the choir."
ED-15	Hydrogen Education State Partnership Program *Charles Kubert; Clean Energy States Alliance*	2.6			X	This project is fully funded. Some reviewers thought this was a solid effort, with good collaboration with the National Council of State Legislators. Others viewed the objectives of the project as important to state and local government outreach, but thought that execution was poor, particularly regarding deliverable quality and dissemination methods. Despite the national scope of the project, outreach seemed to be limited to only a few states. Reviewers suggested extensive collaboration with other national local leader organizations, DOE, and the hydrogen and fuel cell trade community.

Systems Analysis

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
AN-01	Infrastructure Analysis of Early Market Transition of Fuel Cell Vehicles *Brian Bush; NREL*	2.9	X			Reviewers suggested that NREL include industry input and market competition.
AN-02	Analysis of Energy Infrastructures and Potential Impacts from an Emergent Hydrogen Fueling Infrastructure *Andy Lutz; SNL*	3.1	X			Reviewers suggested that SNL consider nuclear and renewables such as solar, wind, and geothermal for infrastructure limitations, and extend the analysis beyond the boundaries of California.
AN-03	Agent-Based Model of the Transition to Hydrogen-Based Personal Transportation: Consumer Adoption and Infrastructure Development Including Combined Hydrogen, Heat, and Power *Matthew Mahalik; ANL*	2.9	X			It was recommended that the project be revised to include metro areas, contrast all the methods of hydrogen production, and utilize additional data from industry and government stakeholders. A calibration is required to relate the model output to real situations, especially for consumer purchasing and selection rationale.
AN-04	HyTrans Model: Analyzing the Potential for Stationary Fuel Cells to Augment Hydrogen Availability in the Transition to Hydrogen Vehicles *David Greene; ORNL*	3.4	X			Reviewers suggested that project incorporate a smaller fueling station size; compare all hydrogen generation pathways; obtain input from industry stakeholders; and consider integration of U.S. and international fuel markets.
AN-05	Biogas Resources Characterization *Ali Jalalzadeh-Azar; NREL*	2.9	X			Reviewers suggested that NREL include analysis of on-site conversion of bio-methane to electricity versus export to natural gas pipelines and sensitivity of cost to the level of impurities.
AN-06	Cost and GHG Implications of Hydrogen for Energy Storage *Darlene Steward; NREL*	2.9	X			Reviewers recommended that future work analyze: where hydrogen storage could be utilized; financial factors of payback period and technology maturity and risk; and other energy storage options such as Li-ion batteries.

Project Number	Project Title *PI Name & Organization*	Final Score	Continue	Discontinue / Further Review	Completed / Other*	Summary Comments
AN-07	Hydrogen and Water: Engineering, Economics and Environment *A.J. Simon; LLNL*	3.1	X			Reviewers suggested that this project examine the water use for hydrogen production compared to overall water flow and use. The project recognizes and addresses the potential impact and barrier of water availability and the cost of water treatment on the cost of hydrogen production. Reviewers recommended that the project account for legacy rights that restrict water use in certain regions and that it be expanded to include other hydrogen production pathways.
AN-08	Analysis of Business Cases with the Fuel Cell Power Model *Marc Melania; NREL*	3.1	X			The model will be periodically updated to address the reviewers' comments from the merit review. Future updates will include validating the model with fuel cell companies, data from actual Combined Heat, Hydrogen and Power (CHHP) applications, review by notable business school and collaborate with EPRI for future input.
AN-10	Fuel Quality in Fuel Cell Systems *Shabbir Ahmed; ANL*	3.3	X			It was recommended that ANL's future work focus on analyzing the impact of fuel contaminants on fuel cell performance, the cost of contaminant removal, and fuel cost.
AN-11	Macro-System Model *Mark Ruth; NREL*	3.4	X			Reviewers suggested including a training plan for public use; considering more out-of-the-box analysis applications for the model; focusing the model on analysis projects and scenarios; and defining model's capabilities.
AN-12	Life-Cycle Analysis of Criteria Pollutant Emissions from Stationary Fuel-Cell Systems *Michael Wang; ANL*	3.5	X			It was noted that ANL's analysis with their GREET model is essential to the Program's benefit analysis. It was suggested that future "well-to-wheels" analysis efforts compare analysis results with data from the California Air Resources Board, the AQMD, and EPA; validate model results for target scenarios; and conduct additional sensitivity analysis.
AN-13	CO_2 Reduction Benefits Analysis for Fuel Cell Applications *Paul Friley; BNL*	3.1	X			Analysis with the MARKAL model is ongoing. Reviewers suggested adding other hydrogen production technologies to the carbon reduction analysis; expanding the range of sensitivity variables; reducing the number of assumptions for biomass with carbon capture and sequestration; and including industry and academia validation of the modeling results.
AN-14	Pathways to Commercial Success: Technologies and Products Supported by the HFCIT Program *Steve Weakley; PNNL*	2.6			X	Reviewers commented that the project provides valuable information about commercial benefits and subsequent product development that result from DOE R&D. However, the project will be removed from the merit review in the future because the project is not a research-type project and does not have research-related targets.

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AN-15	Fuel Cell Power Model: Evaluation of CHP and CHHP Applications *Darlene Steward; NREL*	3.6	X			It was noted that the model has been well received by the fuel cell community and has been utilized to compare projects on a transparent basis with a common set of assumptions. Reviewers suggested that the project continue to validate the model with feedback from industry; calibrate the model to real world testing/operations such as CHP biogas to power; and include integration with renewable sources such as wind and solar.
AN-16	Geospatial Analysis of Hydrogen Production Pathways *Matt Kromer; TIAX, LLC*	2.9			X	The model enables a geo-spatial analysis of hydrogen infrastructure for conventional and renewable hydrogen production. The project has been completed and the model for the analysis has been delivered to DOE.
AN-17	Recent Developments in the Hydrogen Demand and Resource Assessment (HyDRA) Model *Johanna Levene; NREL*	3.3	X			Reviewers recommended that the project include hydrogen infrastructure development and obtain company feedback on infrastructure build-out.

Recovery Act

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ARRA-01	Commercialization Effort for 1 Watt Consumer Electronics Power pack *Chuck Carlstrom; MTI Micro Fuel Cells, Inc.*	3.1	X			The project's sound testing regimen and progress made in power density, packaging, and lifetime of the portable power packs were noted. The incumbent technology for battery recharging will offer significant competition, but this product has a potentially large consumer market. More analyses of performance data and lifetime predictions for this product for comparisons to existing battery recharging and other competing technologies were recommended.
ARRA-02	Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration *Steven Shaffer; Delphi Automotive*	3.1	X			It was noted that there is a significant amount of collaboration with OEMs, which has been beneficial for the project and its progress. A transportation application will be challenging, and the project team should consider accelerating the deployment to the field test. Reviewers suggested that more details on schedules and actions taken against specific barriers be included in future review presentations.
ARRA-03	Highly Efficient, 5kW CHP Fuel Cells Demonstrating Durability and Economic Value in Residential and Light Commercial Applications *Rhonda Staudt; Plug Power, Inc.*	2.7	X			It was noted that a strong project team has been assembled with a focus on the California market. Reviewers recommended that Plug Power strengthen its market assessment and business case and focus on product reliability. Reviewers also noted that technical accomplishments have been good, but progress has been slow, and they suggested additional bench testing in addition to field tests, in order to accelerate the durability verification process. The relationships between the modeling effort and product engineering and between cost analysis and the market price target need to be more clearly addressed. Reviewers recommended that this project compare costs and performance of its CHP system to other competing technologies and to similar CHP systems.
ARRA-06	PEM Fuel Cell Systems Providing Backup Power to Commercial Cellular Towers and an Electric Utility Communications Network *Mike Maxwell; ReliOn, Inc.*	3.6	X			It was noted that the planned number of deployments (over 150) is large enough to have a positive impact on commercialization. There is broad involvement of gas suppliers, customers, and regulators to gain a foothold in the market and to chart a pathway to wider adoption. Reviewers recommended that the costs of the fuel cell units be compared with those of existing technologies, and that next year the project team share lessons-learned and an economic assessment of the technology. It was also suggested that it would be beneficial for the team to develop a public outreach plan to increase public and market awareness of the product.

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ARRA-07	Accelerating Acceptance of Fuel Cell Backup Power Systems *Rick Cutright; Plug Power Inc.*	2.6	X			While backup power appears to be a good application, progress to-date has been slow, with site selection still not completed. Reviewers commented that the market and technical barriers need to be better described and the economic justification for the technology strengthened. Plug Power was advised to provide more detail on the technical approach to specific barriers. It was also suggested that the team re-examine the possibility of operation on hydrogen alone rather than the hybrid hydrogen/LPG system.
ARRA-08	HEB Grocery Total Power Solution for Fuel Cell Powered Material Handling Equipment—Fuel Cell Hybrid Power Packs and Hydrogen Refueling *William Mitchell; Nuvera Fuel Cells*	2.9	X			It was observed that good progress has been made, with the hydrogen generation system and 14 fuel cell systems already deployed at H-E-B. The application is a good market for fuel cells, and it will be valuable for comparisons with battery powered lift trucks. Refrigerated warehouses are a challenging environment, and it was suggested that Nuvera consider reviewing how they evaluate power needs for the fuel cell units. Reviewers stated that it would be useful to see more information on life cycle and durability of the fuel cell units, and that preliminary productivity data should be validated and analyzed to show the overall benefits for the H-E-B warehouse, jobs, and productivity gains.
ARRA-09	7B: Fuel Cell-Powered Lift Truck FedEx Freight Fleet Deployment *Curtis Cummings; FedEx Freight East*	3.3	X			As a greenfield site and a fast paced environment, this is an ideal deployment scenario for this type of fuel cell application. Reviewers noted that good technical progress has been made and that it would be useful for FedEx to provide economic analysis on the lift trucks and how they compare with electric and propane-powered alternatives.
ARRA-10	Fuel Cell-Powered Lift Truck - Sysco Houston Fleet Deployment *Scott Kleiver; Sysco of Houston*	3.6	X			It was noted that Sysco's greenfield site and large number (98) of fuel cell lift trucks provide an ideal deployment scenario. Reviewers encouraged Sysco to continue monitoring progress of the fuel cells and collecting data on their performance; and to clearly identify the value proposition for future deployments. They also suggested that the project team communicate the success of the project publicly to increase awareness of fuel cell applications.
ARRA-11	7B: GENCO Fuel Cell Powered Lift Truck Fleet Deployment *Jim Klingler; GENCO*	3.5	X			It was noted that technical progress to-date had been good, with 59 fuel cell units already deployed at the Wegman's site. The reviewers commended GENCO for assembling a cross-section of partners representing different sectors of the U.S. retail economy, including two hydrogen suppliers. Class I, II, and III lift trucks are included in the project. The reviewers suggested that GENCO continue to monitor progress and provide lessons-learned based on feedback from the operators and customers.

*"Other" includes congressionally directed projects.

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