Prologue

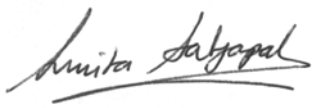
Dear Colleague:

This document summarizes the comments provided by peer reviewers on hydrogen and fuel cell projects presented at the fiscal year (FY) 2013 U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation Meeting (AMR), held in conjunction with the DOE's Vehicle Technologies Office AMR on May 13–16, 2013, in Arlington, Virginia. In response to direction from various stakeholders, including the National Academies, this review process provides evaluations of the Hydrogen and Fuel Cells Program's projects in applied research, development, demonstration, and analysis of hydrogen and fuel cells. A joint plenary session opened the meeting with a keynote address from Dr. David Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, followed by overview presentations from the Vehicle Technologies Office, the Fuel Cell Technologies Office (representing the Hydrogen and Fuel Cells Program), and the Basic Energy Sciences Program. A plenary for Hydrogen and Fuel Cells Program participants included overviews on each of eight program areas: Hydrogen Production and Delivery; Hydrogen Storage; Fuel Cells; Manufacturing R&D; Market Transformation; Technology Validation; Safety, Codes and Standards; and Systems Analysis.

DOE values the transparent, public process of soliciting technical input on projects from relevant experts. The recommendations of the reviewers are taken into consideration by DOE technology managers in generating future work plans. The table that follows lists the projects presented at the review, evaluation scores, and the major actions to be taken during the upcoming fiscal year (October 1, 2013–September 30, 2014). The projects have been grouped according to program area and reviewed according to appropriate evaluation criteria. The weighted scores for all of the projects are based on a four-point scale. To furnish principal investigators (PIs) with direct feedback, all of the evaluations and comments are provided to each presenter; however, the authors of the individual comments remain anonymous. The PIs are instructed by DOE to fully consider these summary evaluation comments, along with any other comments by DOE managers, in their FY 2014 plans. In addition, DOE managers contact each PI individually and discuss the comments and recommendations as future plans are developed.

In addition to thanking all participants of the AMR, I would like to express my sincere appreciation to the reviewers for your strong commitment, expertise, and interest in advancing hydrogen and fuel cell technologies. 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 2014 AMR, which is presently scheduled for June16–20, 2014, in Washington, D.C. Thank you for participating in the FY 2013 AMR.

Sincerely,



Sunita Satyapal
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Hydrogen Production and Delivery

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
PD-014	Hydrogen Delivery Infrastructure Analysis *Marianne Mintz; Argonne National Laboratory*	3.6	X			Reviewers applauded the efforts of this analysis and noted the effective collaboration between national laboratory partners and industry. Recommendations included revising the modeling as updates are made to the H2A Delivery Scenario Analysis Model (HDSAM) and Hydrogen Analysis (H2A) models and to SAE J2601, expanding the analysis to include terminal costs for high-pressure tube trailer delivery, and increasing stakeholder input.
PD-022	Fiber Reinforced Composite Pipelines *Thad Adams; Savannah River National Laboratory*	3.4	X			Reviewers commended the progress in fatigue testing of pipeline materials and the collaboration with ASME. Reviewers recommended that testing be expanded to include higher temperatures and pressures and environmental stressors, and that results be documented in a peer-reviewed journal.
PD-025	Hydrogen Embrittlement of Structural Steels *Brian Somerday; Sandia National Laboratories*	3.4	X			Reviewers were impressed with the project's progress. More research into alternative welding methods and the impact of on-site welding was suggested. Reviewers also recommended accelerating the rate of progress and including cost analysis in the project.
PD-028	Solarthermal Redox-Based Water Splitting Cycles *Al Weimer; University of Colorado*	3.3	X			Reviewers praised the innovative approach to redox kinetics and materials selection for the isothermal hercynite cycle. They suggested that water vapor partial pressure effects, simultaneous O_2 and H_2 production, and prolonged high-temperature operation continue to be addressed. Reviewers also recommended that the packed bed reactor design and scale-up, as well as H2A analysis of cost and performance, receive more attention.
PD-035	Semiconductor Materials for Photoelectrolysis *Todd Deutsch; National Renewable Energy Laboratory*	3.1	X			Reviewers were impressed with this group's advancements in the durability of high-efficiency III-V photoelectrochemical (PEC) materials and devices through nitrogen ion surface treatments. They also commended the group for its strong collaboration with other researchers, especially in their leadership role with the PEC working group. There is some concern over the need to establish better reproducibility in the patent-pending surface treatment, and to test the efficiency and durability of the PEC devices under realistic on-sun conditions.

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PD-036	Maximizing Light Utilization Efficiency and Hydrogen Production in Microalgal Cultures *Tasios Melis; University of California, Berkeley*	3.3			X	Reviewers praised this project for being applicable to both algae and cyanobacteria and noted its applicability to areas outside of H_2 production. Reviewers recommend that the project provide more quantitative information, study stability and fitness of the strains under relevant conditions, reevaluate progress, and establish a target timeline in order to better determine future work. This project is fully funded and anticipated to end in January 2014.
PD-037	Biological Systems for Hydrogen Photoproduction *Maria Ghirardi; National Renewable Energy Laboratory*	3.3	X			Reviewers commended this project for successfully removing the native hydrogenase from green algae and adding an O_2-tolerant clostridial hydrogenase, which allowed small amounts of H_2 to be produced in the presence of O_2. The importance of this effort in meeting long-term goals for photobiological H_2 production was noted. Reviewers recommended increased collaboration as well as investigations of ways to increase H_2 production in the system and of the long-term performance of the mutant strain.
PD-038	Fermentation and Electrohydrogenic Approaches to Hydrogen Production *Pin-Ching Maness; National Renewable Energy Laboratory*	3.1	X			Reviewers commended the project's progress, including meeting milestones ahead of schedule. Most reviewers considered the collaborations productive and beneficial to technical progress in the project. Recommendations included consideration of alternative feedstocks and examination of practical and economic issues of the system design.
PD-039	Hydrogen from Water in a Novel Recombinant Oxygen-Tolerant Cyanobacterial System *Phil Weyman; J. Craig Venter Institute*	3.2			X	Reviewers remarked on the project's effective integration of multiple methods for improving H_2 evolution. Suggested areas for future consideration included system scaling and strain fitness under H_2 production conditions, and tests to examine protein folding and metabolic pathways, gene expression, and *in vitro* hydrogen evolution. The reviewers look forward to future work examining the H_2 production by intact cells. This project is fully funded and anticipated to end in January 2014.
PD-058	Characterization and Optimization of Photoelectrode Surfaces for Solar-to-Chemical Fuel Conversion *Tadashi Ogitsu; Lawrence Livermore National Laboratory/National Renewable Energy Laboratory*	3.5	X			Reviewers praised this project for providing critical theoretical modeling of III-V semiconductor interfaces under PEC operating conditions and for collaborating effectively with the DOE Office of Energy Efficiency and Renewable Energy PEC H_2 Production Working Group. Reviewers suggested that future research emphasize experimental efforts to validate the modeling, especially for the high-efficiency GaInP2 PEC systems. Continued refinement of research and development priorities based on needs of the PEC research community is needed.

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PD-081	Solar Hydrogen Production with a Metal Oxide Based Thermochemical Cycle *Tony McDaniel; Sandia National Laboratories*	3.3	X			Reviewers commended the excellent work in materials design, evaluation of kinetics, analysis of performance requirements, and reactor design for a two-step reaction cycle. Reviewers felt that, in addition to the dish array configuration presented, a solar tower configuration should be modeled and analyzed. Reviewers also recommended that high-temperature reactor operation be tested, including the impact on particle attrition.
PD-088	Vessel Design and Fabrication Technology for Stationary High-Pressure Hydrogen Storage *Zhili Feng; Oak Ridge National Laboratory*	3.6	X			Reviewers noted this project's accomplishments and high potential to reach DOE targets for forecourt storage. Recommendations included more realistic capacity analysis for underground storage and a more robust cost analysis, including scaling of the storage vessel size. A suggested next step was planning for demonstration of the technology, including finding a project partner and location, and providing a clear design of the mock-up vessel.
PD-092	Rapid High Pressure LH2 Refueling for Maximum Range and Dormancy *Salvador Aceves; Lawrence Livermore National Laboratory*	3.1	X			Reviewers were interested in the accomplishments of this project and the potential benefits of pumping liquid hydrogen (LH2) into fuel cell vehicles. Future work should include a cost model and energy efficiency analysis of the process in order to determine the potential of the system for reaching DOE target goals. It was suggested that collaborations be extended to additional industry partners.
PD-094	Economical Production of Hydrogen through Development of Novel, High Efficiency Electrocatalysts for Alkaline Membrane Electrolysis *Katherine Ayers; Proton OnSite*	3.0	X			Reviewers praised the efforts of this early research, development, and demonstration Small Business Innovation Research (SBIR) project to reduce the capital cost of alkaline membrane electrolysis by using inexpensive catalyst materials. Reviewers suggested that H2A cost analysis of this technology should be performed and that more focus should be placed on membrane performance and durability issues.
PD-095	Probing Oxygen-Tolerant CBS Hydrogenase for Hydrogen Production *Pin-Ching Maness; National Renewable Energy Laboratory*	3.4	X			Reviewers commented positively on the project's approach, with multiple paths to address the O_2-tolerance issue. They also noted the successful application of different methodologies and useful collaborations, as well as the need to integrate the results of the promoter-based gene expression work with the maturation gene identification. Suggestions for future work included testing of *in vivo* H_2 production by an organism with all of the improvements incorporated, and examination of potential issues such as protein folding.

*Congressionally directed project (CDP)

Hydrogen Storage

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
ST-001	System Level Analysis of Hydrogen Storage Options *Rajesh Ahluwalia; Argonne National Laboratory*	3.3	X			The project is commended for good coordination with stakeholders and providing realistic system performance projections and data. The reviewers commented that the project can improve by highlighting areas of uncertainty in the models including input assumptions, as well as continue to compare modeling results with available physical testing data for model validation. Input assumptions for balance of plant of the compressed hydrogen storage system should be examined and updated. The reviewers also recommended that the project examine modeling results with regard to sensitivities to fiber winding model assumptions.
ST-004	Hydrogen Storage Engineering Center of Excellence *Don Anton; Savannah River National Laboratory*	3.6	X			This project is part of the Hydrogen Storage Engineering Center of Excellence (HSECoE, Center). Overall, reviewer sentiment was very positive acknowledging all aspects of the project including management, engineering development, and effective collaboration. The reviewers noted that the Center approach has proven much more successful than if the tasks were attempted by individual partners and specifically that communication among Center participants were very well coordinated. The reviewers acknowledged that the Center has done a great job in addressing material behavior and component design, and in developing models to project system performance that will add value to the research community. Interest was expressed about knowing the results of the recent go/no-go decisions for the transition to Phase III and a more detailed Phase III technical plan.
ST-005	Systems Engineering of Chemical Hydrogen, Pressure Vessel, and Balance of Plant for Onboard Hydrogen Storage *Jamie Holladay; Pacific Northwest National Laboratory*	3.3	X			This project is part of the HSECoE. Overall, the reviewers praised the various contributions of the project toward the success of the Center. The reviewers commented that while quality work had been accomplished on slurry development and modeling of reactor designs, those materials will likely be nonstarters for automotive applications and emphasis should be placed on non-slurried liquid fuel forms or pressure vessel designs for cryogenic applications. The reviewers indicated that the work on friction stir welding and dynamic cost modeling could have significant impacts outside of the HSECoE as well.

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ST-006	Advancement of Systems Designs and Key Engineering Technologies for Materials Based Hydrogen Storage *Bart van Hassel; United Technologies Research Center*	3.3	X			This project is part of the HSECoE. The reviewers found the approach of the project to be well formulated and addresses several important issues including gas-liquid separations, impurity mitigation and risk abatement, that are key to the successful implementation of hydrogen storage systems. While the reviewers appreciated the relevance of the work and found the collaborations to be managed effectively, some commented that more specific details on future technical tasks were needed for complete evaluation. Additionally, the reviewers noted that the plan forward should consider a contingency to translate the work to alternative materials or systems during Phase III.
ST-007	Chemical Hydrogen Rate Modeling, Validation, and System Demonstration *Troy Semelsberger; Los Alamos National Laboratory*	3.2	X			This project is part of the HSECoE. The reviewers found the general approach to be effective in evaluating the practical performance of the various system designs considered. The reviewers agreed that the project showed significant progress, especially toward reactor designs and fuel purification, that will be valuable for the research community; however, they also commented that more focus should have been maintained on materials with a simpler regeneration route or that remained a liquid through desorption. Overall, the reviewers found that the project demonstrated good collaborations within the Center and most noted that a more detailed plan for the future would have been useful to completely evaluate the project.
ST-008	System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage *Matthew Thornton; National Renewable Energy Laboratory*	3.3	X			This project is part of the HSECoE. The reviewers commended the principal investigator (PI) for the thorough discussion of the approach and noted that vehicle level modeling is a critical piece for validating hydrogen storage systems. It was suggested that a sensitivity analysis be performed between vehicle powertrains to observe any changes in storage system requirements. The reviewers also commented that the project seems to show good coordination within the Center and other U.S. Department of Energy (DOE)/original equipment manufacturer efforts and deliver timely results for the level of funding.

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ST-009	Thermal Management of Onboard Cryogenic Hydrogen Storage Systems *Mei Cai;* *General Motors*	3.0	X			This project is part of the HSECoE. Overall, the reviewers thought the approach of modeling coupled with experimental validation of thermal management was adequate, but they also thought that more emphasis should have been placed on expediting results. The reviewers maintained that the project is of high value to developing a prototype system and a clear plan for transferring this effort is critical to further success. The reviewers found the results on the influence of particle size and shape on charge/discharge to be valuable, especially for future material efforts. There was concern among the reviewers about the communication of the knowledge base from this project to the Center and public and the transfer of technology developed within this project because it was not clearly discussed.
ST-010	Ford/BASF-SE/UM Activities in Support of the Hydrogen Storage Engineering Center of Excellence *Mike Veenstra;* *Ford Motor Company*	3.4	X			This project is part of the HSECoE. Overall, reviewers were impressed with the project's accomplishments, which included fuel cell modeling, supporting cost studies, leading the failure modes and effects analysis, materials evaluation, and serving as system architect; all of these were noted as important to the overall success of the HSECoE. Reviewers also noted the importance of the involvement of a major automobile manufacturer in providing a "real-world" perspective of these efforts. The only potential concern noted was related to the HSECoE's decision to focus on metal organic framework-5 (MOF-5), which cannot meet DOE's targets. It was therefore unclear to the reviewers how representative this material may be for a full range of sorbent materials.
ST-019	Multiply Surface-Functionalized Nanoporous Carbon for Vehicular Hydrogen Storage *Peter Pfeifer;* *University of Missouri*	2.2		X		The reviewers noted that boron doping resulted in an increase in binding energy. However, they also pointed out the limitations of this approach as increasing amounts of boron may also result in reduced surface area and the formation of boron oxide, all of which can negatively impact hydrogen uptake. As a result, reviewers questioned the ability of boron-doped materials to meet the DOE targets. The reviewers were pleased that Missouri was working with the National Renewable Energy Laboratory to validate its capacity results, but they also noted that a single validation on a less-than-optimal sample does not necessarily validate past results. Finally, the reviewers were disappointed in the progress of this project over the last year and, as a result, questioned if the project should be moving ahead with monolith development.

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ST-021	Weak Chemisorption Validation *Thomas Gennett; National Renewable Energy Laboratory*	3.3			X	The reviewers acknowledged the thorough work of the international team to provide definitive studies on "spillover" in carbon adsorbents. While they noted discernible spectroscopic signatures from a unique C-H interaction, no technologically significant uptake at room temperature was observed. The reviewers noted the important value of this validation effort that has provided definitive evidence of spillover, while also indicating it may not lead to any significant enhancement of room-temperature adsorption.
ST-024	Hydrogen Trapping through Designer Hydrogen Spillover Molecules with Reversible Temperature and Pressure-Induced Switching *Angela Lueking; Pennsylvania State University*	2.2		X		Overall, the reviewers did give credit to the researcher for trying to characterize and demonstrate room-temperature hydrogen storage in MOFs via spillover, but they noted that not only has the project fallen well short of its goal of achieving 3 wt.% hydrogen storage, there is a high unlikelihood that hydrogen storage via the spillover mechanism will meet the DOE targets. This project is currently operating on a no-cost time extension and additional funding is pending a go/no-go review.
ST-028	Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage *Christopher Wolverton; Northwestern University*	2.5		X		In general the reviewers acknowledged the project's strengths in computational expertise, but they found the experimental contributions to be lacking. Reviewers were happy to see that the project team implemented the reviewers' recommendation from last year's DOE Hydrogen and Fuel Cells Program (the Program) Annual Merit Review to add nuclear magnetic resonance characterization efforts to the project. However, the reviewers do not see promise in the hydride systems under investigation in terms of practical use for hydrogen storage applications.
ST-044	SRNL Technical Work Scope for the Hydrogen Storage Engineering Center of Excellence: Design and Testing of Adsorbent Storage Systems *David Tamburello; Savannah River National Laboratory*	3.2	X			This project is part of the HSECoE. The reviewers commented that the approach was well designed and the comprehensive parametric modeling would add significant value to the research community. The reviewers noted that excellent progress had been made on developing an acceptability envelope that integrated material and engineering properties; however, they also noted that several key barriers remained such as loss of usable hydrogen, and volumetric and gravimetric capacities. They acknowledged that this project demonstrated good collaborations across the Center. Finally, the reviewers suggested that a more detailed listing of risks and challenges, as well as forecourt implications, should be provided to determine critical focus areas going forward.

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ST-046	Microscale Enhancement of Heat and Mass Transfer for Hydrogen Energy Storage *Kevin Drost;* *Oregon State University*	3.0	X			This project is part of the HSECoE. The reviewers acknowledged that the approach of combined simulation and experimental investigations to optimize the design of the Modular Adsorbant Tank Insert (MATI) and the Microchannel Recuperator Heat Exchanger is well conceived. Also, the use of MATI to increase media conductivity is very relevant to the goals of the HSECoE. The reviewers noted that it was not apparent that the system could be scaled to deliver 0.02 g/s/kW to an automotive-scale fuel cell and suggested that scaled testing is needed. The reviewers also suggested a focus on understanding the benefits or trade-offs to/with other cryo-adsorption media because the surrogate material (MOF-5) is unlikely to meet DOE targets.
ST-047	Development of Improved Composite Pressure Vessels for Hydrogen Storage *Norman Newhouse;* *Hexagon Lincoln*	3.3	X			This project is part of the HSECoE. Generally, the reviewers considered this project to be a critical aspect of the engineering effort and found Hexagon Lincoln to have the prescribed expertise. They noted that the approach was well thought out; however, they also noted that more data on cryogenic testing of liner and composite materials was needed to support continued efforts on Type 4 tanks. The reviewers acknowledged the switch from Type 4 to Type 1 tanks and thought that this would overcome several of the challenges associated with material's loading and cryogenic operation. The reviewers did note that material loading, sealing, and cryogenic operation of the tank are crucial pieces for the success of the sorbent system.
ST-052	Best Practices for Characterizing Engineering Properties of Hydrogen Storage Materials *Karl Gross;* *H2 Technology Consulting LLC*	3.6			X	The reviewers uniformly complimented the continuing effort in documenting methods used to characterize the hydrogen capacity, reaction kinetics, thermal properties, and other engineering parameters necessary to develop materials with the potential of meeting the corresponding DOE performance parameters. They acknowledged the magnitude of the effort and the excellent progress in this work that has incorporated input from experts in the field. The reviewers are interested in having this document finalized with perhaps an update to earlier chapter references.

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ST-053	Life Cycle Verification of Polymer Liners in Storage Tanks *Barton Smith; Oak Ridge National Laboratory*	2.7		X		The reviewers considered the testing methodology to be effective; however, they noted the lack of progress in reporting permeation results due to many experimental equipment challenges. The reviewers suggested collaborations with tank manufacturers and high-pressure equipment manufacturers to overcome the experimental challenges with sample sealing and temperature control. It was also noted that the project should address liner/composite interactions (delamination) as well as other failure mechanisms such as liner buckling in addition to permeation.
ST-063	Electrochemical Reversible Formation of Alane *Ragaiy Zidan; Savannah River National Laboratory*	3.4	X			The reviewers commended the progress the project has made over the past year in closed cycle generation from $MAlH_4$, increases in reaction efficiency, and separation of AlH_3 product. The development of the Cooperative Research and Development Agreement (CRADA) with a commercialization partner and involvement of key collaborators was viewed as very positive. The reviewers suggested that feedback from system analysis to focus priorities might be helpful, considering the limited resources available.
ST-093	Melt Processable PAN Precursor for High-Strength, Low-Cost Carbon Fibers *Felix Paulauskas; Oak Ridge National Laboratory*	3.4	X			Reviewers commended the project for demonstrating the feasibility of the melt-spun precursor fiber production process. Reviewers commented that the project should shift to further demonstrate the technology using polyacrylonitrile-methyl acrylate (PAN-MA) rather than polyacrylonitrile-vinyl-acetate (PAN-VA) that does not have the properties to produce the necessary high-grade carbon fiber. The reviewers also commented that the project needs to develop a cost model to assess potential cost savings.
ST-098	Development of a Practical Hydrogen Storage System based on Liquid Organic Hydrogen Carriers and a Homogeneous Catalyst *Craig Jensen; Hawaii Hydrogen Carriers, LLC*	2.8			X	Overall the reviewers commented favorably in terms of the approach and collaboration between the team members. Specific project strengths cited included using the cost of the material as a primary filter for material investigation, and the low catalyst loading of the system (100 ppm). The reviewers felt there was a lack of progress in the past year and emphasized that the DOE targets could not be met with this system. However it was noted that this approach to hydrogen storage could benefit the near-term market strategies of the DOE Office of Energy Efficiency and Renewable Energy (EERE).

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ST-099	Development of Low-Cost, High-Strength Commercial Textile Precursor (PAN-MA) *Dave Warren;* *Oak Ridge National Laboratory*	3.1	X			Reviewers commented that this is an important project with a good approach to reducing precursor fiber cost. The reviewers commended the project for making good progress, but they recommended identifying specific quantifiable causes and effects to facilitate the progress in optimizing the precursor formulations and conversion process. Reviewers expressed concern that the textile precursor developer was recently purchased by a foreign carbon fiber producer and over the need to identify other available low-cost precursor fiber sources. Reviewers noted that an updated cost analysis to identify potential cost savings is needed.
ST-100	Hydrogen Storage Cost Analysis *Brian James;* *Strategic Analysis, Inc.*	3.4	X			Reviewer commended the PI for improving the overall compressed H_2 storage system layout to be more reflective of real-world systems. Reviewers commented that the compressed H_2 storage system cost analysis can be improved by including further cost details on balance of plant (BOP) components and conducting sensitivity analysis to highlight key cost drivers within the tank and BOP. These could include the effects of design assumptions such as pressure and burst factors. It was recommended that the project examine sensitivity to economy of scale, such as learning rate, and carbon fiber pricing.
ST-101	Enhanced Materials and Design Parameters for Reducing the Cost of Hydrogen Storage Tanks *Kevin Simmons;* *Pacific Northwest National Laboratory*	3.2	X			Reviewers commended the approach of establishing the validated performance and cost estimator model. Reviewers also commended the broad collaboration that includes key tank manufacturers. Reviewers commented that the project should next focus on determining the optimum compressed H_2 storage operating temperature and pressure for optimized performance to bridge the large gap toward the cost-saving goal of the project.
ST-102	Room Temperature Hydrogen Storage in Nano-Confined Liquids *John Vajo;* *HRL Laboratories, LLC*	3.3		X		Even though the experimental results have been negative and have not shown enhanced hydrogen storage using nano-confined liquids, the reviewers commended the excellent experimental methods and high quality of research exhibited by the project. The reviewers felt the computational effort could be strengthened and would recommend the project be discontinued if no evidence of solubility enhancement can be demonstrated by the end of Phase 1.

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ST-103	Hydrogen Storage in Metal-Organic Frameworks *Jeffrey Long; Lawrence Berkeley National Laboratory*	2.8	X			The reviewers acknowledged the highly qualified team with members that bring synthesis, modeling, structural characterization, and hydrogen uptake measurement efforts to this work. They point out that Co and Ni analogues have shown high binding energy at low coverage but drop to typical values at higher coverage. The reviewers were divided in their assessment of the need for high-pressure (350 bar) measurements, because the goal of the Program's adsorbent research has been to find a material suitable for low-pressure (100 bar) storage. Future work should address both mass and volume metrics.
ST-104	Novel Carbon(C)-Boron(B)-Nitrogen(N)-Containing Hydrogen Storage Materials *Shih-Yuan Liu; University of Oregon*	3.1	X			The reviewers commended the project for the integration of computational and experimental efforts while incorporating fuel cell testing to identify potential issues. The reviewers recommended that the project identify material with higher capacity, as well as identify material impurities under fuel cell operating conditions. The reviewers also recommended further investigation of material intrinsic degradation and thermal stability as well as consideration of spent fuel regeneration complexity of fuel blends before expending extensive material development effort.
ST-107	The Quantum Effects of Pore Structure on Hydrogen Adsorption *Raina Olsen; Oak Ridge National Laboratory*	3.2			X	The reviewers note the generally sound approach directed toward addressing DOE barriers in storage capacity. An improvement in strengthening the link between experiment and theory was suggested, especially given the hypothesis of hydrogen as a Bose Einstein Condensate in a specially configured pore. The inelastic neutron results show some features that are consistent with the proposed structures, but reviewers felt that the data are not fully convincing. An isotope mix was suggested by the reviewers to confirm the effect.
ST-108	Metallation of Metal-Organic Frameworks: En Route to Ambient Temperature Storage of Molecular Hydrogen *Joseph Mondloch; Northwestern University*	2.3			X	The reviewers noted that this presentation was a post-doctoral research grant effort to examine two approaches to metallization of coordination polymers (via atomic layer and solution deposition). As an exploratory effort, it was recognized that little progress was made in addressing EERE barriers, given the challenge of post-synthesis metallization, but that "negative results" are of value to the community. A clearer articulation of proposed future work would have been of value.

*Congressionally directed project (CDP)

Fuel Cells

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-006	Durable Catalysts for Fuel Cell Protection During Transient Conditions *Radoslav Atanasoski; 3M*	3.3	X			Reviewers commented that significant accomplishments and progress have been made toward objectives and overcoming the durability barriers. 3M demonstrated that relatively low catalyst loading (0.029 mg/cm^2) can inhibit oxygen reduction reaction (ORR) activity on the anode, and the ORR inhibition has been verified in stack testing. 3M showed that improved cathode protection of 40%–50% during start-up/shutdown over the baseline oxygen evolution reaction (OER) catalyst was attained, and the OER catalyst did not impact the overall fuel cell performance.
FC-007	Extended, Continuous Platinum Nanostructures in Thick, Dispersed Electrodes *Bryan Pivovar; National Renewable Energy Laboratory*	3.1	X			Reviewers noted that the project has generated some novel catalytic materials with good specific and mass activities. These results show that higher specific activities can be achieved with Pt nanoparticles than had been anticipated. Reviewers also noted the excellent progress in developing new methods to fabricate extended thin-film electrocatalyst structures. However, reviewers noted that progress in membrane electrode assembly (MEA) performance has been disappointing, and that it is doubtful that the MEA performance targets can be met unless this project is extended.
FC-008	Nanosegregated Cathode Catalysts with Ultra-Low Platinum Loading *Nenad Markovic; Argonne National Laboratory*	3.5	X			Reviewers noted that Argonne National Laboratory (ANL) has met all 2015 U.S. Department of Energy (DOE) targets with respect to catalyst activities and durability, though only in rotating disk electrode (RDE) testing and not in an MEA. Reviewers felt that the technical work has been very thorough. With respect to the mesostructured thin films, reviewers wondered what the stability of the single crystal alloy surface would be after cycling. They felt that the next hurdle is scale-up and determining whether the impressive performance transfers into a fuel cell.
FC-009	Contiguous Platinum Monolayer Oxygen Reduction Electrocatalysts on High-Stability, Low-Cost Supports *Radoslav Adzic; Brookhaven National Laboratory*	3.5	X			Reviewers noted that Brookhaven National Laboratory is working on very promising catalyst materials, as evidenced by the licensing and scale-up of the core-shell catalysts to N.E. CHEMCAT. They also noted that the Pt nanospheres and the Pt on PdAu nanowires are promising concepts to get to high mass activity, though the true test will be in a fuel cell under realistic load cycling. Several reviewers questioned the use of electrodeposition for catalysts because this technique is quite challenging. Reviewers recommended more work on H_2/air as well as new work on the possible impacts of contaminants and water management, transport, and ionomer aspects with these new catalysts.

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FC-010	The Science and Engineering of Durable Ultra-Low PGM Catalysts *Mahlon Wilson; Los Alamos National Laboratory*	2.7		X		Reviewers noted that the Pt-PPPy nanowire catalyst work was interesting, but that the performance was below the C-based baseline catalyst. They thought that the project included too many different approaches and more materials should be down-selected. They felt that the ceria work is more focused on membrane stability and has little to do with other parts of the project.
FC-013	Durability Improvements through Degradation Mechanism Studies *Rod Borup; Los Alamos National Laboratory*	3.1	X			Reviewers stated that the approach covers all fuel cell components and the most degrading modes of operation. Reviewers felt that good progress was made in understanding the electrode and membrane degradation, but much less understanding was achieved regarding superimposing factors, specifically how the degradation of one component accelerates the degradation of other components. Reviewers felt that there was too much emphasis on carbon corrosion and they wanted more mitigation recommendations.
FC-014	Durability of Low-Platinum Fuel Cells Operating at High Power Density *Scott Blanchet; Nuvera Fuel Cells*	3.0			X	Reviewers stated that this project has strong interaction between collaborators, but one reviewer noted it does not include an automotive system integrator. The project was commended for its combined model/experimental approach such that real data and theoretical understanding are both contributing to the outcome and achievements of the project. The use of different cycles—from voltage, load, and drive cycles—is very valuable in establishing the linkage between accelerated stress tests (ASTs) and the real-world linkage to stacks in the field. The accomplishment of the model verification using an electrochemical impedance spectroscopy-based parameter determination approach in order to simulate the AST/performance of the various cell configurations was also commended. Results from the completed project should be used to guide future work.
FC-016	Accelerated Testing Validation *Rangachary Mukundan; Los Alamos National Laboratory*	3.3	X			Reviewers felt that the approach to achieving the durability technical target is sound and well designed. Reviewers noted the excellent progress toward objectives, specifically identifying how many cycles of accelerated testing correlate to hours of operation of various applications. Several reviewers suggested testing the ASTs on state-of-the-art MEAs, with the caveat that those state-of-the-art MEAs will not have 5,000+ hours of service.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-017	Fuel Cells Systems Analysis *Rajesh Ahluwalia; Argonne National Laboratory*	3.5	X			Reviewers felt that the approach taken was sound. The collaborative work with Ford, 3M, W.L. Gore, and dPoint was commended by the reviewers. Reviewers suggested extending the modeling from high pressure to lower pressure, examining other catalysts besides nanostructured thin film (NSTF), and verifying stack-related performance with actual stack data.
FC-018	Fuel Cell Transportation Cost Analysis *Brian James; Strategic Analysis, Inc.*	3.6	X			The reviewers agreed with the well-defined assumptions used and the cost estimate methodology, which is widely accepted by industry. FY 2013 data confirm earlier results but with consideration of new components, including quality control. Reviewers were concerned that representative performance characteristics derived from one MEA did not match the newer MEA manufacturing method that was analyzed for cost. Strong collaboration with the ANL fuel cell system model team and industry could enable the necessary performance characterization.
FC-020	Characterization of Fuel Cell Materials *Karren More; Oak Ridge National Laboratory*	3.6	X			The project's strengths are clearly attributed to the Oak Ridge National Laboratory team's continuous efforts to improve its tools and analysis capabilities; engaging with strong and numerous partners from industry, universities, and national laboratories; outstanding experimental proficiency in imaging; and openness to sharply focus on the requirements of fuel cell development. Reviewers gave this project a perfect score of 4.0 for "Collaborations" and for "Relevance/Impact." This work provides significant contributions to understanding degradation mechanisms. The targeted components such as catalyst nanoparticles, polymers, catalyst support materials, MEAs, etc. are the most important ones for longevity and cost reduction. The research contributes to the most important targets: durability and performance. Reviewers recommend including research for understanding the compression effect of the electrodes during operation, interfacial aspects between the electrode and the membrane, and more comparisons of results to realistic operational conditions.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-021	Neutron Imaging Study of Water Transport in Operating Fuel Cells *Muhammad Arif; National Institute of Standards and Technology*	3.4	X			Reviewers felt that the ability to visualize total water content under operation is a highly valuable tool in correlating observed performance and durability effects to cell design. Reviewers noted that the collaboration of the National Institute of Standards and Technology with many other partners was highlighted and appreciated by other principal investigators (PIs) during the DOE Hydrogen and Fuel Cells Program Annual Merit Review. They noted that significant progress had been made in improving resolution and that the analysis of error and accuracy is important in interpreting results. Several reviewers were interested in whether neutron imaging could be used for stack diagnosis.
FC-026	Fuel Cell Fundamentals at Low and Subzero Temperatures *Adam Weber; Lawrence Berkeley National Laboratory*	2.7		X		Reviewers stated that the approach is systematic and involves substantial experimentation and modeling efforts to elucidate an understanding of transport phenomena and water/thermal management at low and subzero temperatures. They felt the relevance, future work, and collaborations were quite strong; however, they felt the approach and accomplishments were lacking. Suggestion for improvements included eliminating the membrane morphology portion, including an automotive system integrator perspective, considering non-NSTF materials, and integrating the individual component models into an MEA performance model.
FC-036	Dimensionally Stable High Performance Membranes *Cortney Mittelsteadt; Giner, Inc./Giner Electrochemical Systems, LLC*	3.1	X			Three viable pathways were investigated for developing dimensionally stable membranes (DSMs): inversion casting, ultraviolet microreplication, and mechanical methods. Reviewers stated that the project has a good plan, strong partnering, a logical approach, and promising test results. However, they felt the project needs a more detailed cost analysis to demonstrate the viability of the proposed manufacturing methods, deeper stress and swelling analysis, and focus on demonstrating DSM performance and durability before further support and fabrication optimization. This former Small Business Innovation Research project began its third and final phase in July 2013 to continue scale-up of its most promising fabrication process.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-044	Engineered Nano-Scale Ceramic Supports for PEM Fuel Cells *Eric Brosha;* *Los Alamos National Laboratory*	2.7		X		Reviewers noted that Los Alamos National Laboratory has identified promising ceramic material based on molybdenum; however, the performance of this material needs further improvement. Reviewers suggest that cyclic voltammograms (CVs) of these materials should be presented, test conditions for cycling should be given, CO stripping should be used to investigate electrochemical surface area, and mass activities should be presented before and after cycling.
FC-048	Effect of System Contaminants on PEMFC Performance and Durability *Huyen Dinh;* *National Renewable Energy Laboratory*	2.9	X			Reviewers commended the project for the amount of data generated and mechanism identified. The study of contaminant mixtures and inclusion of the effect of catalyst loading on the results were also commended. Reviewers gave positive comments regarding the new website. It was recommended that some of the results be reproduced on a large cell or stack scale. One reviewer recommended that rather than developing a universal model to explain voltage loss, the team should focus on how to recover the performance of fuel cells by looking at ‘‘classes’’ of contaminants, and categorizing their introduction to the fuel cell as reversible or non-reversible. It was also suggested to identify additives that are strong contaminants.
FC-052	Technical Assistance to Developers *Tommy Rockward;* *Los Alamos National Laboratory*	3.0	X			Reviewers stated that the work appears to be serving a useful and accessible function of sharing technical assistance to developers through fuel cell and material characterization and technical assistance. They also stated that the PI exhibited a wide range of characterization results, from FTIR and relative humidity degradation characterization of membranes to fuel cell performance of gas diffusion layers (GDLs) to water imaging across the membrane. They noted that the list of “clients” is comprehensive, including automotive original equipment manufacturers (OEMs), laboratories, universities, materials and equipment suppliers, and technical institutes. The reviewers would like to see more in the way of proposed future work such as surveying the stakeholders for their inputs on what is most useful in existing technical support and what could be most useful but is currently lacking.

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FC-054	Transport in PEMFCs *Cortney Mittelsteadt; Giner, Inc./Giner Electrochemical Systems, LLC*	2.7			X	By widely varying the transport and structural properties of fuel cell components (mainly membranes), this project seeks to come up with guiding design principles and transport models for fuel cell component development. Reviewers stated that the approach and collaborations (Virginia Tech and the University of South Carolina) were very good. However, the impact and proposed future work were lacking, in that it was unclear how the model and data would be disseminated and used by industrial developers. Also, the relevance is difficult to assess because it may only indirectly assist in improving fuel cell performance, cost, and durability. This project ends in October 2013.
FC-063	Novel Materials for High Efficiency Direct Methanol Fuel Cells *David Mountz; Arkema*	2.4			X	Reviewers felt the objective, approach, and expertise of the prime contractor were good, but that the execution and final product were not delivered. The new membrane material did not perform significantly better than the perfluorosulfonic acid (PFSA) membrane, and the Pd-based cathode catalysis portion of the project was not successful in reducing costs and improving performance. This project ends in September 2013.
FC-065	The Effect of Airborne Contaminants on Fuel Cell Performance and Durability *Jean St-Pierre; Hawai'i Natural Energy Institute*	3.2	X			Reviewers stated that the approach is good, straightforward, and based on down-selecting from various contaminants. They noted that the use of low- loaded catalysts (0.1 mg Pt/cm^2) is a major improvement and that the addition of cleaning agents and coolants to the contaminants list is appropriate. Reviewers would like to see data showing mitigation /restoration to 90% of cell performance for the seven contaminants for which this has been completed, and information on the mitigation/restoration strategies used for the contaminants.
FC-077	Large Scale Testing, Demonstration, and Commercialization of Fuel Cell Coolant (SBIR Phase III) *Satish Mohapatra; Dynalene*	2.8			X	Reviewers commented on the innovative use of nanoparticles for improved coolant. Reviewers recommended understanding the effect of the coolants on structural plastics and other materials that may be used in automotive fuel cell systems, as well as full-scale field testing at high voltage in a relevant system. This project ends in October 2013.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-081	Fuel Cell Technology Status - Voltage Degradation *Jennifer Kurtz; National Renewable Energy Laboratory*	2.7		X		Many reviewers commended the project for its collaboration and stated that the information gathered was treated with considerable analytical prowess. They also remarked that the project has been a public source for fuel cell durability information. Reviewers expressed concern over the inconsistent conditions under which hours were accumulated and wondered if data sets with similar conditions could be reported separately. The FY 2014 project will focus on cost/price status versus durability status. Each year the project will rotate between durability status and cost/price status.
FC-083	Enlarging Potential National Penetration for Stationary Fuel Cells through System Design Optimization *Chris Ainscough; National Renewable Energy Laboratory*	3.4	X			Reviewers noted that their comments from last year's review were addressed and gave the project favorable reviews. The reviewers commended the inclusion of the Commercial Buildings Energy Consumption Survey (CBECS) and user groups for industry feedback. The reviewers indicated that the National Renewable Energy Laboratory (NREL) is developing a valuable tool to model the applicability of fuel cell combined heat and power systems for various building types around the country. It was recommended that proper model validation be performed.
FC-084	WO_3 and HPA Based Systems for Durable Platinum Catalysts in PEMFC Cathodes *John Turner; National Renewable Energy Laboratory*	2.7		X		Reviewers noted the good, productive collaborations with industry, national laboratories, and universities, and that experts were utilized on the materials investigated. Reviewers also commented on the relevance of this project. However, reviewers were disappointed with the results. Due to the low electronic conductivity of WO_X and consequent low activity of Pt/WO_X catalysts, no further work will be conducted in this area. Future work will use alternative nitride and carbide supports as well as the heteropoly-acid (HPA)-modified graphitized carbons in an attempt to meet the DOE targets. This project will be completed in early 2014.
FC-085	Synthesis and Characterization of Mixed-Conducting Corrosion Resistant Oxide Supports *Vijay Ramani; Illinois Institute of Technology*	3.2	X			Reviewers commended the project for its durability results and for its partnership with an automotive OEM. Reviewers also commented that future plans to reduce particle size were good. Down-selection of supports was recommended.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-086	Development of Novel Non-Platinum Group Metal Electrocatalysts for PEMFC Applications *Sanjeev Mukerjee; Northeastern University*	3.2	X			Reviewers noted substantial progress made over the last fiscal year and that the PI was able to address challenging, critical barriers. Collaboration of an automotive OEM, universities, national laboratories, and materials suppliers was commended. More operation and testing on air were recommended.
FC-087	High-Activity Dealloyed Catalysts *Anusorn Kongkanand; General Motors*	3.4	X			Reviewers commended the approach, organization, and level of collaboration for this project. They noted the substantial increases in mass activity and durability achieved over the past year, with the project's developed dealloyed catalysts meeting DOE targets. Some reviewers recommended expanding the effort to investigate support durability and optimize catalyst layer properties. It was also suggested that ternary system work needs to concentrate on low-cost component metals.
FC-088	Development of Ultra-Low Platinum Alloy Cathode Catalyst for PEMFCs *Branko Popov; University of South Carolina*	2.7		X		Reviewers noted the project strengths include good team work to meet milestones, plenty of performance data on novel catalysts, a PI that is highly experienced in synthesizing materials, and some progress in increasing support stability and catalyst activity/durability. Weaknesses included a lack of comparison to commercial materials, questionable test protocols, and too much data with too little interpretation and evidence to support hypotheses. The kinetic activity targets were only marginally met and the MEA performance at high current density is below expectations. There is a go/no-go decision point at the end of September 2013.
FC-090	Corrugated Membrane Fuel Cell Structures *Stephen Grot; Ion Power*	2.4		X		Reviewers rated the relevance and collaborations as moderate and the accomplishments and potential impact as low. Although the concept is creative and innovative, the challenges in terms of ultimate prospects for increasing power density and lowering manufacturing and materials costs compared to state-of-the-art fuel cell configurations seems too great to overcome. The reviewers also noted that there may be performance issues related to heat and mass transfer, electrical resistance, and durability. They also noted that the full stack issues such as reactant/coolant manifolding have not been considered. The go/no-go decision point, which has a metric of producing power density of at least 70 mW/cm^2 at 0.8 V from a corrugated cell, is at the end of August 2013 and there has been only limited success in fabricating the corrugated cell to test. The major subcontractor, an automotive OEM, is no longer supporting the project.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-091	Advanced Materials and Concepts for Portable Power Fuel Cells *Piotr Zelenay; Los Alamos National Laboratory*	3.2	X			Reviewers noted that the multidirectional approaches are reasoned and sensible. They commented that the PI holds the team together and despite some apparent isolation of the individual efforts, they are all of high quality and are focused on DOE milestones and barriers. Reviewers said that work on "ultrathrifted" Pt/Ru/C catalysts is outstanding and other projects are all very good to excellent. They felt that in some cases (e.g., catalysts supported on Cu and on Au), there could be more work done to address durability.
FC-092	Investigation of Micro- and Macro-Scale Transport Processes for Improved Fuel Cell Performance *Jon Owejan; General Motors*	3.3			X	All nine reviewers seemed to agree on the excellent approach, accomplishments, collaboration, and relevance of this project. A reviewer noted that the project is well balanced between practical in situ characterization/diagnostic experiments and direct insightful modeling. The project addresses the key barriers to understanding and improving the transport issues for lower platinum group metal (PGM) MEAs. The publishing of all project data and models (via website, conferences, and journals) is of tremendous benefit to the PEM fuel cell community at large. An effective transport model will help developers decrease transport losses and achieve high power density with smaller systems, decreasing the cost. This project will be completed in November 2013.
FC-096	Power Generation from an Integrated Biomass Reformer and Solid Oxide Fuel Cell (SBIR Phase III Xlerator Program) *Quentin Ming; InnovaTek*	3.0	X			Reviewers commented that the project has hit its milestones, met the go/no-go criteria, and addressed the performance barriers. Reviewers commended the achievement of 40% efficiency using bio-kerosene. Recommendations were made to focus on durability. This project will be completed in May 2014.
FC-097	Stationary and Emerging Market Fuel Cell System Cost Analysis – Material Handling Equipment *Kathya Mahadevan; Battelle*	3.2	X			Reviewers commented that the project strengths include the strong methodology, detailed analysis, and identification of cost drivers (areas where R&D efforts need to be applied). Suggested areas for improvement were better use of collaborators and consideration of the two parallel efforts at Strategic Analysis, Inc. (SA) and Lawrence Berkeley National Laboratory. This project passed a go/no-go decision point in March 2013 after completing its material handling equipment report.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
FC-098	A Total Cost of Ownership Model for Design and Manufacturing Optimization of Fuel Cells in Stationary and Emerging Market Applications *Max Wei;* *Lawrence Berkeley National Laboratory*	3.1	X			Reviewers noted that this project has a systematic methodology, appears to be making progress toward the objectives, and includes health and environmental benefits analysis. However, it appears to lack accurate cost inputs because companies are reluctant to share that data. It has a high degree of overlap with Battelle and SA, so this should be reconciled to eliminate redundancy. Reviewers questioned why there was a lack of volume effect on balance of plant component costs. This project will have a go/no-go decision in October 2013.
FC-100	High Aspect Ratio Fuel Cell Catalysts *Brian Larsen;* *National Renewable Energy Laboratory*	2.8		X		Combining catalyst preparative variations with electrochemical performance evaluation was commended. Reviewers expressed concern, however, about the lack of a systematic approach to design improved materials, lack of collaborations, and lack of durability testing. The project has been discontinued after further review.
FC-103	Roots Air Management System with Integrated Expander *Dale Stretch;* *Eaton Corporation*	3.5	X			Reviewers agreed with the approach Eaton has taken to reduce cost and improve performance. They commended the collaboration with Kettering University to provide computational fluid dynamics modeling, ANL to provide system modeling, SA to provide cost modeling, and finally Ballard to provide the integration and demonstration of the system with a stack. There is some concern that results will not be available to support the final design decision on schedule.
FC-104	High Performance, Durable, Low-Cost Membrane Electrode Assemblies for Transportation Applications *Andrew Steinbach;* *3M*	3.0	X			A number of the reviewers stated that this new project is highly relevant, has a good approach, and has good teaming. Some reviewers expressed concern regarding the NSTF technology, including the water management issues to be addressed in this integration activity.

*Congressionally directed project (CDP)

Manufacturing R&D

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
MN-001	Fuel Cell MEA Manufacturing R&D *Michael Ulsh; National Renewable Energy Laboratory*	3.4	X			Reviewers applauded the new approach planned—focusing more on exploratory studies. They also commended the National Renewable Energy Laboratory (NREL) for coordinating with industry to develop and improve diagnostics critical to fuel cell membrane electrode assembly (MEA) and gas diffusion layer (GDL) manufacturing. One reviewer questioned the new diagnostic to measure the ionomer/carbon ratio as the presentation did not indicate a strong industry need for this diagnostic. Reviewers suggested that NREL indicate how these techniques will be used in a feedback process loop control.
MN-004	Manufacturing of Low-Cost, Durable Membrane Electrode Assemblies Engineered for Rapid Conditioning *Colin Busby; W.L. Gore*	3.2	X			Reviewers noted that the approach of the project to develop methods to produce fuel cell MEAs in volume is good. Reviewers stated that it was unclear what progress has been made since last year other than selecting a low-cost backer. No results from the University of Tennessee-Knoxville are evident. Reviewers thought that the addition of cost analysis by Strategic Analysis, Inc. was good. Reviewers were concerned about the loss of UTC Power/United Technologies Research Center as stack testers.
MN-006	Metrology for Fuel Cell Manufacturing *Michael Stocker; National Institute of Standards and Technology*	3.0			X	This project is complete. Reviewers felt that the general approach to the effort was appropriate but that additional input from other researchers at laboratories or in academia may have been useful. They felt that the Large Aperture Projection Scatterometer (LAPS) device has some potential but that there still seem to be some process control issues to resolve. Reviewers felt that the benefits of this technique compared to X-ray fluorescence (XRF) are not clear. They also felt that the ability of LAPS to measure two-sided coatings simultaneously may not be needed. The researchers are urged to get better input from industry.
MN-007	High-Speed, Low-Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies *Emory De Castro; BASF*	3.6			X	This project is complete. Reviewers felt that BASF laid out and accomplished a methodical approach to addressing the problems in the statement of work. They noted that the throughput (line speed) was significantly increased, the paper gas diffusion electrode (GDE) cost goal was met, and variability now meets acceptable level. In addition, they commended the ink cost savings and the performance gain of the GDE.

*Congressionally directed project (CDP)

Technology Validation

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
TV-008	Technology Validation: Fuel Cell Bus Evaluations *Leslie Eudy; National Renewable Energy Laboratory*	3.8	X			The reviewers commented that the project was well designed, proving critical to the wide-scale adoption of fuel-cell-powered buses, and providing valuable insights for both U.S. Department of Energy (DOE) project managers and transit fleet operators. It was suggested that performance and reliability comparisons with previous generation buses, as well as bus deployments already performed or underway in Europe, should also be considered.
TV-016	Stationary Fuel Cell Evaluation *Chris Ainscough; National Renewable Energy Laboratory*	3.3	X			The reviewers noted that this relatively new addition to the Technology Validation portfolio takes advantage of previously developed and effective approaches. It was noted that results should be compared not only to DOE targets, but also to results for other conventional and emerging prime power technologies. Reviewers suggested that evaluation of stationary fuel cells should be expanded to other states, even if the evaluation includes only those projects that provide incentives for stationary fuel cells. Focusing data collection on specific system sizes and expanding analyses to include data on fuel cell maintenance, degradation, and reliability were also suggested.
TV-018	Hydrogen Recycling System Evaluation and Data Collection *Rhonda Staudt; H2Pump*	3.3	X			The reviewers commented that developing a system that will reclaim hydrogen from industrial waste is an innovative technology that addresses on-site renewable hydrogen creation and warrants validation. It was noted that some plan to recover schedule slippage is needed, as the go/no-go decision point and data collection were behind schedule. The reviewers requested more details on the cost per kilogram of hydrogen supplied. While hydrogen recycling could be an attractive business proposition for a subset of industrial hydrogen users, uncertainties exist regarding how much of the future demand for hydrogen could be met by this method, and reviewers felt that the potential is limited.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
TV-019	Hydrogen Component Validation *Kevin Harrison; National Renewable Energy Laboratory*	3.4	X			The reviewers expressed the opinion that the National Renewable Energy Laboratory's (NREL's) testing and analysis is valuable in accelerating commercialization of near-commercial technologies. Reviewers suggested that other manufacturers and component types could also be investigated, and that attention should be given to comparing results with DOE goals and targets. The reviewers noted that it may be desirable to more aggressively market NREL's component validation capabilities to industry so that they can take advantage of NREL's testing prior to demonstrating their new products or components to customers.
TV-020	Validation of an Advanced High-Pressure PEM Electrolyzer and Composite Hydrogen Storage, with Data Reporting, for SunHydro Stations *Larry Moulthrop; Proton OnSite*	3.3	X			The reviewers noted that the project fits well with DOE goals and is expected to lower costs with improved and more efficient components, as well as the potential to speed permitting-related approvals. Reviewers noted good collaborations with component suppliers and users, but also that expansion of the evaluation to include other fueling stations, organizations, and technologies should be considered. Reviewers suggested that the project should thoroughly evaluate how the advanced components being validated affect the costs of delivered hydrogen and ensure appropriate data is collected to support cost estimates.
TV-021	Forklift and Backup Power Data Collection and Analysis *Jennifer Kurtz; National Renewable Energy Laboratory*	3.6	X			Reviewers believed that NREL's business case analysis of the economic and operating performance of fuel cell forklifts and backup power systems has contributed to the commercial ramp-up of these systems. While detailed data were presented for forklift systems, reviewers suggested some additional analysis and information on backup power systems. Reviewers strongly suggested that this project should be continued beyond its proposed end date in order to establish a long-term performance record for these systems and to portray trends over several years.

*Congressionally directed project (CDP)

Safety, Codes and Standards

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
SCS-001	National Codes and Standards Deployment and Outreach *Carl Rivkin; National Renewable Energy Laboratory*	3.3	X			Reviewers recognized this project as essential to the harmonization and development of codes and standards. Reviewers praised the coordination with code development organizations (CDOs) and standards development organizations (SDOs) and the value of the work being done in California. However, reviewers stated that the project focus, approach, and plan should be improved by incorporating clear, significant deliverables and associated timelines as well as metrics for tracking outreach efforts. In addition, the project scope should be expanded to address a range of needs such as codes and standards for hydrogen quality, metering, and certification of components and systems.
SCS-002	Component Standards Research & Development *Robert Burgess; National Renewable Energy Laboratory*	2.8	X			Reviewers acknowledged the importance and need for this project in advancing hydrogen infrastructure and codes and standards development and implementation. Specific strengths cited included the project's strong coordination and effective flow of information between SDOs, CDOs, and national/international laboratories. However, reviewers identified the need for stronger collaboration and coordination with industry as well as outreach to help transfer knowledge. Reviewers would also like to see a better defined project scope and clearer milestones to better evaluate the project.
SCS-004	Hydrogen Safety, Codes and Standards: Sensors *Eric Brosha; Los Alamos National Laboratory*	3.3	X			Reviewers recognized the strong coordination with industrial partners and overall project management and execution. However, reviewers noted concerns regarding the project's ability to deliver sensors that meet the specified targets. Reviewers also cited some uncertainty regarding industrial partners' ability to commercialize the technology. The reviewers suggested future work that includes the investigation of cross-sensitivity to methane (CH_4); the development of durability, maintenance, and manufacturing requirements; and manufacturing, maintenance, and other cost estimates and targets for relevant applications.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
SCS-005	R&D for Safety, Codes and Standards: Materials and Components Compatibility *Aaron Harris; Sandia National Laboratories*	3.6	X			Reviewers commended the communication with industry and the quality of the data and analytical methods. Stronger direct support to industry would strengthen this project, along with additional collaboration with other government-funded related research. Improved testing capabilities such as testing at -50°C would build credibility for embrittlement testing and would strengthen this project. Reviewers suggested further harmonization between SAE International and the Canadian Standards Association, along with more publications of research including preliminary results and conclusions to enable better review and feedback for future work.
SCS-007	Hydrogen Fuel Quality *Tommy Rockward; Los Alamos National Laboratory*	3.4	X			Reviewers praised the focus, dedication, and alignment of the project work with near-term real-world needs. This work is seen as a key success and important stepping stone toward implementation of hydrogen fuel quality standards. Reviewers noted a shortage of resources and industrial partner support for accelerating commercialization of the in-line analyzer. Reviewers also cited competing technical interests and the lack of analysis as well as cost data on contaminant levels as a project weakness. Reviewers suggested reexamining the project scope to include the investigation of the cost effectiveness of the technology and collaboration with an industrial partner to advance commercialization efforts of the in-line gas analyzer.
SCS-010	R&D for Safety Codes and Standards: SCS Project Overview - Hydrogen Behavior *Aaron Harris; Sandia National Laboratories*	3.2	X			Reviewers emphasized the project's strong research and experiments in validating data and models on H_2 release behavior. Strengths also include research collaborations and international harmonization efforts. However, the complexity of the project requires better efforts to simplify/clarify the objectives and communicate progress and future plans to project managers and the general public. Reviewers suggested the addition of underground storage into the fuel storage matrix and the need for more frequent and widespread publication and outreach, including coordination with International Organization for Standardization (ISO) TC 197.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
SCS-011	R&D for Safety Codes and Standards: SCS Project Overview - Risk *Aaron Harris; Sandia National Laboratories*	3.2	X			Reviewers recognized this project for its strong technical capabilities, thoroughness, and scientific basis, which is critical for enabling the siting of hydrogen projects, specifically refueling stations. The ability to compare risk with other industries is also a major improvement. However, reviewers expressed concern over the robustness of underlying assumptions and complexity of the toolkit that may lend itself to mis-use. Reviewers recommended considering applications for evaluating the risk associated with equipment or processes, along with incorporating stakeholder input to help shape future work.
SCS-019	Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools *Nick Barilo; Pacific Northwest National Laboratory*	3.6	X			Reviewers noted the project's strengths in sharing safety information and providing guidance and tools to increase awareness for industry. The safety panel was also highlighted for its collaboration and for providing a critical service to the community. However, reviewers identified the need to involve third-party certifiers and improve the coordination between the safety panel and safety planning in projects funded by the Fuel Cell Technologies Office. Reviewers suggested continued feedback to SDOs and that developing a comprehensive strategy around mobile platform applications will continue to build on the success of such safety knowledge tools.
SCS-021	NREL Hydrogen Sensor Testing Laboratory *Bill Buttner; National Renewable Energy Laboratory*	3.3	X			Reviewers applauded the work to understand the needs of industry and the effective collaboration with international partners. This work was also recognized for enabling sensor developers to improve sensors and measure progress toward goals. However, reviewers noted the importance of having a clear context, purpose, and goal for developing sensors to address the critical needs facing the deployment of hydrogen and fuel cell technologies. Reviewers recommended clear messaging about the role of sensors in achieving safety levels defined in codes and standards and suggested investigating the use of wide area detection and contact sensing technologies for early detection of H_2 leaks.

*Congressionally directed project (CDP)

Market Transformation

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
MT-004	Direct Methanol Fuel Cell Material Handling Equipment Deployment *Todd Ramsden; National Renewable Energy Laboratory*	3.2			X	Reviewers noted that the hydrogen infrastructure cost barrier was definitely addressed, showing that a methanol refueling system is a small fraction of that for hydrogen; however, the direct methanol fuel cell (DMFC) lift truck power system durability is an issue that requires a complete evaluation. Reviewers recommended involving more than one vendor in the project.
MT-006	Fuel Cell Combined Heat and Power Commercial Demonstration *Kriston Brooks; Pacific Northwest National Laboratory*	3.6	X			Reviewers commented that the project is well planned, milestones are being met, and the analysis is useful. Reviewers also noted that various user types help to define the potential market better, although some market examples such as hospitals need much higher power levels. The lack of information on technical improvements needed should be addressed in the future.
MT-007	Landfill Gas–to–Hydrogen *Shannon Baxter-Clemmons; South Carolina Hydrogen and Fuel Cell Alliance*	2.8	X			While reviewers agreed that this application and project objectives are of great value, this project is significantly behind schedule due to technical problems. The project team has been unable to resolve the nitrogen diluent in the gas composition. The reviewers noted that while this problem is not a showstopper, it needs to be addressed with outside expertise. Reviewers stated that this project should continue to completion because the objectives hold great promise for turning landfill gas into usable fuel.
MT-008	Hydrogen Energy Systems as a Grid Management Tool *Mitch Ewan; Hawaii Natural Energy Institute*	3.2	X			Reviewers stated that the project presents a good opportunity for public acceptance of hydrogen fuel because the hydrogen is entirely from a renewable source, in this case geothermal power. Reviewer comments were also positive regarding the number of collaborators and stakeholders in industry and government along with resource leveraging. One reviewer noted the lessons learned after the project's completion would be of high value to similar projects. Reviewers also commented that the project focus needs to be narrowed to reduce project risks.
MT-011	Ground Support Equipment Demonstration *Jim Petrecky; Plug Power*	3.2	X			Reviewers supported the project's approach in that it was modeled after successful material handling equipment (MHE) deployment projects. Reviewers positively noted that the expansive team and stakeholder involvement aligned with the Market Transformation program objectives. Reviewers were concerned that the schedule was very aggressive but noted that concrete go/no-go decision milestones will minimize risks. One reviewer stated that the market size may be too small and that other applications should be brought in.

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
MT-012	Fuel Cells as Range Extenders for Battery Electric Vehicles *Aymeric Rousseau; Argonne National Laboratory*	3.1			X	Reviewer opinions varied widely from the project being unnecessary to extremely valid and useful for electric vehicle technologies. Reviewers stated that the results and data presented were valid for extending zero emission vehicle range and of great relevance. Results from the completed study should be used to guide future work in this area.

*Congressionally directed project (CDP)

Systems Analysis

Project Number	Project Title *Principal Investigator Name & Organization*	Final Score	Continue	Discontinue/ Further Review	Completed or CDP*	Summary Comments
AN-030	Worldwide Status of Hydrogen Fuel Cell Vehicle Technology and Prospects for Commercialization *David Greene; Oak Ridge National Laboratory*	3.5			X	Reviewers commented that this analysis project was very relevant to the Fuel Cell Technologies Office (FCTO) goals and objectives and made good progress. They commended the project for being comprehensive and providing the necessary evaluation of the technology status. The collaboration used in the project was excellent. The project findings should be incorporated in FCTO's program assumptions.
AN-031	Siting Strategies for Early Hydrogen Refueling Infrastructure in California: Learning from the Gasoline Experience *Michael Nicholas; University of California, Davis*	3.1	X			Reviewers commented that the project has made excellent progress. Reviewers felt that the project's strength stems from the field of resources and collaboration. The project is very relevant to the analysis of infrastructure development and more emphasis should be placed on market deployment and the interaction with vehicle deployment. Reviewers suggested future studies should focus on the minimum number of fueling stations needed for the early market vehicle rollout.
AN-032	Design and Economics of an Early Hydrogen Refueling Network for California *Joan Ogden; University of California, Davis*	3.4	X			Reviewers commented that this analysis project is very relevant to FCTO goals and objectives and made significant progress. The project's findings will contribute to understanding near-term hydrogen infrastructure costs and the appropriate level of support. The collaboration used in the project was excellent but should be expanded to include other countries that are installing infrastructure. The project could be expanded to include investigating impacts of low station utilization.
AN-033	Analysis of Optimal On-Board Storage Pressure for Hydrogen Fuel Cell Vehicles *Zhenhong Lin; Oak Ridge National Laboratory*	3.1	X			Reviewers observed the project approach was sound and straightforward, with good focus on analysis. The project provides vital information on station development and deployment and consumer value of fuel cell electric vehicles (FCEVs) relative to range and fuel cost trade-offs. They commended the project for the collaboration with industry and academia. The project is in the initial phases and has made modest-to-good progress and should continue to incorporate new cost data for other fueling pressures. The project should incorporate industry input on costs associated with modular station design. The project should include an "annoyance factor" of having to refuel more often with lower-pressure fuel.

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AN-034	Life Cycle Analysis of Hydrogen On-Board Storage Options *Amgad Elgowainy; Argonne National Laboratory*	3.2	X			Reviewers continue to commend this project for the excellent ongoing progress and relevance for life cycle assessments. The project should include more collaboration with industry to vet the results. Reviewers thought this project had the strength of being built on the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model architecture for providing life cycle analysis capabilities for onboard storage. Reviewers suggested that a broader context of storage options for vehicles be considered.
AN-035	Employment Impacts of Infrastructure Development for Hydrogen and Fuel Cell Technologies *Marianne Mintz; Argonne National Laboratory*	3.2	X			Reviewers concluded that the JOBS model is crucial for evaluating the impact of fuel cell technologies on job creation and provides a broader understanding of the role fuel cell technologies can play in the U.S. economy. Reviewers acknowledged the impressive list of stakeholders and collaborators for the project. They recommended the model be expanded to include hydrogen infrastructure and FCEV deployments as well as for the manufacturing of solid oxide fuel cells because they are now in production.
AN-036	Pathway Analysis: Projected Cost, Well-to-Wheels Energy Use and Emissions of Current Hydrogen Technologies *Todd Ramsden; National Renewable Energy Laboratory*	3.3	X			Reviewers observed that this project had an excellent choice of comparison technologies and models and is relevant to the FCTO goals. They acknowledge the project has good collaboration from a diverse set of stakeholders. The project could be strengthened by adding definition of the technology time frame, methodology of model validation, and future technologies.
AN-037	Hydrogen from Biogas: Resource Assessment *Genevieve Saur; National Renewable Energy Laboratory*	3.4	X			Reviewers commented that waste to fuel is relevant to solving environmental problems and reducing greenhouse gas emissions. The approach was clear and addressed renewable resource assessment. The project has made good progress. Moving forward, work should compare cleanup costs associated with hydrogen generation from wastes and correlate biogas resources with regional analysis.
AN-038	Global Hydrogen Resource Analysis (Hydrogen Implementing Agreement, Task 30A) *Tom Drennan; Sandia National Laboratories*	3.1			X	The reviewers commented that the project approach needs to ensure greater rigor in the methodology and consistent inputs from different countries. The project has made good progress but has exhibited limited quality assurance of the analytical tool. The project had good collaboration from a large array of countries but the effectiveness of the collaboration was not clear. The relevance of the project needs more explanation and demonstration. The reviewers concluded that the project needs to be completed and the results disseminated.

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AN-039	Life Cycle Analysis of Water Use for Hydrogen Production Pathways *Amgad Elgowainy; Argonne National Laboratory*	3.2	X			Reviewers commented that the project approach is clear and adequate to address a critical issue for future energy, including hydrogen. The project is in the initial phases and has few accomplishments at this point. The project will benefit from stakeholder and academic collaboration. Water availability and usage for energy generation is an important issue and the GREET model offers a high value for comparative life cycle analysis of water usage.
AN-040	Analysis of Fuel Cell Integration with Biofuels Production *Mark Ruth; National Renewable Energy Laboratory*	2.9			X	Reviewers commented the project approach was clear and the analysis was thorough. The project was well executed and is complete. The collaboration was limited but could have benefited from inclusion of industry stakeholders. The study was valuable to understand the impacts of integrating fuel cells in a bio-refinery.
AN-042	Hawai'i Hydrogen Initiative (H2I) Financial Scenario Analysis *Michael Penev; National Renewable Energy Laboratory*	3.5			X	According to reviewers, the project and analysis was well designed and utilized existing tools to conduct the scenario evaluations. The approach was adequate for the project scale and integrates other models for the evaluation. The analysis draws on contributions from a diverse set of stakeholders. Significant progress has been made in evaluating the infrastructure for Hawai'i. Additional scenarios should be explored that include an optimistic case. The model developed and analysis conducted for Hawai'i serves as a good structure and baseline for other different regions of the country.
AN-043	Analysis of Community Energy *Darlene Steward; National Renewable Energy Laboratory*	3.3			X	Reviewers commented that the project approach was satisfactory and progress was adequate. The project has benefited from a diverse group of stakeholders, but more regional data should be used to account for seasonal and geographic differences. The reviewers mentioned that the project was relevant to managing renewable power resources at a local level. Application of additional industry review, actual equipment cost input, and location data would benefit this project.

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