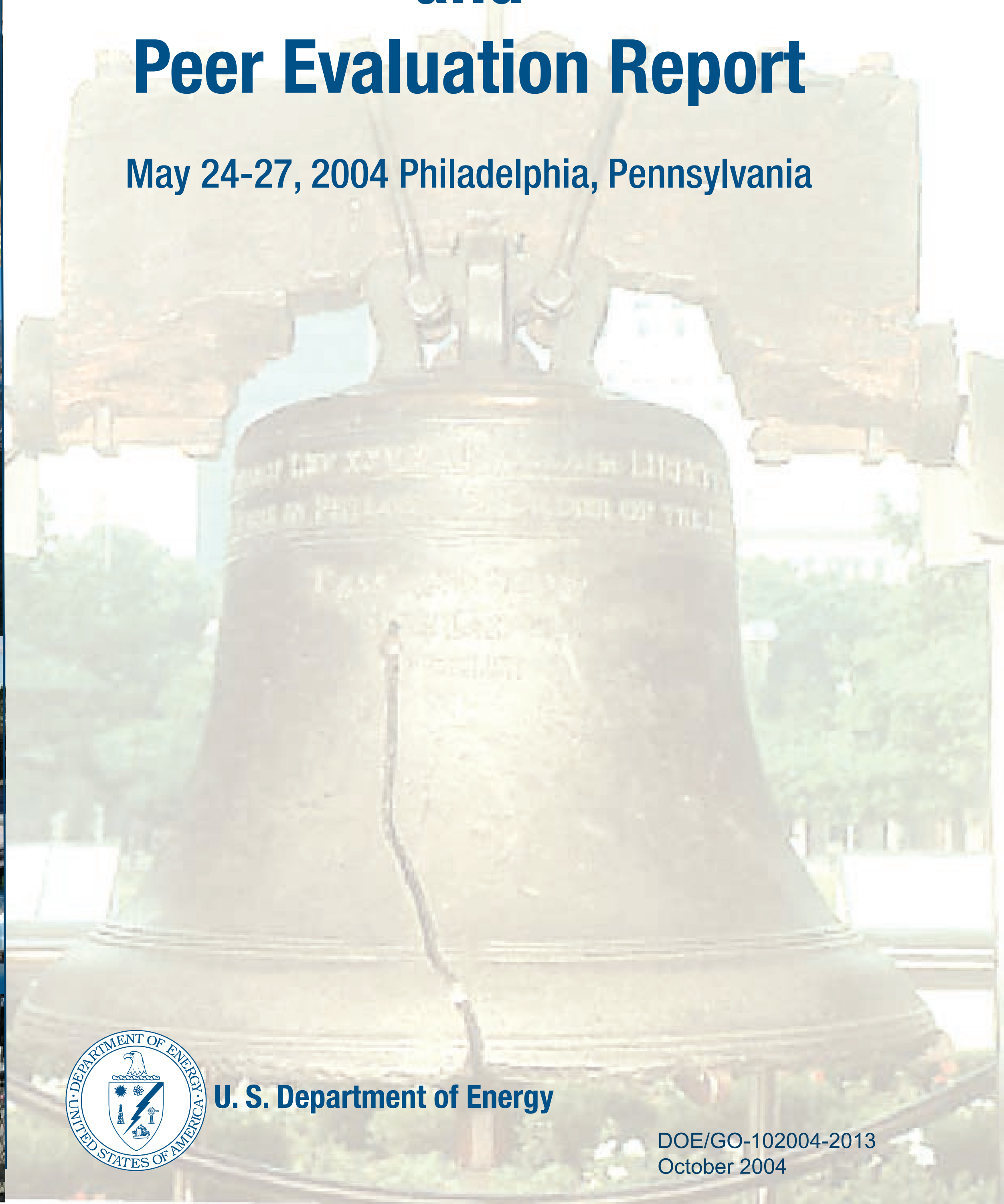


DOE Hydrogen Program

2004 Annual Merit Review and Peer Evaluation Report

May 24-27, 2004 Philadelphia, Pennsylvania

U. S. Department of Energy

DOE/GO-102004-2013
October 2004

Dear Colleague:

This document summarizes the comments provided by the Peer Review Panel at the U.S. DOE Hydrogen Program FY 2004 Annual Merit Review, held on May 24-27, 2004 in Philadelphia, Pennsylvania. This was the first review that began to reflect the entire DOE Hydrogen Program, in response to direction from the Under Secretary for Energy, Science, & Environment. That direction requires that the Offices of Energy Efficiency and Renewable Energy (EERE), Fossil Energy (FE), Science (SC), and Nuclear Energy, Science, and Technology (NE) all participate in order to give the hydrogen community an overall view of the breadth and depth of DOE's effort in support of the President's Hydrogen Fuel Initiative. For the first time, representatives from FE, NE, and SC gave overview presentations on their program plans related to hydrogen at the merit review meeting. With the planned inception of hydrogen-related projects within these Offices in fiscal year (FY) 2005, future Hydrogen Program Annual Program Reviews will include projects by all Offices within DOE on hydrogen-related technologies.

The recommendations of the panel have been taken into consideration by DOE technology development managers in the development of work plans for FY 2005. The tables below list the projects discussed at the review and the major actions to be taken during the upcoming fiscal year. The projects have been grouped according to which activity area (production, delivery, storage, fuel cells, etc.) they support. The average scores are on a 4- point scale. To furnish all principal investigators (PIs) with direct feedback, raw evaluations and comments were provided to each presenter. However, the authors of the individual comments will remain anonymous. The PIs of each project are instructed to fully consider these summary evaluation comments, as appropriate, into their FY 2005 plans.

Project No.	**Project Title, Performing Organization**	**Average Score**	**Continued**	**Dis - continued**	**Project Completed**	**Summary Comment**
Hydrogen Production and Delivery:						
HPD-1	*Hydrogen Production and Delivery Sub-Program Review*, DOE	3.40				
HPD-2	*Ceramic Membrane Reactor Systems for Converting Natural Gas to Hydrogen (ITM Syngas)*, Air Products	3.40	X			Based on economic analysis provided to date, the focus of this project is central versus distributed production of hydrogen from syngas. FE will continue to fund.
HPD-3	*Integrated Ceramic Membrane System for H_2 Production*, Praxair	3.05	X			In final phase, focus should be on contaminant effects. Project will be completed in FY05.
HPD-4	*Low Cost Hydrogen Production Platform*, Praxair	3.22	X			Need to evaluate impact of new technologies such as membranes on cost projections. Project will be completed in FY05.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
HPD-5	*Defect-free Thin Film Membranes for H_2 Separation & Isolation*, SNL	3.04	X			Focus on real-world operations and simulate system performance. Continuously evaluate suitability of selected materials.
HPD-6	*Autothermal Cyclic Reforming and H_2 Refueling System*, GE Energy	3.25	X			Project will be completed in FY05 with full scale demonstration.
HPD-7	*Development of Supports and Membranes for Hydrogen Separation*, ORNL	3.24	X			It is not clear that this project is at a "critical mass" level. Consider increased funding or combine project with other efforts.
HPD-8	*Adapting Planar Solid Oxide Fuel Cells for Use with Solid Fuel Sources in the Production of Distributed Power*, Ohio University	2.55	X			Consider system integration issues. Do not limit applicability to a single system.
HPD-9	*Maximizing Photosynthetic Efficiencies and Hydrogen Production in Microalgal Cultures*, UC Berkeley	3.39	X			Project has exceeded milestones and current scope will be completed in FY05.
HPD-10	*Biological Systems for Hydrogen Photoproduction*, NREL	3.19	X			Work solidly addresses a major issue arising from biological hydrogen production and addresses a way to circumvent the problem.
HPD-11	*Photoelectrochemical Water Splitting*, NREL	3.01	X			Good progress, but needs a more focused program approach to PEC hydrogen production.
HPD-12	*Photoelectrochemical Hydrogen Production Program*, University of Hawaii	3.06	X			Work will continue with funding from UNLV congressionally directed project.
HPD-13	*Discovery of Photocatalysts for Hydrogen Production*, SRI International	2.42	X			Progress has been slow with many delays due to intellectual property and partner funding concerns. Project will be completed in FY05.
HPD-14	*High Temperature Solid Oxide Electrolyzer System*, INEEL	3.18	X			Need collaboration with industry or university partners. Partially funded by NE in 2005.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
HPD-15	*Renewable Electrolysis Integrated System Development and Testing*, NREL	3.07	X			Well thought-out work with an emphasis on achieving cost targets. Focus on the wind/solar power interface is useful to industry.
HPD-16	*Hydrogen Generation from Electrolysis*, Teledyne	3.07	X			Consider taking H-gen systems to a new level with some "outside the box" developments. Accelerate phase 1 and 2 to get to demo unit sooner.
HPD-17	*Development of Solar-Powered Thermo-Chemical Production of Hydrogen from Water*, University of Nevada	3.16	X			Conclude cycle screening and focus on research and experimentation.
HPD-18	*Moving Toward Consistent Analysis in the HFC&IT Program: H2A*, NREL	3.43			X	Current scope (production and delivery) will be completed in FY04.
HPD-19	*Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0*, ORNL	2.78	X			Good start on a complex problem. Should be funded at a low level to allow for corrections to the model.
HPD-20	*WinDS-H_2 Model and Analysis*, NREL	2.68	X			Current project scope is complete. Expand to include other intermittents (e.g., solar and biomass).
HPD-P1	*Novel Catalytic Microchannel Fuel Processing Technology*, InnovaTek	3.53			X	Project planned for sucessful completion in FY04.
HPD-P2	*Startech Hydrogen Production*, Startech Environmental	2.43	X			New Project. FY 04 Congressionally directed. Emphasize demonstration of process feedstock flexibility.
HPD-P3	*Water-Gas Shift Membrane Reactor Studies*, NETL	2.87	X			Need to determine effects of contaminants in coal gasification stream. FE to continue funding this work under the Coal to Hydrogen Program.
HPD-P4	*Fluidizable Catalysts for Hydrogen Production from Complex Feedstocks*, NREL	2.80		X		Redirect underlying technology to distributed production of H_2 from bio-derived liquids.
HPD-P5	*Hydrogen from Biomass: Process Research*, NREL	2.88		X		Redirect underlying technology to distributed production of H_2 from bio-derived liquids.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
HPD-P6	*Aqueous Phase Catalyzed Biomass Gasification*, PNNL	2.63	X			Increase funding and initiate collaborations to enhance technology transfer.
HPD-P7	*Hydrogen from Biomass: Catalytic Reforming of Pyrolysis Vapors*, NREL	2.57		X		Redirect underlying technology to distributed production of H_2 from bio-derived liquids.
HPD-P8	*Creation of Designer Alga for Efficient and Robust Production of H_2*, ORNL	3.40	X			Include a go/no-go decision point in 2 or 2.5 years based on whether or not H_2 production increases.
HPD-P9	*Hydrogen Reactor Development and Design for Photofermentation and Photolytic Processes*, NREL	3.07	X			New project in FY04 at low level of funding. Essential for any photo conversion process.
HPD-P10	*Photoelectrochemical H_2 Prod. Using New Combinatorial Chemically Derived Materials*, University of California Santa Barbara	3.02			X	Project team appears to be effective in fully characterizing the materials synthesized by combinatorial methods. Project will be completed in FY04.
HPD-P11	*High Efficiency Electrolysis Materials Research*, SNL	2.77	X			Proof of principle experiments for the synthesis of electrocatalysts need to be conducted early in the project to determine likelihood of success.
HPD-P12	*Low-Cost, High-Pressure Hydrogen Generator*, Giner Electrochemical	3.20	X			Consider feasibility of achieving higher pressures.
HPD-P13	*Hydride Based Hydrogen Compression*, Ergenics	3.07			X	Address cost benefits of hydride compression. Project will be completed in FY04.
HPD-P14	*Technical and Economic Studies of Regional Transition Strategies Toward Widespread Use of H_2 Energy*, UC Davis	3.37	X			Basic model can be easily shared. Need to consider other vehicles in the transition. Include a better understanding of demand and price drivers.
HPD-P15	*Hydrogen Production in a Greenhouse Gas Constrained Situation*, Tellus	2.98	X			Should continue to fund these comparative studies; needed for making sound decisions.
HPD-P16	*Fuel Choice for FCVs: Hydrogen Infrastructure Costs*, TIAX	3.00	X			Project should continue to be funded at a low level so that the model may be updated as technical progress is made.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
HPD-P17	*New York State HI-Way Initiative*, GE Global Research	2.71	X			New project. FY 04 Congressionally directed. Too early to evaluate.
HPD-P18	*EVermont Renewable Hydrogen Fueling Station*, Northern Power Systems	2.55	X			New project. FY 04 Congressionally directed. Too early to evaluate.
HPD-P20	*Photopolymerization/Pyrolysis Route to Microstructured Membrane Development*, LANL	3.00	X			Novel approach that could yield novel materials. As progress is made, collaboration opportunities should be identified.
HPD-P21	*Developing Improved Materials to Support the Hydrogen Economy*, Edison Material Tech Center	2.20	X			New Project. FY 04 Congressionally directed. Solicitation issued and sub-projects to be selected in FY04
HPD-P23	*Hydrogen Generation from Electrolysis*, Proton Energy Systems	3.20	X			This work is properly focused on the wind to H_2 car fueling issue. Would benefit from DFM analysis of the entire system in addition to the planned manufacturing analysis.
Hydrogen Storage:						
ST-1	*Hydrogen Storage Sub-Program Review*, DOE	3.47				
ST-2	*Low Cost, High Efficiency, High Pressure Hydrogen Storage*, Quantum	2.57	X			New project. Continue work aimed at achieving cost target.
ST-3	*Optimum Utilization of Available Space in a Vehicle through Conformable Hydrogen Tanks*, LLNL	2.61	X			Moving in the right direction but needs more focus on experimental work/testing.
ST-4	*Radiolysis Process for the Regeneration of Sodium Borate to Sodium Borohydride*, INEEL	2.32		X		Terminate project based on poor review. Borate conversion to borohydride not clear.
ST-5	*Low Cost, Off-Board Regeneration of Sodium Borohydride*, Millenium Cell	2.45	X			New project. Assess feasibility as part of Center of Excellence, subject to Congressional appropriations. Address regeneration efficiency.
ST-6	*Chemical Hydride Slurry for Hydrogen Production and Storage*, Safe Hydrogen	2.68	X			New project. Define system component mass and volume. Partner with Mg producers.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
ST-7	*Hydrogen Storage by the Reversible Hydrogenation of Liquid and Solid Substrates*, Air Products	2.86	X			New project. Recommend downselecting to 1 or 2 systems after year 1.
ST-8	*Doped Sodium Aluminum Hydride: Fundamental Studies and Development of Related Hydrogen Storage Materials*, University of Hawaii	3.00	X			Continue portions of work as part of Center of Excellence, subject to Congressional appropriations. Start to shift work from sodium alanates to more promosing materials with potential to meet DOE 2010 targets.
ST-9	*Hydride Development for Hydrogen Storage*, SNL	3.32	X			Continue portions of work as part of Center of Excellence, subject to Congressional appropriations. Continue to stress materials discovery work but include engineering sciences studies as a key effort.
ST-10a	*High Density Hydrogen Storage System Demonstration Using NaAlH4 Complex Compound Hydrides*, UTRC	2.84	X			Complete current 1-kg hydrogen prototype work. Shift scope to develop 2nd generation 1-kg prototype with potential to satisfy DOE 2005 systems targets.
ST-10b	*High Density Hydrogen Storage System Demonstration Using NaAlH4 Complex Compound Hydrides*, UTRC	2.83	X			New project (2Q FY04) on exploratory materials development vs. stystem study effort in ST10a. Consider collaboration with Metal Hydride Center of Excellence, subject to Congressional appropriations.
ST-11	*Discovery of Novel Complex Metal Hydrides for Hydrogen Storage through Molecular Modeling and Combinatorial Methods*, UOP	2.98	X			New project (2Q FY04). Stress materials discovery of compounds with potential to meet DOE 2010 system targets. Consider collaboration with Metal Hydride Center of Excellence, subject to Congressional appropriations.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
ST-12	*Sub-Nanostructured Non-Transition Metal Complex Grids for Hydrogen Storage*, Cleveland State University	2.16	X			New project (2Q FY04). Focus on work to prove concept feasibility. Include hydrogen storage measurements in phase 1 of the program. Demonstrate benefits of nanosturctured grid over bulk phase behavior.
ST-13	*Hydrogen Storage in Carbon-based Materials*, NREL	2.72	X			Continue portions of work as part of Center of Excellence, subject to Congressional appropriations. Implement go/no-go decision and shift work to beyond SWNTs.
ST-14	*Standardized Testing Program for Chemical Hydride & Carbon Storage Technologies*, SwRI	3.04	X			Good progress, but should focus on getting highly repeatable results from testing samples. Need to develop testing protocols and disseminate to technical community early.
ST-P1	*Next Generation Physical Hydrogen Storage*, LLNL	2.32	X			Innovative approach to making lighter/strong material for pressure vessels but needs to address practical (cost, manufacturing etc) issues as well.
ST-P3	*Fuel Cell and Hydrogen Research*, University of South Florida	1.48	X			New Project. FY04 Congressionally directed. Too early to evaluate.
ST-P4	*Development of Complex Hydride Hydrogen Storage Materials and Engineering Systems*, University of South Carolina	2.34	X			New Project. FY04 Congressionally directed. Program consists of 5 subprojects addressing hydrogen production, hydrogen storage, and PEM fuel cell components.
ST-P5	*Advanced Manufacturing Technologies for Renewable Energy Applications*, Natl Center for Manf. Sciences	1.64	X			New Project. FY04 Congressionally directed. Need to better define work scope and benefits.
Fuel Cells:						
FC-1	*Fuel Cells Sub-Program Review*, DOE	3.30				

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
FC-2	*Integrated Manufacturing for Advanced Membrane Electrode Assemblies*, De Nora	3.11	X			High temperature membrane activities show promise. Project planned for completion in FY2005.
FC-3	*Development of High Temperature Membranes and Improved Cathode Catalysts*, UTC	2.62	X			Project will be redirected to continue development effort and not proceed to stack testing.
FC-4	*Advanced MEAs for Enhanced Operating Conditions*, 3M	3.30	X			Project making good progress. Project planned for completion in FY2005.
FC-5	*Dev.of High-Perf., Low-Pt Cathodes Containing New Catalyst & Layer Structures*, Superior	2.88	X			Catalysts show promise towards meeting Pt loading target.
FC-6	*High-Temperature Membranes*, Case West Reserve University	3.11	X			Continue effort; issue solicitation for new projects.
FC-7	*Electrodes for Hydrogen-Air PEM Fuel Cells*, LANL	2.91	X			Determine threshold of sulfur poisoning.
FC-8	*High-Temperature Polymer Membranes*, ANL	2.64	X			Focus on increasing proton conductivity and durability.
FC-9	*Development of Polybenzimidazole-based, High-Temperature MEAs*, Plug Power	2.83	X			Continue development effort targeted towards stationary applications.
FC-10	*Enabling Commercial PEM Fuel Cells with Breakthrough Lifetime Improvements*, Dupont	3.27	X			Optimize and refine testing methods, mitigation strategies, MEA structure, composition and processing conditions.
FC-11	*MEA and Stack Durability for PEM Fuel Cells*, 3M	3.02	X			Link accelerated tests to lifetime, and accelerate strategies to mitigate decay mechanisms, including catalyst support.
FC-12	*Development of a Low-Cost, Durable Membrane and Membrane Electrode Assembly*, Atofina Chemicals	2.84	X			Continue development of innovative membrane concept.
FC-13	*New Electrocatalysts for Fuel Cells*, LBNL	3.26	X			Funding increased in FY05; concentrate on surface electronic properties
FC-14	*Low-Platinum Catalysts for Oxygen Reduction at PEM Fuel Cell Cathodes*, NRL	2.71	X			Need to focus on non-Pt catalyst development.
FC-15	*Low-Platinum Loading Catalysts for Fuel Cells*, Brookhaven	3.31	X			Funding increased due to promising non-Pt results.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
FC-16	*Development,, Characterization and Evaluation of Transition Metal/Chalcogen Based Cathode Catalysts for PEM Fuel Cells*, Ballard	3.03	X			New project. Need to incorporate Go-No Go decision points.
FC-17	*Novel Approach to Non-Precious Metal Catalysts*, 3M	3.07	X			New project. Good technical expertise. Need clear milestones/targets.
FC-18	*Novel Non-Precious Metals for PEMFC: Catalyst Selection Through Molecular Modeling and Durability Studies*, University of South Carolina	2.80	X			New competitively selected project. Suggest industry collaboration.
FC-19	*Scale-Up of Carbon/Carbon Bipolar Plates*, Porvair	2.91	X			Good progress. Planned completion in May 2005
FC-20	*Cost-Effective Surface Modification for Metallic Bipolar Plates*, ORNL	3.14	X			Collaboration with NREL producing significant results.
FC-21	*Platinum Recycling Technology Development*, Ion Power, Inc.	2.71	X			Consider including other MEA manufacturers. Consider adding go/no go decision point based on cost benefit analysis.
FC-22	*Platinum Group Metal Technology Development*, Engelhard	2.93	X			Recommend including Nafion recovery. Creative approach, but consider potential environmental effects as well.
FC-23	*Advanced High Efficiency, Quick Start Fuel Processors for Transportation Application*, Nuvera	2.96	X			Modified to focus on stationary application, "Cost-Effective High Performance Advanced Reforming Module."
FC-24	*Fuel Processors for PEM Fuel Cells*, University of Michigan	2.30	X			Complete development phase in FY2005 and do not build 10kW fuel processor.
FC-25	*Plate Based Fuel Processing System*, Catalytica	2.62	X			Complete development phase in FY2005 and do not build 10kW fuel processor.
FC-26	*Quick Starting Fuel Processors - A Feasibility Study*, ANL	2.85			X	Project successfully completed.
FC-27	*Development Status of a Rapid-Cold-Start, On-Board, Microchannel Steam Reformer*, PNNL	2.38	X			Project redirected to offboard forecourt application.
FC-28	*Catalysts for Autothermal Reforming*, ANL	3.17	X			R&D refocused to include SRM and POX for off-board reforming.
FC-29	*Water Gas Shift Catalysis*, ANL	3.00	X			Focus on more active, sulfur-tolerant, and thermally and chemically rugged WGS catalysts.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
FC-30	*Selective Catalytic Oxidation of Hydrogen Sulfide*, ORNL	2.70	X			Should perform measurements at low pressure of H_2S.
FC-31	*Development of a 50kW Fuel Processor for Stationary Fuel Cell Applications Using Revolutionary Materials for Absorption-Enhanced NG Reforming*, ChevronTexaco	2.95	X			Clarify plan to expand to larger plant; test under "real" conditions; use commercial catalyst to verify approach.
FC-32	*Advanced Buildings PEM FC Project*, IdaTech	2.75	X			Continue development. Ensure technology performance before scale-up.
FC-33	*150 kW PEM Fuel Cell Power Plant Verification*, UTC Fuel cells	2.96	X			Continue reliability development through root cause failure analysis.
FC-34	*Back-up/Peak-Shaving Fuel Cells*, Plug Power	2.95	X			Continue development of stacks, freeze/thaw tolerance, and dry carbide operation. Develop contingency plans.
FC-35	*Economic Analysis of Stationary PEM Fuel Cell Systems*, Battele	2.52	X			Economic Analysis needed to determine benefits.
FC-36	*Fuel Cell Systems Analysis*, ANL	3.09	X			Need to come up with specific plans for next fiscal year.
FC-37	*Development of a Thermal and Water Management (TWM) System for PEM Fuel Cells*, Honeywell	2.56	X			New project. Logical plan. Include input from fuel cell developers.
FC-38	*Fiber Optic Sensors for Fuel Cell Applications*, ORNL	2.95	X			Should focus on laboratory-based research needs for multipoint direction.
FC-39	*Atmospheric Fuel Cell Power System for Transportation*, UTC Fuel Cells	2.47	X			Project is planned for completion in early FY2005.
FC-40	*Cost and Performance Enhancements for a PEM Fuel Cell Turbocompressor*, Honeywell Sensing	2.86	X			Ensure final design allows for various operating conditions.
FC-41	*Development and Test of the Toroidal Intersecting Vane Machine (TIVM) Air Management System*, Mechanology, LLC	3.16	X			Good progress. Project is planned for completion in FY2005.
FC-42	*Development of Sensors for Automotive PEM based Fuel Cells*, UTCFC	2.75	X			Project is planned for completion in FY2005.
FC-43	*Sensor Development for PEM Fuel Cell Systems*, Honeywell	2.93	X			Continue development, considering environment for transportation applications.
FC-44	*Neutron Imaging Study of the Water Transport Mechanism in a Working Fuel Cell*, NIST	2.90	X			Concentrate on dissemination of results in the open literature.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
FC-45	*Microstructural Characterization of PEM Fuel Cells*, ORNL	3.44	X			Scope and funding expanded in FY05.
FC-46	*Stack Durability on Hydrogen and Reformate*, LANL	3.80	X			Continue steady-state tests and expand tests over drive cycles
FC-47	*Direct Methanol Fuel Cells*, LANL	3.50	X			Focus on fundamentals of key components.
FC-48	*Modeling and Control of a Solid Oxide Fuel Cell Auxiliary Power Unit*, PNNL	2.73	X			Good progress in collecting real vibration data and modeling thermal stresses. Coordinate with other SOFC efforts.
FC-49	*Bipolar Plate-Supported Solid Oxide Fuel Cell "Tuffcell"*, ANL	3.21	X			Focus on stack sealant and electrical contact issues.
FC-P1	*Fuel Cells Vehicle Systems Analysis*, NREL	3.11	X			Work on environmental effects on fuel cell vehicle operation.
FC-P2	*Cost Analyses of Fuel Cell Stacks/Systems*, TIAX	3.24			X	Project completed; new cost analysis solicitation to be issued.
FC-P3	*Development of Novel CO2-Selective Membrane for H_2 Purification*, Ohio State University	3.05			X	Project successfully completed in FY04.
FC-P4	*Microchannel Reformate Cleanup: Water Gas Shift and Preferential Oxidation*, PNNL	2.72		X		Project discontinued due to fuel processing go/no-go decision.
FC-P5	*Effects of Fuel Composition on Fuel Processing*, ANL	2.56		X		Project discontinued due to fuel processing go/no-go decision.
FC-P6	*Development of Advanced Catalysts for Direct Methanol Fuel Cells*, JPL	2.95	X			Project redirected to focus on cathode catalyst.
FC-P7	*Non-Precious Metal Cathode Electrocatalysts*, ANL	2.39	X			Need to show need for continued study of metal oxides.
FC-P8	*Low-Friction Coatings and Materials for Fuel Cell Air Compressors*, ANL	2.70			X	Project successfully completed.
FC-P9	*Montana PEM Membrane Degradation Study*, Montana State University	3.00	X			New Project. FY04 Congressionally directed.
FC-P10	*High Temp. MEA for PEMFC Device Based on SPEKK Blends*, Oxford Perf. Materials	2.60	X			Congressionally directed project (multiyear).
FC-P12	*Polymer Blend Proton Exchange Membranes*, UConn	2.47	X			Concentrate on temperatures up to 120°C and low relative humidity.
FC-P13	*New Electrocatalysts for Fuel Cells*, Foster Miller	2.30	X			Increase efforts on materials that will have high temperature stability.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
FC-P14	*High Temperature Polymer Electrolytes Based on Ionic Liquids*, LANL	2.60	X			Need to consider alternative polymer backbones and work on water solubility.
FC-P19	*New Polymeric Proton Conductors*, LBNL	2.55			X	Project successfully completed in FY04.
FC-P20	*Fuel Cell Reformer Emissions*, TIAX	2.90			X	Project successfully completed in FY04.
FC-P22	*Residential Fuel Cell Demonstration by the Delaware County Electric Cooperative*, Delaware Co.Electric Co-op	3.12	X			New Project. FY 04 Congressionally directed.
FC-P23	*Smart Energy Management Control Systems*, University of South Alabama	2.55	X			New Project. FY 04 Congressionally directed.
FC-P24	*Graphite Based Thermal Management*, ORNL	2.96		X		Project discontinued. This approach will not meet cost targets.
FC-P25	*CO Sensors for Fuel Cell Applications*, LANL	3.10		X		Discontinued due to no-go decision.
Technology Validation:						
TV-1	*Technology Validation Sub-Program Review*, DOE	3.41				
TV-2	*Power Parks System Simulation*, SNL	2.53	X			Need to make compatible with H2A and with mass production projections.
TV-3	*Hawaii Hydrogen Power Park*, State of Hawaii	3.10	X			Design completed. H_2 Power Park to be installed in Oahu.
TV-4	*DTE Energy Hydrogen Technology Park*, DTE Energy	3.00	X			Station to be opened in November 2004.
TV-5	*Hydrogen from Biomass for Urban Transportation*, Clark Atlanta University	3.05			X	Project successfully completed.
TV-6	*Alkaline Fuel Cell-Battery Hybrid Systems with Ammonia or Methanol as H_2-Supply*, Apollo	2.20			X	Project completed, but had poor program relevance.
TV-7	*UNIGEN® Regenerative Fuel Cell For Uninterruptible Power Supply*, Proton	2.64			X	Project successfully completed.
TV-8	*Controlled H_2 Fleet & Infrastructure Analysis*, NREL	3.32	X			Continue funding. Focus on real world analysis.
TV-9	*Development of a Turnkey H_2 Refueling Station*, Air Products	2.93	X			Achieved 2005 target for purification. Continue effort.
TV-10	*Development of a Natural Gas-to-Hydrogen Fueling System*, GTI	3.02	X			Complete validation of refueling station. Consider collaboration with Air Products on dispenser.

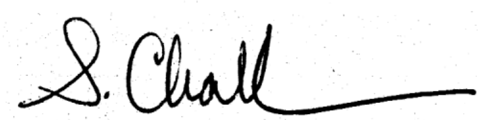
Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
TV-11	*Novel Compression and Fueling Apparatus to Meet Hydrogen Vehicle Range Requirements*, Air Products	3.05	X			Complete validation of novel isothermal compression. Publish performance data when available.
TV-12	*Auto-Thermal Reforming Based Refueling Station at SunLine*, Hydradix/SunLine	2.95			X	Hydradix completed installation. Operation of unit with safety and data collection continues. Publish performance data for generator.
TV-13	*R&D of a PEM Fuel Cell, Hydrogen Reformer, and Vehicle Refueling Facility*, Air Products	2.96	X			Successfully demonstrated meeting co-production target. Need to validate.
TV-14	*LAX Airport Hydrogen Fueling Station - Small Footprint H_2 Capability at the Corner Filling Station*, Praxair	3.13	X			Groundbreaking occurred in June 2004. Station to be completed by November 2004. Provide data on cost and efficiency.
TV-15	*Hydrogen and Natural Gas Blends: Converting Light and Heavy Duty Vehicles*, Collier Technologies	2.90	X			Project to convert nine trucks within six months. Consider hybrid technology.
TV-16	*Fuel Cell Powered Underground Mine Loader Vehicle*, Vehicle Projects	2.95	X			Congressionally directed project (multiyear). Project to be completed in 2005. Consider other applications for this technology configuration.
TV-P1	*Validation of an Integrated System for a Hydrogen-Fueled Power Park*, Air Products	2.80	X			Successfully completed design (phase 1). Include demonstration in next phase.
TV-P2	*Fuel Cell Installation and Demonstration Project In Gallatin County, Montana*, Zoot Enterprises	2.33			X	FY 03 Congressionally directed project. Project completed. However Zoot is currently experiencing operational difficulties. Continuation beyond funded scope not recommended.
TV-P3	*Global Assessment of Hydrogen Based Technologies*, University of Alabama	2.60		X		FY 03 Congressionally directed project. Include industrial partners in existing effort.
TV-P4	*Hydrogen Power Park Business Opportunities Concept Project*, Pinnacle	3.53	X			Modeling activity indicated four potential power park options. Proceed with implementation of APS system.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
TV-P5	*NextEnergy Microgrid and Hydrogen Fueling Facility*, NextEnergy	2.88	X			FY03 Congressionally directed project. Proceed with development of microgrid system. Conduct in depth risk and safety analysis.
TV-P7	*Hydrogen Fuel Project*, RTC of Washoe County	2.50	X			New Project. FY 04 Congressionally directed. Work scope needs definition.
TV-P9	*Renewable Hydrogen Fueling Station System*, University of Nevada-Las Vegas	3.00	X			Congressionally directed project (multiyear). Increase collaboration with other Nevada fueling station.
TV-P11	*Hawaii Hydrogen Center for Development and Deployment of Distributed Energy Systems*, Hawaii Natural Energy Inst.	3.20	X			New Project. FY 04 Congressionally directed. Develop quantitative phased, go/no go decision criteria and contingency plans.
Safety Codes and Standards:						
SCS-1	*Safety and Codes & Standards Sub-Program Review*, DOE	3.46				
SCS-2	*Hydrogen Codes and Standards*, NREL	3.55	X			Continue funding in FY2005 and sustain important collaborations.
SCS-3	*Electrochemical Sensors for PEMFC Vehicles*, LLNL	3.04	X			Focus on cost, durability, and drift for FY2005.
SCS-P1	*Interfacial Stability of Thin Film H_2 Sensors*, NREL	2.89	X			Good laboratory results under ideal conditions will be explored under more demanding conditions.
SCS-P2	*Codes & Standards Analysis*, University of Miami	3.50	X			Will continue for FY2005 and expand scope as funding alter.
Education:						
ED-1	*Education Sub-Program Review*, DOE	3.60				
ED-2	*Baseline Knowledge Assessment*, ORNL	3.48	X			Continue funding in FY05 to complete project.
ED-P1	*Demonstration of a PEM Fuel Cell with On-Site Generation of Hydrogen*, NC State University	2.69	X			Project should be completed in FY05 with no new funding required.
ED-P2	*Washington State Fuel Cell Education and Demonstration Program*, Central Washington Univ.	3.92			X	Project successfully completed in FY04.

Project No.	Project Title, Performing Organization	Average Score	Continued	Dis - continued	Project Completed	Summary Comment
ED-P3	*Development and Dissemination of PEM Fuel Cell Educational Modules*, University of North Dakota	3.17	X			Project should be completed in FY05 with no new funding required.
ED-P4	*Lansing Community College Alternative Energy Center*, Lansing Community College	3.29	X			New Project. FY04 Congressionally directed.
ED-P5	*Shared Technology Transfer Project*, Nicholls State University	2.08	X			New Project. FY04 Congressionally directed.

We would like to express our sincere appreciation to the members of the Peer Review Panel. It is they who make this report possible, and upon whose comments we rely to help make programmatic budget decisions for the new fiscal year. Thank you for participating in the FY 2004 Hydrogen Program Merit Review and Peer Evaluation meeting.

We look forward to your participation in the FY 2005 Merit Review and Peer Evaluation which is scheduled for May 23-26, 2005 in the Washington, D.C. area.



Steven G. Chalk
DOE Hydrogen Program Manager
Office of Energy Efficiency and Renewable Energy

TABLE OF CONTENTS

INTRODUCTION

This report is a summary of comments from the Peer Review Panel at the FY 2004 DOE Hydrogen Program Annual Merit Review, held on May 24-27, 2004, at the Philadelphia Downtown Marriott in Philadelphia, Pennsylvania. The work evaluated in this document supports DOE and the results of this merit review and peer evaluation are major inputs utilized by the Department in making its funding decisions for the next fiscal year.

The objectives of this meeting were to:

- Review and evaluate FY 2004 RD&D accomplishments and FY 2005 plans for DOE laboratory programs and industry/university cooperative agreements.
- Provide an opportunity for program participants (hydrogen production manufacturers, hydrogen storage manufacturers, fuel cell manufacturers, etc.) to help shape the DOE sponsored R&D program so that the highest priority technical barriers are addressed. The meeting also serves to facilitate technology transfer.
- Foster interactions among the universities, industry and national laboratories conducting the R&D.

During the plenary session on the first morning, all four DOE offices involved in Hydrogen Fuel Initiative activities (FE, NE, EE and SC) each gave overviews of their programs. Those presentations became a prelude to the 2005 Annual Merit Review, which will expand in scope to cover projects of the entire DOE Hydrogen Program. Projects from FE, EE and NE will be reviewed next year, and an introduction to the set of projects to be awarded by SC in 2005 will be provided.

The Peer Review process followed the guidelines of the Peer Review Guide developed by EERE. The Peer Review Panel members, listed in Table 1, attended the meeting and provided comments on the projects presented. These panel members are peer experts from a variety of hydrogen and fuel cell related backgrounds including national laboratories, hydrogen production manufacturers, hydrogen storage manufacturers, fuel cell manufacturers, universities, and other U.S. Government agencies. They were screened from a conflict of interest (COI) perspective per the Peer Review Guide. A complete list of the meeting participants is presented as Appendix A.

Table 1: Merit Review Panel Members

No.	Name	Organization
1	Radoslav Adzic	Brookhaven National Laboratory
2	Michele Anderson	Office of Naval Research
3	Raymond Anderson	Idaho National Engineering and Environmental Laboratory
4	Don Anton	United Technologies Research Center
5	Tim Armstrong	Oak Ridge National Laboratory
6	Paolina Atanassova	Cabot Superior Micropowders
7	Carol Bailey	SENTECH, Inc.
8	Addison Bain	Consultant
9	Jay Bauman	DuPont Fuel Cells
10	Farshad Bavarian	Chevron Texaco
11	Bud Beebe, SMUD	Sacramento Municipal Utility District

No.	Name	Organization
12	Thomas Benjamin	Argonne National Laboratory
13	Larry Blair	Consultant
14	Alex Bogicevic	Ford
15	Rod Borup	Los Alamos National Laboratory
16	Lynnae Boyd	National Renewable Energy Laboratory
17	Dick Bradshaw	Stirling Strategic Services, LLP
18	Rich Carlin	Office of Naval Research
19	Eric Carlson	TIAX
20	William Chernicoff	Department of Transportation – Volpe
21	Russell R. Chianelli	University of Texas at El Paso
22	Prashant Chintawar	Nuvera
23	Hongli Dai	DuPont
24	Davison, Brian	Oak Ridge National Laboratory
25	Mark Debe	3M
26	Emory DeCastro	Etek Denora
28	Glenn Eisman	Plug Power
29	Feinberg, Ed	Consultant
30	Karl Fiegenschuh	Ford
31	Scott Freeman	DaimlerChrysler
32	Don Frikken	Becht Engineering Company St Louis Office
33	Alexi Gabrielov	Shell Hydrogen
34	Esin Gulari	National Science Foundation
35	David Haberman	IF,LLC
36	Pat Hagans	UTC Fuel Cells
37	Jim Hansel	Air Products and Chemicals, Inc.
38	Mike Heben	National Renewable Energy Laboratory
39	Shinichi Hirano	Ford
40	Nashat Jalil	Daimler Chrysler
41	Craig Jensen	University of Hawaii
42	Will Johnson	W L Gore
43	Scott Jorgensen	GM
44	Maurice	State of Hawaii
45	Michael Kelly	Millennium Cell, Inc.
46	John Kerr	Lawrence Berkeley National Laboratory
47	John Kopasz	Argonne National Laboratory
48	Theodore Krause	Argonne National Laboratory
49	Romesh Kumar	Argonne National Laboratory
50	Daniel Loffler	IdaTech
51	Melissa Lott	QSS Group, Inc.
52	Andy Lutz	Sandia National Laboratories
54	Len Marianowski	Gas Technology Institute
55	David Masten	GM

No.	Name	Organization
56	Jim McGrath	Virginia Tech
57	Gerald Meyer	Johns Hopkins University
58	Jeremy Meyers	UTC Fuel Cells
59	Mike Miller	Southwest Research Institute
60	William S. Millman	Office of Basic Energy Sciences, DOE
61	Kevin Mills	U.S. Army
62	Michael Niehues	DaimlerChrysler
63	George Parks	Conoco Philips
64	Richard Paur	Army Research Office
65	Larry Pederson	Pacific Northwest National Laboratory
66	Guido Pez	Air Products & Chemicals, inc.
67	Harold L. Phillippi	Exxon Mobil Research and Engineering
68	Walter Podolski	Argonne National Laboratory
69	Michael Quah	NextEnergy
70	Rick Rocheleau	Hawaii Natural Energy Institute
71	Mark Roelofs	DuPont
72	Jerry Rogers	GM
73	Philip Ross	Lawrence Berkeley National Laboratory
74	Gary Sandrock	SunaTech, Inc.
75	Bill Schank	Ford
76	Ed Schmetz	Department of Energy
77	Jesse M. Schneider	DaimlerChrysler RTNA
78	Andreas Shell	DaimlerChrysler
79	John Shen	Department of Energy
80	Ron Sims	Consultant (retired Ford)
81	Carl Sink	Department of Energy
82	William Smith	Infinity Fuel Cell and Hydrogen, LLC
83	Rhoads Stephenson	Motor Vehicle Fire Research Institute
84	Ken Stroh	Los Alamos National Laboratory
85	Robert Sutton	Argonne National Laboratory
86	Scott Swartz	NexTech
87	Amy Taylor	Department of Energy/NE
88	George Thomas	Sandia National Laboratories
89	Levi Thompson	University of Michigan
90	Doanh Tran	DaimlerChrysler
91	James Ulhlein	BP
92	Francisco Uribe	Los Alamos National Laboratory
93	Suellen V Ooteghem	Brookhaven National Laboratory
94	Nick Vanderborgh	Consultant
95	Victor Maroni	Argonne National Laboratory
96	Gerald Voecks	GM
97	Fred Wagner	GM

No.	Name	Organization
98	Brian Weeks	Texas Energy Center
99	Jim Wegryzn	Brookhaven National Laboratory
101	Doug Wheeler	Consultant
102	John Williams	Quantum
103	Keith Wipke	National Renewable Energy Laboratory
104	Chris Wolverton	Ford
105	Bob Wysocki	Shell
106	Bob Zalosh	Worcester Polytechnic Institute
107	Tom Zawodzinski	Case Western Reserve University
108	Ragaiy Zidan	Savannah River National Laboratory

SUMMARY OF MERIT REVIEW PANEL'S CROSS CUTTING COMMENTS AND RECOMMENDATIONS

The Peer Review Panel members provided a number of comments and recommendations that apply to the Annual Merit Review and peer review process, as well as overall management of the DOE Hydrogen Program. These comments are provided in Appendix B of this report. DOE will utilize these comments to improve both the program and future review meetings.

ANALYSIS METHODOLOGY

As shown in Table 1, a total of **108** panel members participated in the merit review process. A total of **164** project presentations were given at the meeting and a total of **1095** review sheets were received from the Peer Review Panel (not every panel member reviewed every project). These members were asked to provide numeric scores (on a scale of one to four, with four being the highest) for five aspects of the research on their Evaluation Form, a sample of which can be found as Appendix C to this report.

The five aspects were:

- Relevance to overall DOE objectives;
- Approach to performing the research and development;
- Technical accomplishments and progress toward achieving the project and DOE goals;
- Technology transfer and collaborations with industries, universities, and other laboratories; and
- Approach to and relevance of proposed future research.

The numeric scores given to each project by the reviewers were averaged to provide the overall score for that project for each of the five criteria. An average score for the five criteria was also calculated within each of the project categories. In this manner, a project's overall score can be compared to other projects in that category.

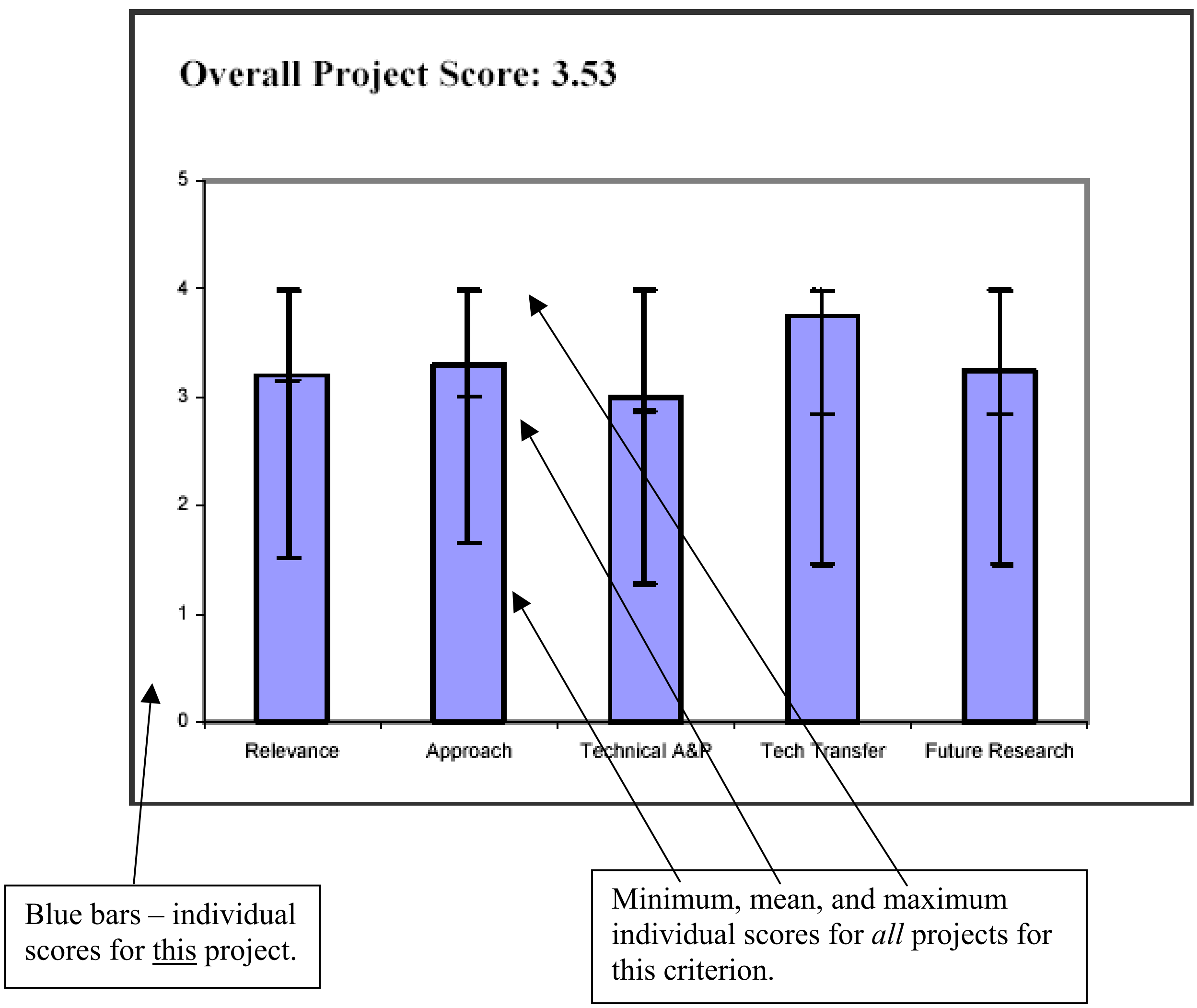
Reviewers were also asked to provide qualitative comments on the five research aspects, as well as the specific strengths and weaknesses of the project, and any recommendations for additions or deletions to the work scope.

These comments, along with the quantitative scores, were placed into a database for easy retrieval and analysis. These comments are summarized in the following sections.

ORGANIZATION OF THE REPORT

This report is organized in six sections, in an effort to group projects according the sub program in which they fall in DOE Hydrogen Program planning. A brief description of the general type of research being performed in each category is presented.

The remaining pages of each section present the results of the analysis for each of the projects discussed at the merit review. A summary of the qualitative comments is provided, as well as graphs showing overall score and how the particular project compared with all other projects presented. An example of a graph is provided below:



Production and Delivery

Summary of Annual Merit Review Hydrogen Production and Delivery Subprogram

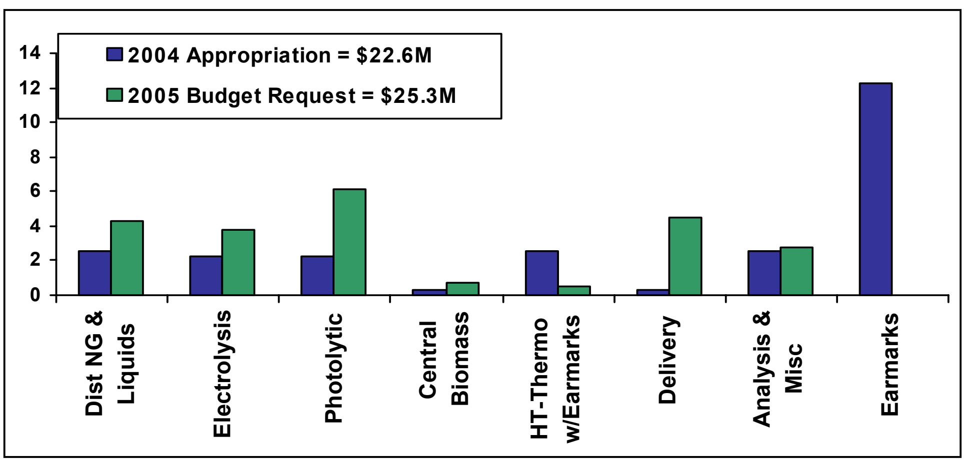
Summary of Reviewer Comments on Production and Delivery Subprogram:

Reviewers identified the Production and Delivery Technologies Subprogram to be an essential component to the Hydrogen Program mission, and critical to the success of the President's Hydrogen Fuel Initiative. The production and delivery projects are considered to be appropriately diverse and strongly focused on addressing key issues necessary to reach technical targets.

In general, the reviewers noted that the Production and Delivery Subprogram has good coverage of possible paths to production, progress was made towards goals from 2003, and the Subprogram has a well-balanced portfolio. Some reviewers commented that projects have made significant progress toward technology commercialization.

The major concerns identified in some areas by reviewers were: 1) collaboration roles with other research organizations need to be clarified; 2) key assumptions underlying process economics need to be stated; 3) criteria for project success need to be better defined; and, 4) specific technology development needs to be reviewed as part of an overall hydrogen energy system. Reviewers further identified the need for increased clarity in economic evaluations including price assumptions and "per mile" costs.

Hydrogen Production and Delivery Funding by Technology:



Majority of Reviewer Comments and Recommendations:

In general, the reviewer scores for the Production and Delivery Subprogram are comparable with or slightly higher than those of the other Subprograms (the maximum, minimum, and average scores for Production and Delivery are 3.53, 2.20, and 3.00, respectively). These scores compare to the overall Hydrogen Program maximum, minimum, and average project scores of 3.92, 1.55, and 2.92, respectively. The Production and Delivery Subprogram portfolio includes a mix of projects, from well-defined research activities that are succeeding to new projects with little to no progress or technical accomplishments yet to report.

The major recommendations for the Production and Delivery Subprogram are summarized below. DOE will act on reviewer recommendations as appropriate for the overall Hydrogen Production and Delivery effort.

- **Separations:** Some reviewers stated that DOE should focus on using advanced separations technologies to improve the economics of small-scale distributed systems and clarify if membrane fabrication costs are included in the material cost targets. Other reviewers said that the costs and commercial viability of membrane reactor systems should be considered.

- **Distributed Production Technologies:** The reviewers stated DOE should focus on applications that produce high-purity hydrogen for PEM fuel cells by improving the amount of hydrogen separated per mole of methane and de-emphasize partial oxidation processes that produce less hydrogen per mole of methane.

- **Photobiological**: Reviewers commented that the projects in this area were tightly focused on overcoming very specific barriers at the possible expense of meeting longer-term goals. Overall, the reviewers felt that systems analysis and engineering should be performed in this technology area to determine whether success could lead to meeting DOE hydrogen production goals of being competitive with traditional fuels. Reviewers saw good collaboration and progress.

- **Photoelectrochemical:** Sufficient funding in this area for long term development is lacking, however some progress was made since last year. A concern of reviewers is that this area represents a "splintered" collection of smaller projects, and that a dedicated, multi-disciplinary program that is well organized and integrated should be put in place.

- **Electrolysis**: The reviewer comments were generally favorable in the area of regenerative solid-oxide electrolyzer cells for hydrogen production from steam, but future work plans had not been defined. Technology transfer and collaboration got lower ratings from reviewers. The advanced electrolysis work received lower scores primarily because there are new projects in this area and not much progress had been made.

- **High Temperature Thermochemical:** The reviewer comments were generally favorable for projects in this area. The analytical approach to screening all possible solar driven thermochemical cycles against well chosen criteria and establishing a public database for this information was viewed positively. Some concern was raised that too much effort was placed on analytical screening and not enough effort on experimental work. The reviewers viewed this approach to hydrogen production as important to pursue.

- **Biomass:** The reviewers raised concerns that there are several projects in the biomass pyrolysis reforming area that could be combined with clearer focus on the program goals.

Reviewers also had concern over the small degree of progress, although most of the projects in this area began this year.

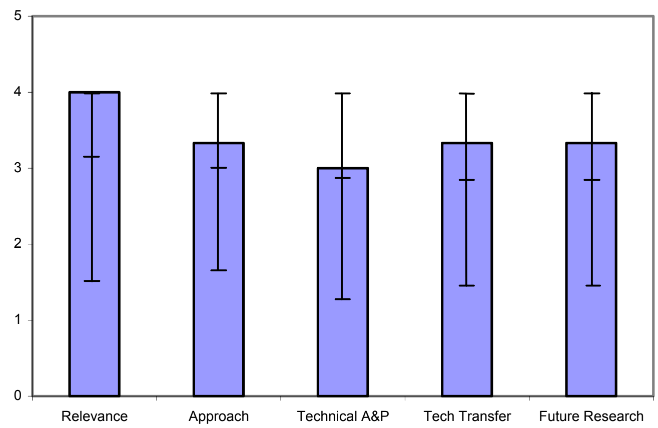
- **Analysis:** This area received generally high scores from reviewers. The reviewers suggested developing consensus forecasts in major scenarios depicting different types of transitions, e.g. import reduction, fossil reduction, and alternate energy breakthroughs. Good technology transfer and collaboration was recognized and the results appear to be useful tools. Future work needs to be defined.

Project # HPD-1: Hydrogen Production and Delivery Subprogram Overview
Devlin, Pete; DOE, Team Lead

Brief Summary of Presentation

The purpose of this Hydrogen Production and Delivery Subprogram Overview and introduction is to describe subprogram goals/objectives, budgets, barriers/targets, approach to R&D, technical accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and puts into context the R&D and analysis projects which will be presented in this subprogram area during the Annual Merit Review.

Overall Project Score: 3.40



Question 1: Relevance to overall DOE objectives

This presentation earned a score of **4.00** for its relevance to DOE objectives.

- A good overview for audience members not overly familiar with this particular subprogram.
- Good summary presentation. Split shown among near and long-term R&D, with different targets and goals. Good summary of key barriers in each.
- Production: at what pressure?
- Resource Price Assumption - Delivery: per mile? At what pressure? Pipe? On-site?
- Very clear -- targets, quantitative, gains, and challenges clearly described.

Question 2: Approach to performing the research and development

This presentation was rated **3.33** on its approach.

- Electrolysis should be compared with battery as storage technology.
- Impact of natural gas demand needs attention- transition must be managed.
- Overall natural hydrogen production goals need to be set.
- Confirm a detailed roadmap has been/ will be developed for each identified barrier.
- "Sharply focused" does not apply, but a portfolio approach is exactly what is called for.
- Challenges clearly described. Plans described, but unclear as to how plans address challenges.
- Judging from the TDM presentation, I would say it is good. However, this was not reflected in all the talks that followed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This presentation was rated **3.00** based on accomplishments.

- More details on accomplishments would have been useful- annual progress as well as comparison with target.
- Key milestones were noted to be measured against a "design" as opposed to prototype and proven.

- Confirm milestone measurement is to be used on theory (design) or proof of principal.
- Most areas making good progress.
- Delivery just started.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.33** for technology transfer and collaboration.

- Complexities of relationships could become a barrier.
- Consider setting up competitive contest between researchers in few areas.
- Collaboration is fundamental to the effort.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.33** for proposed future work.

- Program for selecting future projects seems effective.
- Confirm/ consider integration of coal into the fuels for conversion.
- Sidebar: I believe coal is in the plan as a solid fuel, but was not in the presentation.

Strengths and weaknesses

Strengths
- Good coverage of possible paths to production.
- Good progress in goal specification from 2003.
- Production has well-balanced portfolio.

Weaknesses
- Does not address National goals for hydrogen production. What volumes would be necessary in 2010? 2015? How does the plan address this?
- What are resource price assumptions (NG, Biomass, etc.). Tech collaboration needs further specification.
- Too many general cooperative agreements.
- H_2 production streams need to state/ pressure/ temperature specifications.
- As shown, the costs imply only cost of production, not total cost. Although the focus is hydrogen, a complete picture, consider, where appropriate, showing costs of H_2 to include base fuel costs.
- All goals are set in a $ basis. Confirm what year is used as a basis for projected financial goals.
- Consider increasing design/operational pressure goals for all projects up to 15,000 - 20,000 psi. Dependent upon timing for ASME developing design, fabrication and testing requirements.
- Delivery needs definition.

Specific recommendations and additions or deletions to the work scope

- State National goals.
- Set up competition among collaborators.
- Pressure assumptions should be stated.
- Address per mile costs for delivery.
- Compare electrolysis to battery capture.
- Assess impact of natural gas demand.

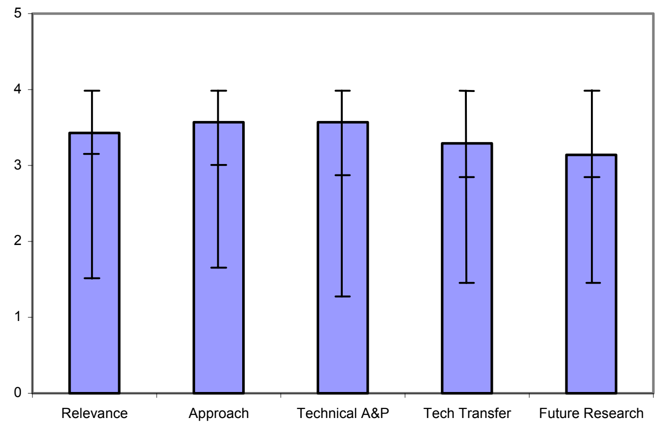
- Set annual progress goals.
- Set resource price assumptions at several levels.
- No mention of nuclear as an engine for H_2 production by thermal or electrochemical processes.
- Subprogram suggestions: (1) Establish several common benchmarked experiments for membranes, such as a "mix" to test H_2 flux, selectivity (or 2 or 3 conditions to reflect different schemes). Other areas have similar challenges to review and compare. (2) Many of the small projects plan some level of economics. Again, a common assessment and how much needed at what level, sets of baseline data of vessels/materials/electricity would help comparisons -- even if a project revises numbers based on their needs and results. (3) Examine ways to link small with larger projects, even if informally.

Project # HPD-2: Ceramic Membrane Reactor Systems for Converting Natural Gas to Hydrogen (ITM Syngas)
Chen, Christopher; Air Products and Chemicals Inc.

Brief Summary of Project

In this project, Air Products and Chemicals, Inc. is working towards developing ceramic membrane reactor systems for converting natural gas to hydrogen and synthesis gas for liquid transportation fuels. The reactor is intended to be scaled up through pilot-scale testing and pre-commercial demonstration. Technical, engineering, operational and economic data necessary for full commercialization is being collected and analyzed.

Overall Project Score: 3.40



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.43** for its relevance to DOE objectives.

- Significant development for H_2 production if successful.
- Scale of demo appropriate for project.
- Estimate of $ significance of membrane to entire process would be useful.
- A novel technology with great promises.
- Potentially an important project in meeting significant targets.

Question 2: Approach to performing the research and development

This project was rated **3.57** on its approach.

- Good engineering of compact micro channel reactor, especially mechanical design.
- Using chemical potential for O_2 to drive transport vs. change in p is a good approach.
- Good mix of basic (material development) and applied (fabrication, manufacturing) research.
- Confirm the progress plans with other (downstream) processes for such items as CO/CO_2 control and additional hydrogen purification.
- A well thought approach was presented.
- Discussions on issues related to the interfacing between oxygen transport and methane reforming could be expanded.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.57** based on accomplishments.

- Impressive results.
- Good work with PDU and increasing flux.
- Would be good to know how the economics look, i.e. how much would better flux help?
- Met target! Very encouraging.

- 39% balance of plant cost reduction is impressive.
- Creep exposure/ failure is a function of pressure, temperature, and time.
- Consider adding the time factor into the creep summary analysis; define service life at various conditions.
- Consider adding methodology for consistent creep analysis, e.g. Omega, Miller, etc.
- Maybe helpful if 05/03-05/04 accomplishments were highlighted.
- Is a housing needed for the ITM module? If so, what is the arrangement?
- No data to show the ITM performance for carrying out the methane reforming.
- Met or exceeded goals.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.29** for technology transfer and collaboration.

- Ok. Hard to evaluate with one slide but not critical.
- Role of other industrial participants were adequately discussed.
- Lots of collaborations listed, but no indication of how each is involved.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.14** for proposed future work.

- High cost/ long term project.
- Reaching the point where DOE funding should begin to be phased out.
- There's still room for improvements but there does seem to be headroom.
- Working on partial oxidation catalyst for CH_4.
- Looks good.
- Continuing according to plans.
- Good promise for generating economically viable process.
- Seal reliability key for commercial operation.
- No milestone to show the progressing of ITM performance in methane reforming, such as target goals, potential problems (if any).
- Mainly focused on scale-up/ demonstration.

Strengths and weaknesses

Strengths
- Good collaborations and interactions with others.
- Good approach and concept.
- Potentially very energy efficient.
- Good engineering and effective materials development.
- An enthusiastic PI.
- 56% industry cost share (reflects corporate commitment).
- Good approach; research carried out well.
- Shows value of integration approach rather than simply trying to develop a material that might not be fabricated into a real device.
- A very good presentation.
- Cost sharing by contractors was substantial.
- Overall solid, valuable work.

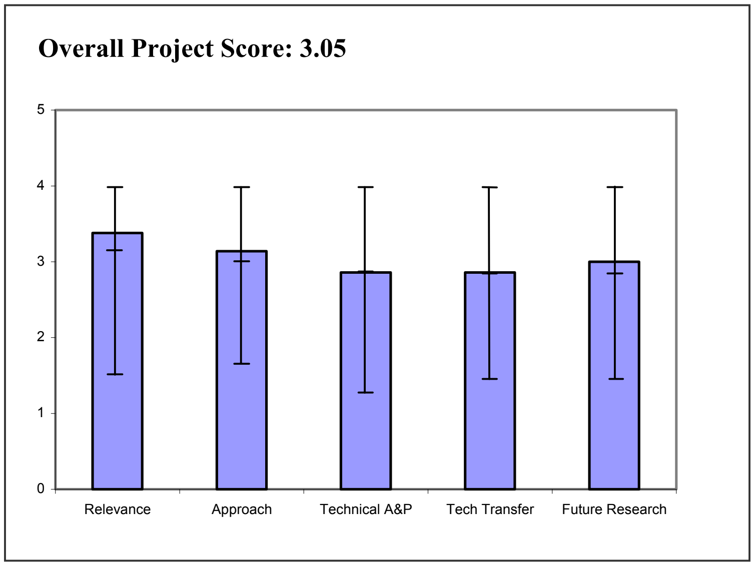
Weaknesses

- Partial oxidation produces less H_2 per CH_4 then steam reforming. This gives a H_2/CO ratio more appropriate for FT synthesis liquids.
- Lack of demonstrated time on test.
- May be less head room than the presentation implied.
- Would like to have heard what the particular barriers are to commercialization.
- Heard the good news, but wondered about possibly undiscussed bad news.
- Scope and details of the technical data presentation could be expanded.

Specific recommendations and additions or deletions to the work scope

- Discuss whether this technology is applicable for distributed H_2 production or only large scale production.
- Consider showing H_2 production costs that include cost of base material, in this case, natural gas.
- Inclusion of a "conclusions" slide would be helpful.

Project # HPD-3: Integrated Ceramic Membrane System for H_2 Production
Schwartz, Joseph; Praxair, Inc.



Brief Summary of Project

In this project, Praxair, Inc. is developing an integrated ceramic membrane system for hydrogen production. The objectives of this project are to perform technoeconomic feasibility analysis for the system and define the development needed to prepare the concept for pilot testing and demonstration.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.38** for its relevance to DOE objectives.

- Direct relationship between project and DOE objectives not described.
- This membrane work has wide applicability in meeting H_2 production targets.
- Far from DOE targets in some cases.
- Not deeply concerned about safety criteria yet.
- Value of H_2 separation obvious to program.
- Pd membranes obvious choice of costs are reasonable.
- Combining water-gas shift reaction and H_2 separation in one step is critical in reducing H_2 production cost.
- Potentially a useful component, if targets can be met.

Question 2: Approach to performing the research and development

This project was rated **3.14** on its approach.

- Approach is focused on overcoming barriers such as thin film limitations and flux.
- Shouldn't Pd-Cu alloy be looked at?
- Though no- no go decision points were mentioned, the criteria for the decisions were not given.
- Pd-Ag technology is out-dated.
- 1.8 micrometers Pd-metal film a challenge.
- Reasonable approach.
- Not sure of novelty.
- Long history of Pd membranes for hydrogenation- none commercialized due to membrane fouling and costs.
- A well-thought approach was presented.
- Discussions could be expanded on issues related to the interfacing between water-gas-shift reaction and H_2 transport through membrane.
- Adequate approach, but not clear flux target will be met.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.86** based on accomplishments.

- Likely to not meet DOE flux goal.
- No test protocol for analyzing affects of trace impurities (H_2S, CO) on performance.
- Pace of effort seems slow and uninspired. Won't demo 50,000 hours durability for FY 2005.
- Good results on flux.
- 1% of capital is a good result.
- Difficulty with fabrication/sealing?
- Good to see what's needed for DOE flux target (1.8 microns).
- Lacks details on the technical accomplishments (e.g. substrate choice, experience with Pd alloys selection, and Pd film deposition).

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.86** for technology transfer and collaboration.

- Limited to 2 performing partners.
- Why internal development of support tube? Vendors exist (Pall, Moot), but were not utilized.
- Commercialization is within the realm of the contractor.
- Research institute is leveraged.
- PI stated intention to add partners as needed.
- Praxair seems resistant to partnering.
- Limited collaboration, but not critical.
- Might look for alloy (S or CO tolerance) or WGS experts in universities or National Labs if internal experts aren't available.
- Praxair has assembled a good team.
- Who is to provide water-gas-shift reaction expertise? Is it needed?
- Not a large number of collaborators, but good interaction.
- Might benefit from collaboration with someone with a better membrane technology.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Key test information lacking.
- Clear understanding of need to meet targets or get on to something else.
- Emphasis on the "reasonable time frame."
- Doing reaction may be much more difficult due to fouling.
- Should consider fabrication costs- are they comparable to materials costs?
- Contaminant work will be critical.
- A good plan to include critical steps.
- Performance targets for the HTM were not adequately discussed e.g. hydrothermal stability, durability.

Strengths and weaknesses

Strengths
- Good progress in past year.
- Clear goals.
- Clear go/no-go measures.
- Cohesive project.
- Good approach and results look promising.
- Next year should identify barriers.
- Has made good progress since May 03.

Weaknesses
- Partial oxidation produces less H_2 per CH_4 than steam reforming.
- Choice of membrane material prone to react with H_2S/CO.
- Process economics not presented -- how were they arrived at?
- Seems to have high risks for failure.
- Need to define criteria for success.
- Not sure how much fundamental work has been done to look at potential problems and approaches to optimizing alloys.
- Discussions on the water-gas-shift reaction were not adequate (catalyst choice, reaction type).
- Inclusion of a "conclusions" slide would be helpful.
- Not clear that this technology can meet flux target.

Specific recommendations and additions or deletions to the work scope

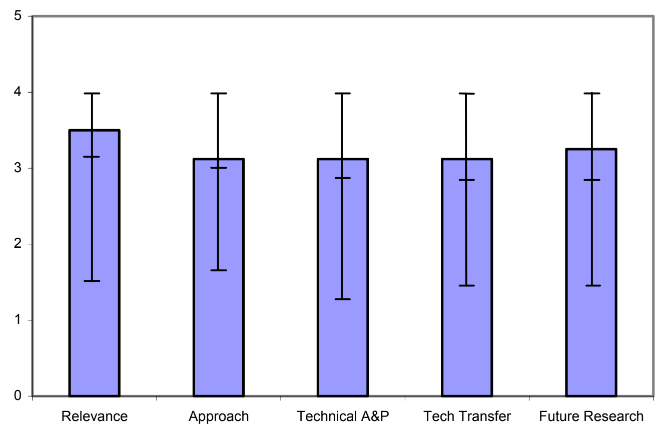
- Effect of contaminants should be looked at soon -- CO and S in particular.
- Applicable to steam reforming?
- Suggest WGS catalyst partner as a good idea.
- Need new membrane material.
- Systems approach -- make sure work is focused on the total system, including catalysts, operating temps.
- Consider collaboration with HPD-5 or HPD-7 projects.

Project # HPD-4: Low Cost Hydrogen Production Platform
Aaron, Tim; Praxair, Inc.

Brief Summary of Project

In this project, Praxair, Inc. is working towards the development of a low cost hydrogen production platform. Their efforts include defining process/equipment concepts and developing preliminary designs suitable for mass production of a small on-site hydrogen system; performing a technoeconomic study; and developing business cases regarding the viability of the development project. Using steam methane reforming and purification process technologies as the base case, they will evaluate different systems and identify the system most likely to be commercially viable when mass produced.

Overall Project Score: 3.22



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Very useful for intermediate need for distributed H_2 production.
- Objectives need to be more clearly stated.
- Project appears to integrate a system, which is relevant, but little detail is given.
- DFMA approach is relevant.
- Good for near term optimization of existing technology.
- A very useful study to guide future R&D work.
- Useful study of significant portion of an important system.

Question 2: Approach to performing the research and development

This project was rated **3.12** on its approach.

- Very practically oriented.
- Weak in the "research" aspects.
- Approach light on details.
- Used best practice engineering design approach.
- Not much detail on approach.
- Packaging of the off-the-shelf technologies.
- 33% cost share by Praxair.
- Design for manufacturing and assembly is good tool for program.
- Should give estimate of best costs for existing technologies.
- Good look at what's required for total system vs. components.
- Relationship between this project and the H_2 refueling stations in operation was not adequately discussed.

- Should have included compression, storage and dispensing in scope of this project; participation in other projects does not have the focus on DFMA that this project has.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.12** based on accomplishments.

- Making good progress toward a very practical approach for distributed H_2 production.
- Good progress towards meeting cost targets.
- It looks like cost targets will not be achievable within constraints of this project.
- Close to meeting 2005 cost target, have already met target at some sizes.
- Not obvious how much has been added from last year given large increase in spending.
- Probably significant progress, but isn't necessarily evident.
- How much were savings on high temp component?
- Hiatus due to late funding seems to have slowed project down.
- Improvement in optimized system (reduced mass of system, reduced parts and assembly complexity, and increased thermal efficiency) was not quantified.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.12** for technology transfer and collaboration.

- Technology transfer/collaboration generally not applicable.
- No university or National Lab involvement, but industry participants are highly qualified.
- ISO work valuable.
- Probably no need for academics.
- DFMA expertise in universities?
- Good collaboration between a few participants.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- On target.
- This is brute force engineering, not much innovation.
- Looks good.
- On track.
- Demonstration-focused.
- Appropriate for chosen scope.

Strengths and weaknesses

Strengths
- Related Praxair activities aid the project.
- Although not strongly research-oriented, a high value project.
- Good collaborations and progress!
- Best possible approach.
- Economic evaluations done periodically to gauge progress.
- The product should work (i.e. make hydrogen).

- Good basic approach for minimizing costs.
- Thorough integration.
- A useful study to show incremental improvement in the proposed system.
- Addresses a useful issue using current technology.

Weaknesses
- What are the innovations that contribute to achievement of the DOE goal?
- Will it really turn out to be "low cost?"
- Innovations for the proposed work were not adequately discussed.
- Inclusion of a "conclusions" slide would be helpful.
- Application of DFMA to compression/storage/dispensing would have been a valuable addition.

Specific recommendations and additions or deletions to the work scope

- Other organizations working on similar units - how do they compare?
- Evaluate impact of new technologies such as membranes on cost projections.
- Would benefit from extension to potential new technologies (Praxair H_2 membrane)?
- Improvement potential in compression, storage, and dispensing, if any, should be discussed.
- Expand to a complete package (compression/storage/dispensing).
- Can interactions between this project and ongoing refueling stations be increased?

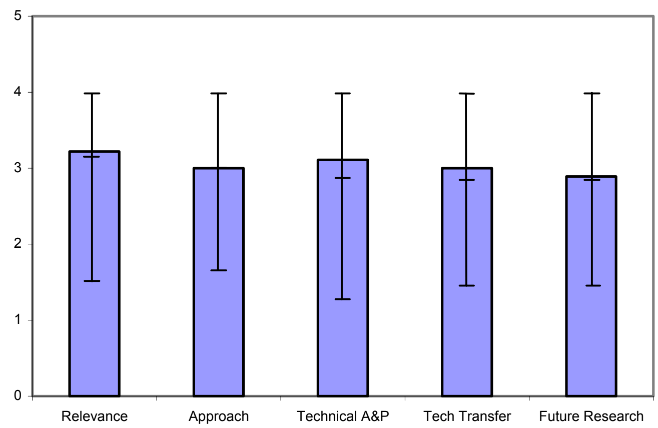
Project # HPD-5: Defect-free Thin Film Membranes for H_2 Separation & Isolation

Nenoff, Tina; Sandia National Laboratories

Brief Summary of Project

In this project, Sandia National Laboratories (SNL) is working towards synthesizing defect-free thin film membranes for H_2 separation and isolation which can replace existing expensive and fragile Pt catalysts. This work includes testing the separation of light gases (pure and mixtures) through the membranes and demonstrating effective light gas separations and commercialization potential of zeolite membranes. SNL will model the permeation of light gases through various frameworks/pores for optimized performance and validate them with actual permeation data obtained through tests on a unique in-house permeation unit.

Overall Project Score: 3.04



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.22** for its relevance to DOE objectives.

- Goal is clear and holds promise.
- Membrane separation of H_2 is relevant and likely critical to achieving the objectives, but the project's focus on real-world application was not readily apparent.
- More of a science program.
- Not clear exactly where it fits into the vision in the near term.
- Probably longer range solution-higher risk than some other membrane technologies.
- Effectiveness of zeolite to separate/purify hydrogen has yet to be established.
- Potentially a useful component.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Test procedures need to be flushed out with discussion on temperature, pressure, sensitivities (impurities).
- Barriers identified and comprehensively addressed.
- Fostering industrial contacts is important, and a systems analysis component of the project should be considered to meet the challenges in operation of a fuel processor.
- Conceptually well thought out approach. But is it really producing "defect free" films?
- Steam stability at 600C? What is the critical selectivity required. Selectivity doesn't not seem that high.
- How does this compare to other ceramic membranes?
- Good balance of membrane materials synthesis and testing.

- Confirm the process plans to the interface with other (up and downstream) processes for CO/CO_2 control and additional hydrogen purification.
- No comments were made in comparing the zeolite film growth technique used in this work with those by other researchers.
- Importance of temperature on zeolite performance was not discussed adequately. Will 300C (FY 05 plan) be the optimum temperature?
- Good work on fundamental understanding to date.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.11** based on accomplishments.

- Project more focused than last year.
- Explain separation factor so audience knows what it means and its impact.
- Issue of tests at various temperatures addressed.
- Making progress in determining selectivity, temperature effects.
- Good progress for $200K.
- In some sense, the project is approaching a few of the key performance indicators.
- Good work measuring selectivities and evaluating membranes.
- H_2S and H_2O work good.
- Some very good H_2/CO_2, CO, CH_4 separation selectivities with missed vis-à-vis pure gases. But this means that membrane performance prediction, i.e., its engineering modeling will be a challenging problem, but one that has to be touched.
- Technical details were inadequate (e.g., substrate choice, film deposition technique and significance of "defect filled" and "defect free").
- Have made good progress on most of approach to date, need to move on to a specific application, rather than hypothetical gas mixtures.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Interactions appear appropriate for this project.
- Are any of the industrial partners actually potential customers of the technology? If not, they should be.
- Good partnership with university for meeting and simulation.
- Visibility in research community is good.
- Getting "free" materials from informal collaborators.
- Forging university collaborations.
- Good publication record.
- Ok.
- Pall is a good partner.
- High temperature collaboration is key.
- A number of collaborators.
- The PI is trying to make things happen.
- Presentations, but no real collaboration. Would benefit from collaboration to move the technology along.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.89** for proposed future work.

- Focus on testing.
- Obvious "voids" from work in 03/04 now identified.
- Future work plan is appropriate.
- There may be better ways to create a non-porous film architecture (on a suitable support) than this project is focused on.
- Keep tight focus.
- Move to high temperature is critical.
- Modeling is critically needed for understanding and hence predicting membrane performance with mixed gases.
- Good plan to do membrane testing at elevated temperature.
- Heading in the right direction.

Strengths and weaknesses

Strengths
- Beneficial partnerships.
- Work focused on more promising means of success and objective of lowering process cost.
- Enthusiastic PI.
- Well executed.
- Novel membrane approach for H_2.
- Project is proof of principle.
- Zeolite membrane performance data were reported.
- Promising piece of the puzzle.

Weaknesses
- Low temperature membrane - what is working range of temperature and pressure?
- Zeolites are steam sensitive - is this taken into consideration?
- Will $Si(OH)_4$ be an issue?
- Testing appears to be all low temperature - makes this difficult to compare with other technologies.
- How does this membrane's performance compare to others - Pd, microporous, proton transport?
- Low pressure; insufficient H_2 purity.
- Microstructure quality an issue.
- GC analysis may be better than RGA for gas analysis.
- Material balances?
- Inclusion of "conclusions" slide would be helpful.
- Lack of performance data at high temperatures.
- Lack of contacts with industrial companies with expertise in zeolites (e.g. UOP).
- Needs to be evaluated in a specific application.

Specific recommendations and additions or deletions to the work scope

- Need to step up testing.
- Focus on real-world operations and simulate systems performance.
- Continuously evaluate suitability of selected materials.

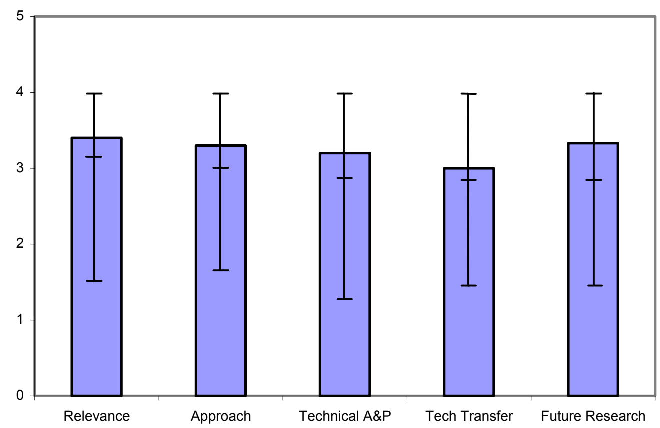
- Electron microscopy in cross-section; use focused ion beam-based extraction methods to produce TEM images of the through-thickness architecture.
- Consider expanding tests to include higher pressures.
- The fundamental aspects of zeolite membrane should be emphasized in this project to advance the know-how in film growth – e.g., role of substrate; variables control which leads to defect free film; trade-off between H_2 flux and selectivity; and collaboration with HPD-3 project?
- Consider adding a task to the project scope that would demonstrate costs and commercial viability.

Project # HPD-6: Autothermal Cyclic Reforming and H_2 Refueling System
Kumar, Ravi; GE Energy

Brief Summary of Project

GE Energy, Environmental Research Corporation and Praxair are designing, fabricating, and demonstrating a reliable and safe H_2 refueling system based on autothermal cycling reforming. This system will be capable of producing 40 kg/day of H_2, sufficient for the refueling of at least 1 bus or 8 cars daily. The project goal is < \$3/kg of hydrogen for 900kg/day units projected for 100's of units per year.

Overall Project Score: 3.25



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- ACR concept opens up new means of lowering small scale SMRs.
- An important project demonstrating significant hydrogen production at the distributed production scale.
- This project addresses demonstration and validation of reforming technologies and provides a benchmark for cost.
- Promising approach for H_2 production.
- An optimized combination of ACR and PSA could offer cost advantages over the current technology.
- Appears ready for relatively near-term deployment, relative to other production technologies.
- A complete package for forecourt NG reforming.

Question 2: Approach to performing the research and development

This project was rated **3.30** on its approach.

- Barriers clearly known.
- Key elements of cost and reliability well underway to be improved.
- Based on subsystem hardware development and system integration followed by testing and validation.
- Focused on integration - can identify issues associated with system integration.
- Stability work good.
- High pressure reforming vs. compression decision?
- A flow sheet with temperature/pressure for each block would be helpful.
- Sound approach for the proposed work.
- Barriers not specifically discussed - difficult to assess how they are being handled. (Need for longer life catalyst discussed).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.20** based on accomplishments.

- Many current performance goals achieved.
- Future goals seem likely to be achieved.
- Significant progress moving toward hardware testing.
- Good engineering performance.
- Good validation of low pressure technology.
- Catalyst lifetime tests look good.
- Modeling for high pressure proceeding well.
- Good integration of GE ACR technology with novel filling method, storage and dispenser.
- Need to confirm stable operations for a long time, continuous run.
- Uniqueness of ACR over conventional reformer was not adequately discussed.
- Integrated operations of all 3 steps (ACR & WGS & PSA) could pose challenges.
- Good progress on PSA and other downstream steps.
- Data presented were not accompanied by (a) pressure and (b) choice of catalysts.
- Seem to be on schedule and making good progress - no discussion of major breakthroughs.
- Very comprehensive evaluation of technology, including start/stop and turndown ratios (both very important for transit forecourt operations) and structural modeling.
- Identified some purification technical targets that are not being met; claimed that they expected to meet them without saying how.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Somewhat limited in coordination with the "user" community.
- Strong team exists but only limited external interaction.
- Would this project benefit from interaction with other DOE related projects?
- Seems to have a close interface between GE and Praxair.
- Good incorporation of Hydro-Pac and Praxair expertise.
- Integration of technologies from various manufacturers.
- Industry partnership exists.
- Good team arrangement.
- Needs expertise help in water gas shift step?
- Good collaboration but with a very limited number of partners.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Realistic project plan.
- Moving to system operation, testing and evaluation.
- High pressure prototype designed and under fabrication.
- Working with ASME to develop new standards for H_2 storage tanks.
- Project on schedule for successful completion.
- Good future work plan.
- Future research seems to focus on process optimization/improvement and increased operating life.

Strengths and weaknesses

Strengths
- Good demonstrated sulfur tolerance.
- A very complex project that is well managed.
- This approach will be important for near-term hydrogen production from natural gas.
- Involves significant industry cost share.
- Performance levels achieved (30 hour continuous operation, 30 start-stop cycles, <0.5% CO from shifts reactor).
- Novel reforming approach with good integration into fueling solution.
- A very interesting process concept which utilizes the expertise of GE and Praxair.
- Innovative, complete forecourt package.

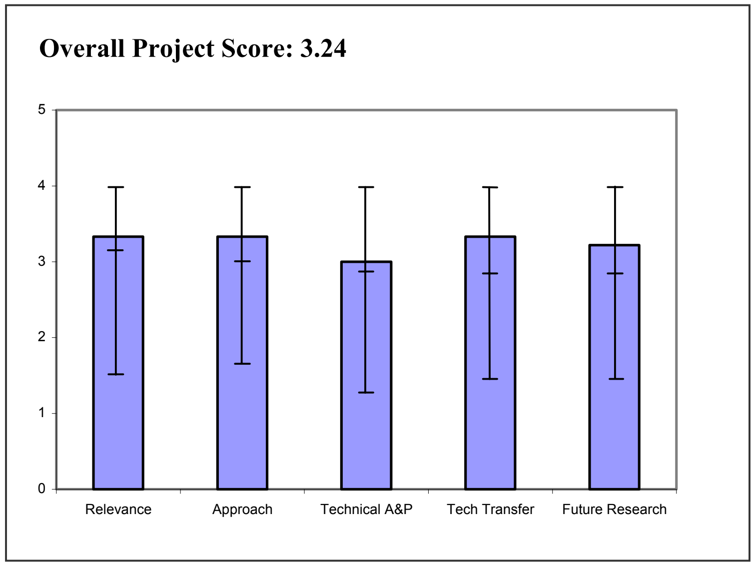
Weaknesses
- Need more time on testing.
- What is the lifetime of the catalyst?
- Final work done now is important, but not quite as novel as development and extension of ACR concept itself.
- Lack of outlines for the proposed operation of integrated system.
- A conceptual discussion would be helpful, e.g., how extensive is the integrated system operation?
- Did not explain in great depth elements being measured in this review.

Specific recommendations and additions or deletions to the work scope

- Explore opportunities for utilizing universities in this project.
- Consider expanding future work to consider higher (15,000-20,000 psi) pressures.
- Performance goal and detailed operation plan needs to be worked out (e.g., startup test duration), extent of integrated operations.

Project # HPD-7: Development of Supports and Membranes for Hydrogen Separation
Armstrong, Tim; Oak Ridge National Laboratory

Brief Summary of Project



This Oak Ridge National Laboratory (ORNL) project will (1) develop porous metal supports for hydrogen separation membranes that are compatible with the supported membrane and operational environment using a flexible fabrication process, and (2) develop thermodynamically stable, high temperature, high proton flux proton transport membranes (PTM) using a computational combinatorial chemistry approach. The latter will expand the computational model under development at ORNL that will allow the materials properties to be predicted based on the electronic properties of the elements of the periodic table.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Innovative work.
- Separation technology is important to hydrogen production goals and objectives.
- Both the substrate and the proton transport membrane aspects of the project are relevant to reducing costs and increasing efficiency.
- Needs to show more progress towards performance targets.
- Consider providing estimated costs at present, any barriers to meeting cost target, and if necessary, roadmap to address costs.
- Results from porous metal support tube development could yield benefits to membrane R&D.
- Purification of H_2 is essential to implementing H_2 economy using fuel cells.
- Potentially a useful component.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Team understands the barriers and goals.
- Ambitious approach given limited funding.
- Good materials science.
- Approach on porous metal support tube was sound.
- Proposed approach for proton transport membrane (PTM) is very wide in work scope.
- Very specific to address development of H_2 membranes, support tubes and proton transport membrane.
- Also has many go/no go points in Phase 1.
- A good plan.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Work has led to a possible new low temperature proton conductor.
- Significant progress based on minimal funding for this project.
- Progress against DOE targets not explained.
- Considerable progress was reported.
- Good progress for $200K.
- Is the water enhanced conductivity "durable" (i.e., does it persist with continued operation)?
- Some preliminary data were presented and looked promising.
- Little discussion of barriers. It appears, however that lots of progress has been made.
- Really neat work is being done.
- Good progress to date; still early though.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Coordination so far and future plans are comprehensive.
- Good interactions given the modest size of this effort.
- Good collaborations.
- Numerous collaborators (Ames Lab, WPI, NETL, Rutgers.)
- Consider more formal interactions and collaborations.
- Interactions with industry are needed to seek inputs and guidelines for the proposed work.
- Looking for partners to help commercialize and work with other labs and universities.
- Adequate collaboration to date; working on developing others should improve the work.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.22** for proposed future work.

- Go/no go considerations put early limits on whether to proceed on testing programs.
- Future work needs increased funding.
- Plan probably on target, but not well explained in relation to current progress.
- Hopefully they will continue to make progress with proton conducting membranes.
- A sound future work plan.
- Work is very focused and based on past progress.
- Good plan.

Strengths and weaknesses

Strengths
- Uses the strong materials development expertise at ORNL using existing technology at the lab.
- Good facilities and broad-based expertise in materials science; they are doing enough science to gain useful insights about ion conduction in solids.
- PI has expertise in porous metal supports.
- Really interesting project - seems to be making good progress.
- Getting a good understanding of the fundamentals.

Weaknesses

- Timeline to commercialization seems to be much longer than needed.
- The current status of the project in reaching the targets was not shown.
- Based on the efforts so far, it is uncertain how much progress has been made toward reaching the flux, cost, and purity goals.
- It is not easy to orchestrate a well-paced program of this kind at a National Laboratory for $200K.
- For proposed work on porous metal support PTMs , it would be helpful to differentiate the proposed work from the past/ongoing work by other researchers.
- Would have been better if they discussed barriers and explained better how/why innovations are so innovative.
- Will need to bring in others to move technology forward at the appropriate time (not yet).

Specific recommendations and additions or deletions to the work scope

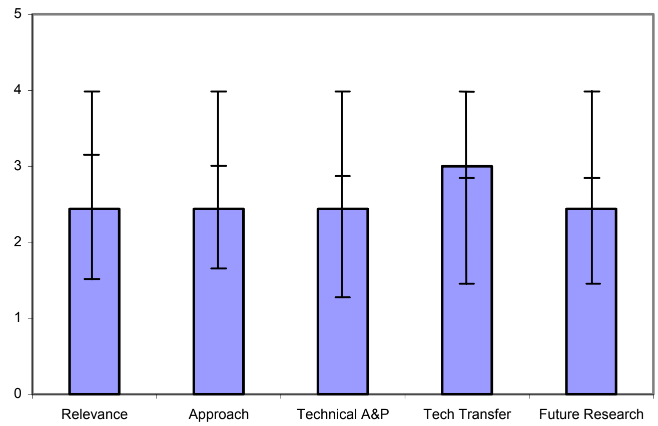
- It is not clear that this project is funded at a "critical mass" level. Funding should be increased or project combined with other efforts.
- Project presently looks at high temperature operations -- confirm that materials chosen can operate successfully under lower temperature conditions and applicable operating pressures: e.g., start at -50F or establish lower temperature limits often called critical exposure temperature (CET).
- Place a higher priority for porous metal support tube development which could have broader and near-term applications than PTM.

Project # HPD-8: Adapting Planar Solid Oxide Fuel Cells for Use with Solid Fuel Sources in the Production of Distributed Power
Bayless, David; Ohio University

Brief Summary of Project

In this project, Ohio University will quantify impacts of syngas composition on performance of a commercial planar solid oxide fuel cell (pSOFC) cell and stack (H_2S content, CO/H_2 ratio and energy content of gas, particulate, metal content), demonstrate long term operation of pSOFCs using actual sold fuel-derived syngas, integrate CHP into distributed H_2 production, develop fuel cell CHP from solid fuels, test pSOFCs for tolerance to syngas contaminants using single cell and stack platforms, and use CO tolerant pSOFCs for H_2/CO separation without gas shift reactors.

Overall Project Score: 2.55



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.44** for its relevance to DOE objectives.

- The use of a renewable energy source such as biomass is positive but issues such as contaminants and GHG emissions must be considered.
- Project addresses stationary and transportation applications of syngas derived H_2.
- H_2 for transportation is a by-product. Does not address biomass gasification targets such as H_2 cost.
- DOE also supports separate work on SOFC development.
- It is not clear how the proposed work would complement the ongoing SOFC program.
- Relevance not clearly established but is important for near-term implementation of H_2 economy.
- When evaluated as a Hydrogen Production Technology project it is not clear how this would be a significant advancement.

Question 2: Approach to performing the research and development

This project was rated **2.44** on its approach.

- Appears to duplicate FE work.
- Very complicated concept with little understanding of many barriers.
- No actual technical details given to support approach.
- No information given on how cost and durability factors will be assessed.
- Fuel flexible (syngas).
- Will require work on carbon sequestration, which is out of HFCIT preview.
- Fuel cell work is out of scope of hydrogen production subsystem.
- Not focused on reducing cost of hydrogen or meeting H_2 production objectives.
- This is basically the same as H_2 from coal.

- Details of the approach were lacking (e.g., the SOFC test duration and baseline case - feed gas composition, temperature and pressure).
- Considerable efforts will be spent on the gasifier and syngas H_2/CO ratio adjustment.
- Not being familiar with this project, it is unclear exactly what they are testing.
- In general, this work seems relatively well focused.
- How are economics calculated?
- Seems to be only economical if H_2 is co-produced!
- Appropriate for what they are planning to do.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.44** based on accomplishments.

- Some degree of testing done. Should have been initiated at SOFC to bridge the setup time at OU.
- No performance indicators of the specific process or costs.
- Little progress for a large budget project.
- Testing has just begun.
- Need to show directly how the efforts contribute to achievement of the technical targets.
- Making some progress with modeling effort.
- Progress was reported but lacks details.
- Progress seems significant and some barriers are identified.
- Seems that there has been significant progress on experimental setup and modeling.
- Making progress within defined scope.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- What are partners' roles?
- Mentions many partnerships but no discussion of their role.
- It's not clear that interactions have benefited projects to date.
- Academic partners, industrial partners, and power company involved.
- Partnering with Case Western.
- Should try to work with DOE SOFC development team members.
- Should seek partnership with experience in gasifier and syngas clean up.
- Quite a bit of collaboration with universities and industry.
- Degree of that collaboration unclear.
- Several collaborators listed, but little identification of their roles.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.44** for proposed future work.

- SOFC has performance issues with their stack operating on CH_4.
- Wouldn't single cell tests on H_2S, Hg be beneficial?
- Plans generalized.
- Little detail regarding future plans.
- The future plans do not address the hydrogen production targets sufficiently.

- The fuel cell work is not applicable in the H_2 production sub-program of DOE and does not address costs of H_2 directly.
- Schedule of proposed future work was presented.
- Future work sounds like it focuses on lowering cost and improving system (moving towards commercialization).
- Appropriate for what they are trying to do.

Strengths and weaknesses

Strengths
- Good application of SOFCs.
- Good test facility established.
- Leveraged with funds from the State of Ohio.
- Use of CO tolerant SOFCs.
- Use of solid fuel which is easily and safely transported.
- Work to study the impact of syngas composition including trace contaminants on SOFC performance.
- Should provide valuable inputs to guide coal-based SOFC applications.
- Seems to be making really good progress.

Weaknesses
- All the test stands exist at SOFC -- why didn't testing start earlier using their facilities?
- Significant funding for little results.
- No attention given to problem of CO_2 emissions from syngas generation of biomass.
- Project does not address the fundamental work that needs to be done to reduce H_2 costs.
- The project is focused on a single system.
- Title of work is "Adapting Planar SOFC for use with…". What does "adapting" mean?
- Focus of the efforts should be clarified: SOFC or both SOFC and gasifier?
- Not sure electricity production as the primary product is in keeping with program intent.
- The use of sequestration was not clear.
- When evaluated as a Hydrogen Production Technology project, it is not clear what the advantage is.
- Mainly appears to eliminate WGS by adding a SOFC; is this a good thing?

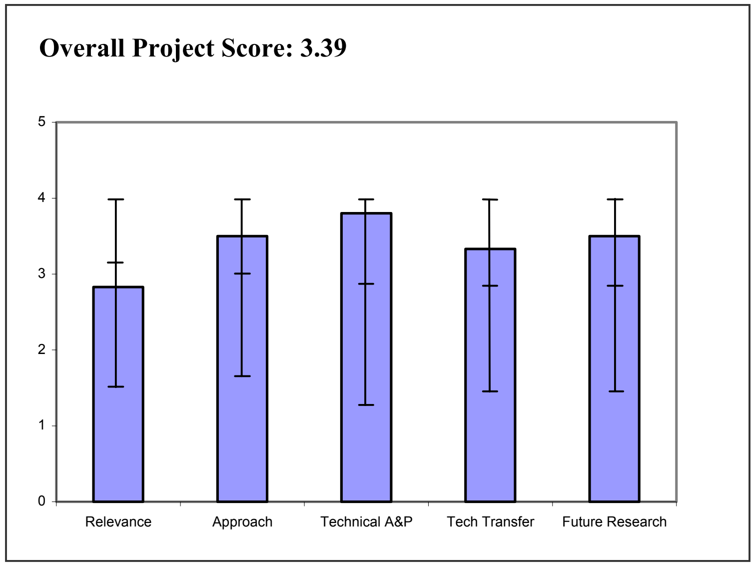
Specific recommendations and additions or deletions to the work scope

- Look at other impurities in coal gas - Sb, P, etc.
- There are lots of heavy metals in gas stream.
- To this reviewer's knowledge no one has looked at heavy metal effects on SOFC performance.
- Delete H_2 distribution -- make project a fuel cell project CO + H_2 to a SOFC.
- This project seeks to "reinvent the wheel" in terms of biomass technology that has been previously explored.
- Focus work on specific system aspects that can have the greatest impact on achieving DOE targets. Considering system integration issues but not limiting applicability to a single system.
- For materials of construction, consider confirming operation capability under cold, e.g., -50 F temperatures.

Project # HPD-9: Maximizing Photosynthetic Efficiencies and Hydrogen Production in Microalgal Cultures

Melis, Tasios; University of California, Berkeley

Brief Summary of Project



In order to maximize photosynthetic efficiencies and H_2 production in Microalgal cultures, the University of California, Berkeley developed genetically engineered microalgae with enhanced photosynthetic solar conversion efficiencies and biomass/hydrogen production capabilities under mass culture conditions. The adopted approach was to apply DNA insertional mutagenesis and screening in the model green alga *Chlamydomonas reinhardtii* for the isolation of 'truncated Chl antenna' transformants and apply biochemical, genetic and molecular analyses of the transformant cells, followed by DNA sequencing to identify genes that confer a 'truncated Chl antenna size'.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.83** for its relevance to DOE objectives.

- Addresses only one barrier but focus is tight.
- Will help both efficiency and reactor design.
- Difficult to see direct relationship to overall DOE objectives.
- Not critical to Fuel Initiative but a potential long-term sustainable source of H_2.
- Ultimately, the success of this work could contribute substantially to the DOE H_2 program vision.
- Probably always behind in reaching a useable technology.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- Tightly focused on one critical barrier.
- Project is focused on overcoming barriers.
- Genetic manipulation is a cutting edge approach. Though high risk, it has potential for major breakthroughs with unforeseeable consequences/benefits.
- Good application of insertional mutagenesis.
- The presentation focused only on reducing the light capturing antennae size; the total approach for H_2 production was not conveyed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.80** based on accomplishments.

- Surpassed goal.
- Small project.
- Exceeded 2004 goal - doubled it!
- Improved photon penetration.
- Mechanism(s) of gene function in H_2 production still unknown.
- Excellent bio-engineering research toward producing more efficient light capturing mutant organisms. No assays for H_2.
- Will the greater (now 15%) light gathering efficiency actually translate into a corresponding enhancement in H_2 production?
- Ahead of schedule!

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Collaborations good with other photobiological EERE- H_2 projects.
- Premature for tech transfer.
- Extensive collaboration with peers doing related research.
- Good interactions with labs.
- Positive interaction with auto industry participant.
- Could benefit with bioinformatics and/ or genetic research companies.
- NREL and ORNL collaborate.
- Critical collaboration with NREL.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.50** for proposed future work.

- Good but would reemphasize "future work slide" task 4.
- For target goal - task 1 future is less important - "understanding" is targeted goal achieved by random screen approach.
- PI discussed need to test task 2 in order to have methods that may extend impact on regulation to other algae.
- Project goal is well defined.
- Logical plan for follow-on research.
- They have a ways to go to reach the production targets of other methods.

Strengths and weaknesses

Strengths
- Focus.
- Random approach with strong screen.
- Basic research being done; i.e., exploratory research methods.
- Knowledgeable PI.
- Effective collaborations.

Weaknesses
- Concern on how easy to extend to additional algae beyond *Chlamydomonas*
- Concern on GMO - something better than antibiotic for large scale use.
- Managing oxygen and achieving sustained H_2 production.

Specific recommendations and additions or deletions to the work scope

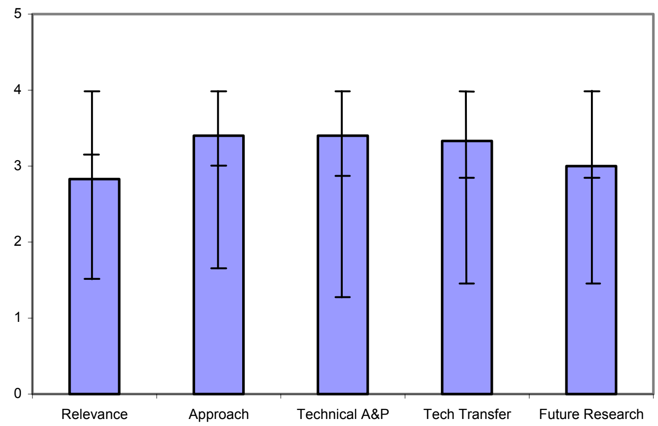
- If not already being done, systems analysis and engineering should be included in the project to determine whether the ultimate success of the project will lead to meeting DOE H_2 production goals of being competitive with gasoline.
- PI is very goal-oriented and should be "team leader" for all of the photobiological hydrogen work because he has shown the most progress. He is also most organized with his approach of all those working on photobiological hydrogen production.
- Combine the four separate mutations as highest priority.
- Consider second row of mutation and screen on best mutant "tlaX."
- Need to more closely relate algae types, mutant with H_2 photosynthesis, H_2 as well as O_2 production.

Project # HPD-10: Biological Systems for Hydrogen Photoproduction
Ghirardi, Maria; National Renewable Energy Laboratory

<u>**Brief Summary of Project**</u>

The goal of this project is to develop hydrogen production technologies based on microbial water-splitting processes. The project is organized into three tasks: 1) engineer an algal hydrogenase that is resistant to oxygen inactivation; 2) develop and optimize a physiological method to produce culture anaerobiosis and subsequent H_2 production activity in algae; and 3) introduce bacterial hydrogenase with increased oxygen resistance into a water-splitting photosynthetic cyanobacterial system.

Overall Project Score: 3.19



<u>**Question 1: Relevance to overall DOE objectives**</u>

This project earned a score of **2.83** for its relevance to DOE objectives.

- One barrier addressed continuous production.
- Difficult to relate project to overall DOE objectives.
- The long-term aspect of the work means it is not critical to the President's H_2 Initiative, but is relevant to the long-term vision of DOE.
- Methodology is still along way from practicality.
- Cleary a very long term project which should at present be nearer a basic science endeavor.
- Relevant, but progress has been extremely slow.

<u>**Question 2: Approach to performing the research and development**</u>

This project was rated **3.40** on its approach.

- Staged reactors, nutrient limitation, and immobilized test to decouple growth, light, and H_2 production are good methods.
- The multiple sub-tasks were disconnected in the presentation - either focus or better indicate crucial integration.
- Just trying new things, or has prior approach reached a limit?
- Good bioscience.
- Integration with fiberglass support is a novel idea.

<u>**Question 3: Technical accomplishments and progress toward project and DOE goals**</u>

This project was rated **3.40** based on accomplishments.

- Great results in subtask 2 moderated by other subtasks.
- Long term photobio is an achievement.

- Success in subtask 1 on methods in protein expression of hydrogenase.
- Reduced volume and improved H_2 production.
- Achieved continuity of H_2 production.
- Improved O_2 resistance.
- Significant results and progress directed toward achievement of targets.
- Continuous H_2 production for 6 months with two-stage process.
- Impressive progress on subtasks 1 to 3.
- Might it be possible to utilize a synthetic analog of hydrogenases to perform the e- + H+ <- -> H_2 reaction; even in the presence of O_2?
- Much work but thus far little hydrogen produced.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- This is long term so perhaps tech transfer is premature criteria.
- Apparent extensive effective collaborations with others.
- Good collaboration with university - work seems to be complementary.
- International collaboration is positive.
- More interactions with genetic companies may be useful.
- Collaboration with ORNL, UCB, U of IL, and former Soviet Union.
- Excellent collaborations ranging from computational modeling to "bioengineering."
- If the approach works then O_2 may be an issue.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Subtask 2 process is strong.
- Subtask 1 is very basic but crucial for future bio-inspired approach.
- Subtask 3 is important to extend to other species, but is hydrogenase knock-out the first best step?
- Starting to look at ferrdoxin mediated processes.
- Continuation of excellent scientific work.
- Performing economic analysis at this present early science stage will have little value.
- A quantitative definition of process goals should be helpful.

Strengths and weaknesses

Strengths
- Success in subtask 1- hydrogenase expression shows strong value of mutual EERE and Office of Science support of different tasks. This is a credit to the principal investigators.
- Leverage by an Office of Science Program.

Weaknesses
- Disjointed in three subtasks.
- Need to track; explain better energy: light, carbon reserves, nutrients between multistage, cycle systems, etc.
- The PIs understands parts of the balance. This would make project more "sensible" to "engineers" and hard scientists.

- Presentation was a bit unclear.
- How to avoid O_2 induced deactivation?

Specific recommendations and additions or deletions to the work scope

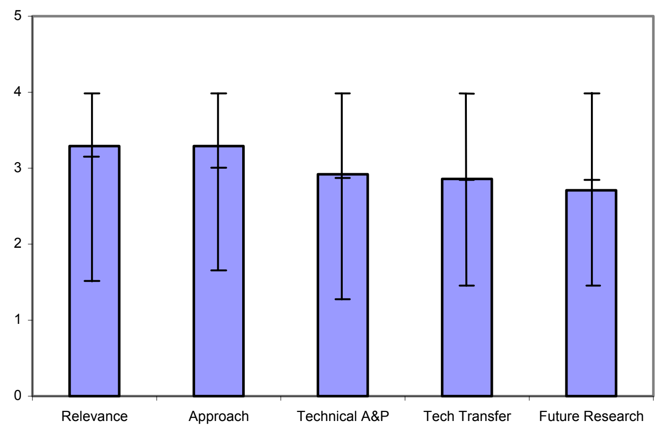
- An economic analysis would be an appropriate next step.
- Further integration with other DOE projects will be of great benefit (appears already to be a strength of the project).
- This work solidly addresses a major issue arising from photobiological hydrogen production and addresses a way to circumvent the problem but progress has been slow.
- The PI should be encouraged to take a far more active leadership role in this project.
- All photobiological projects should be combined under one team.

Project # HPD-11: Photoelectrochemical Water Splitting
Turner, John; National Renewable Energy Laboratory

Brief Summary of Project

The goal of this research is to develop a stable, cost effective, photoelectrochemical-based system to split water using sunlight as the only energy input. The work during this year focused on identifying and characterizing new semi-conductor materials that have appropriate bandgaps and are stable in aqueous solutions.

Overall Project Score: 3.01



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.29** for its relevance to DOE objectives.

- Addresses durability and efficiency targets and points out another important goal: band edge alignment with H_2O redox potentials.
- Photovoltaics in general is "limping" towards achieving any practical performance targets.
- Supportive in the terms of providing a means of generating H_2 by a sustainable source.
- Addresses a specific area within production that needs research.

Question 2: Approach to performing the research and development

This project was rated **3.29** on its approach.

- Excellent understanding of underlying scientific issues and use of this knowledge to develop improved materials.
- Good focus not only on demonstration of improved materials but also on consistent preparation of them.
- Concentrates on one candidate material at a time.
- What's new with this approach?
- The record for new semi conductor materials is important. But it somehow needs to be "catalyzed," made more convergent. For example by utilizing computational modeling.
- PI is staying focused on specific material performance issues and is addressing issues.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.92** based on accomplishments.

- Preliminary GaPN results are very promising for meeting band gap target.
- Progress on consistent materials preparation reported.
- Some progress with GaPn.
- Appears to be funding limited.
- Reasonable progress toward new semiconductor materials.

- The electrolytic conversion problem should be more efficiently addressed by considering the potential chemistry between the semiconductor components and the electrolyte.
- Progress is being made in finding stable materials for photoelectrochemical systems.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.86** for technology transfer and collaboration.

- Students from CSM and U. of Colorado involved in project.
- Collaboration with Mexico and other countries.
- Other than students, impact of these collaborations on this project not clear.
- Define role of collaborators.
- Where are more US collaborators?
- Clearly working closely with others in the field.
- Collaborations with U. of CO and Colorado School of Mines.
- Not well explained.
- Do they exist?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.71** for proposed future work.

- Clear endpoint for completion of materials development and collaboration and transition to systems demonstration in FY 06.
- Requires more defined specifics.
- The key phrase here is "reasonable time frames."
- Project needs computational chemistry guidance, a better understanding of degradative semiconductor electrode/electrolyte chemistry.
- Appears to be well planned and structured.

Strengths and weaknesses

Strengths
- Excellent understanding of scientific challenges and approaches to overcoming them to meet PEC goals.
- Good progress.
- Enthusiastic, well-versed in topic.
- I imagine that the student researchers are well motivated by the PI.

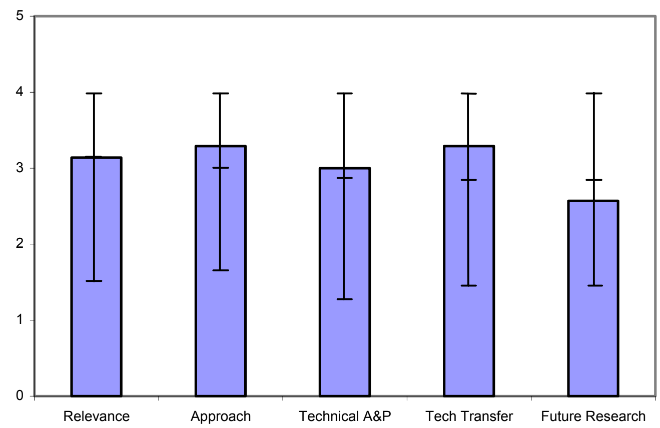
Weaknesses
- Despite lack of funding for catalyst development, should be aware of any progress that could impact their ultimate goal of a system demo.
- Other important issues such as electrode development are missing.
- Need to develop collaborations in this area.
- Need more focused goals -- this is a never-ending project.
- Long way to go to commercial success.
- Funding. Very encouraging but needs 10X or 100X more funding to achieve objectives that are meaningful on a National scale.
- The present splintered format of a half dozen small projects in this area isn't working.

Specific recommendations and additions or deletions to the work scope

- The use of combinatorial methods should speed development.
- If EERE has a serious interest in developing photoelectrochemical systems, it should put in place a dedicated, multi-disciplinary program that is well-organized, well-integrated, and centrally directed.
- Recommend a collaboration with computational groups (not necessarily only at NREL) which could provide guidance on the search for more effective semiconductor.
- Recommend the addition of an industry partner even at this early stage to help set goals and objectives and define a product configuration.

Project # HPD-12: Photoelectrochemical Hydrogen Production Program
Miller, Eric; Hawaii Natural Energy Institute

Overall Project Score: 3.06



Brief Summary of Project

In this project, Hawaii Natural Energy Institute (HNEI) is developing high efficiency, cost-effective photoelectrochemical processes for the production of hydrogen by engineering stable multi-junction photoelectrodes based on low-cost materials and designing, fabricating and testing optimized photoelectrodes suitable for eventual commercial-scale use.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.14** for its relevance to DOE objectives.

- Addresses durability target, but estimates for achieving cost target not yet available.
- Within National interest, clearly.
- Not very close to useful target values for production.
- Alignment in terms of potentially providing H_2 with a sustainable source.
- Addresses several objectives; materials, low cost, efficiency, and collaboration.

Question 2: Approach to performing the research and development

This project was rated **3.29** on its approach.

- Multifunction approach promising to overcome challenges by separating functions between the layers and enabling more focused development on individual targets for each layer.
- Dual materials approach to improve WO_3 and Fe_2O_3 is good.
- Like approach.
- Using standard approaches to band gap engineering.
- Combinatorial and *ab initio* features are useful.
- The advantage of the hybrid photoelectrode vis-à-vis alternative designs could have been better articulated.
- Strong focused approach taken on development of hybrid photoelectrodes.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Progress on Fe_2O_3 development but still a lot of challenges in this area.
- Doping mentioned as a solution - but what are proposed dopants?
- Proof of concept hybrid device demonstrated.
- Seems to have assembled good team of collaborators to accelerate progress.

- While accomplishments are being made, do not see the significant improvements needed to meet 2010 goals.
- Moving along well.
- Wait and see where they are a year from now.
- Good progress on doped WO_3 and Fe_2O_3 electrodes. But no data was provided on the lifetime of these new systems.
- Steady progress up through proof of concept has been achieved.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.29** for technology transfer and collaboration.

- They have a team of industry and university partners working with them.
- Will be interesting to see if sufficient level of expertise is now available to accelerate development beyond the exploratory WO_3 and Fe_2O_3 pure and doped samples prepared so far.
- Improved from past years.
- Strong point.
- Lots of collaborations are being formed, i.e., the so called "PEC Dream Team."
- Project is pulling together a "dream team" of collaborators which offer great promise.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.57** for proposed future work.

- Incorporates Intematix for combinational expertise and SWRI for manufacturability but planned technical work only touched on.
- A clearer plan for the next year with some intermediate goals should be developed.
- Future work lacking details.
- The project is clearly still at a "discovery" stage with significant hurdles (e.g., electrode longevity) to be yet determined.
- It seems premature to at this time to be considering a development plan towards commercialization.
- Timeline for goals is not evident.

Strengths and weaknesses

Strengths
- Good detailed approach - focusing on metal oxide materials development.
- Good discussion of the progress to date.
- Hybrid approach seems to have good likelihood of becoming a product.

Weaknesses
- Development effort seems a bit slow for a 3 year old project.
- They should really pick up the intensity or there won't be time to demonstrate the durability goals.
- Too heavily focused on out of date metal oxide systems.
- I do not see road to improvements.
- Future work discusses commercialization. I do not see technology developments that are ready to be commercialized.
- Little explanation of goals/timeline.
- Need to ensure that appropriate goals exist and are being pursued in a timely manner.

- Funding -- only a modest amount expended to date and no 2004 funds.
- The collaboration plan could unfold into a stronger, broad based, more concrete effort to nail down the answers to advancement issues for PEC H_2 production.

Specific recommendations and additions or deletions to the work scope

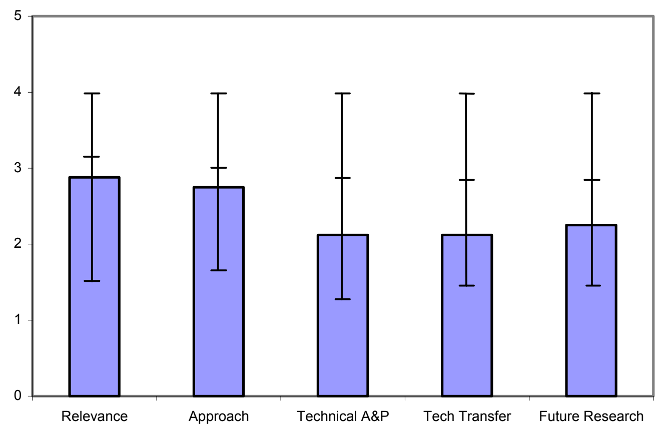
- Need to shift focus to new metal oxide systems.
- Integrate combinatorial approaches to development of metal oxides.

Project # HPD-13: Discovery of Photocatalysts for Hydrogen Production
MacQueen, Brent; SRI International

Brief Summary of Project

This SRI International, NanoGram Corporation, and Neophotonics project addresses efficiency (band gap and edges), durability and cost of photocatalyst materials for use in direct water-splitting systems for the production of hydrogen. The materials discovery required to meet the technical targets will be expedited by the use of high throughput screening tools being developed in this project. The inclusion of a partner with the means to produce commercially relevant amounts of materials will hasten the development required to make PEC hydrogen viable.

Overall Project Score: 2.42



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- Focus is on improving efficiency of existing durable oxide materials.
- Recognize need for order of magnitude improvement in durability.
- Primarily a materials development study.
- Not moving in on DOE's target values yet.
- Discovery of low cost materials with improved efficiency is critical to goal's realization.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- High throughput approach allows rapid materials screening.
- Industrial partner provides manufacturing/scale up expertise.
- Approach not well defined.
- Laser pyrolysis may lead to new materials development but impact on cost and durability remains to be proven.
- Impressive high throughput evaluation of semiconductor electrode materials - but only for the proton reduction to H_2 reactor.
- Semiconductor synthesis via nanoparticles "forming" into electrodes.
- Focus on high throughput analysis of new materials is outstanding.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.12** based on accomplishments.

- Variety of samples made and characterized but random materials classes pursued don't indicate a clear path forward.

- Progress is minimal.
- Do not see the path to meeting DOE's 2010 goals.
- Major delays in program.
- Difficulty in bringing all aspects of the planned project together.
- Project does not seem to be off to a productive start.
- Good first set of data but what does it teach us?
- Need a multidimensional database to relate H_2 evolution rates with material and other contributing factors.
- Business issues (multiplied) among partners is hampering optimal progress.
- Stay focused!

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.12** for technology transfer and collaboration.

- Existing interactions not focused on this application - no clear added value or impact.
- Need more coordinated interactions with other organizations.
- No significant collaborations with the exception of NanoGram (who apparently went into bankruptcy during project).
- Logistical issues.
- Weak on collaboration.
- Needs to publish and otherwise disseminate the excessive body of information that will emerge.
- Not yet evident that progress has been made from last year on collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.25** for proposed future work.

- Sounds like a lot of IP issues remain between SRI and NanoGram and based on Phase 1 and 2 delays these are not likely to be easily resolved.
- Future plans too broad and not based on prior results.
- Modeling aspect is good.
- Why is generation of database and modeling emphasized in phase 3 at the end of the project?
- Efficiency and catalyst lifetime need to be explored in a productive way.
- Ferroelectrics may open a door to improved performance.
- Consider ways to screen both electrode reactions (H_2 and O_2).
- Note that on CH_3OH oxidation product may interfere with the quantification of H_2.
- Develop ways to efficiently "mine" the large body of ensuing data for maximum progress towards project objectives.
- Benefit of doubt: Looks very promising.
- Need to stay focused and minimize external distracters.

Strengths and weaknesses

Strengths
- Very good technical capability is evident.

Weaknesses

- Can make and screen lots of materials but no effort to characterize some samples to understand why improvements or failures are achieved.
- Numerous delays are seriously impacting the likelihood this project can succeed in meeting DOE's goals.
- Modeling and materials developments need to be linked.
- The delays in this project have defeated the benefits of using a combinatorial methodology.
- It isn't clear that laser-based PY process will be cost effective.
- Again, external issues seem to be distracting from focus on production goals.
- Are legal issues a show stopper?

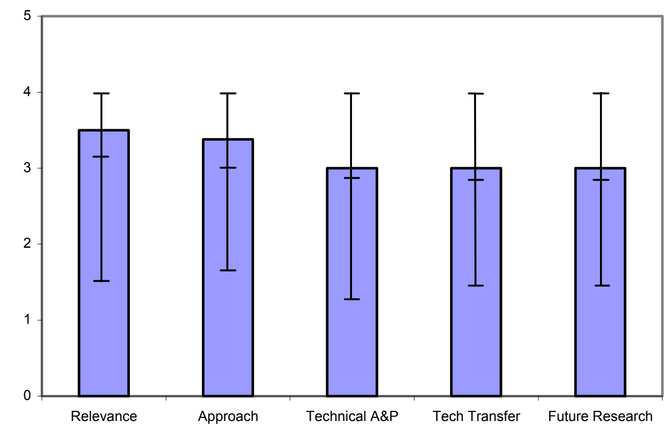
Specific recommendations and additions or deletions to the work scope

- End this project. Too many issues to succeed.
- The presenter needs to pace his presentation -- he ran out of time and did not adequately cover accomplishments and future plans.
- Too much emphasis on background tutorial -- this was not needed.
- A need for combinatorial development would improve development efforts.

Project # HPD-14: High Temperature Solid Oxide Electrolyzer System
Herring, Steve; Idaho National Engineering and Environmental Laboratory

Brief Summary of Project

Overall Project Score: 3.18



Idaho National Engineering & Environmental Laboratory (INEEL) is currently researching and developing high and ultra-high temperature processes to produce hydrogen through chemical cycle-water splitting technology or other non-carbon-emitting technology utilizing heat from nuclear or solar sources. The project is seeking to develop energy-efficient, high-temperature, regenerative solid-oxide electrolyzer cells (SOECs) for hydrogen production from steam, reduce ohmic losses to improve energy efficiency, increase SOEC durability and sealing with regard to thermal cycles, minimize electrolyte thickness, improve material durability in a hydrogen/oxygen/steam environment, and develop and test integrated SOEC stacks operating in the electrolysis mode.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Very promising opportunity to overcome tech barriers in an important technology.
- This primarily is a high temperature materials development project.
- Excellent for stationary. Unclear for automobiles.
- Could meet several targets in a year or two at the rate they are going.
- Process is a key component of DOE's hydrogen production strategy.
- Production of pure H_2 without production of CO_2 in an energy efficient way.

Question 2: Approach to performing the research and development

This project was rated **3.38** on its approach.

- Very comprehensive understanding of tech issues.
- Straight-forward engineering development of cell technology incorporating high temp materials.
- Using nuclear heat and electrolysis (presumably from nuclear electricity) is what appears feasible for H_2 production in the near term.
- Research is actively addressing hard technical barriers.
- The project timeline is very aggressive given the current state of the art and small amount of initial funding i.e., single cells in 2004, 200 KW in 2008.
- Very focused in addressing technical barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Good progress this fiscal year.
- Project in early stages but shows promise.
- Progress seems slow- only single cell testing and 6-cell stack testing with significant performance degradation over short time period.
- Well done!
- Good H_2 production for >1000 hr.
- Significant progress is being made.
- Good progress - button cell tests, materials development, stack development and testing.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Interaction appropriate.
- Work with INERI in Canada just starting.
- This should be collaboration with SOFC electrolyzer manufacturers.
- It is basically a high temperature stack engineering project.
- Does Ceramatic meet this requirement?
- Partnering and information outreach could be more extensive.
- Excellent effort at sharing results and incorporating ideas from collaborators.
- Collaboration with industry, international and non-profit.
- University collaboration was unclear.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Future work not adequately described.
- Well thought out plan for the future.
- Little detail given on how project will move to 50 kW, 500 kW, and 5 mW.
- How will heat source be integrated into project?
- Future plans were not evident from presentation, with exception of testing of ten-cell stack.
- Future work scales up and improves upon past work.

Strengths and weaknesses

Strengths

- Uses the right kind of power source for near-term (and for the longer range for that matter).
- Adaptable to solar heat source as well.
- Aligns well with DOE stated goals.
- Very focused and making good progress.

Weaknesses

- Several organizations (companies) have demonstrated capabilities to make and test electrolyzers -- why are they not part of this project?
- NASA has funded development of electrolyzers at TMI (Cleveland, OH) for many years -- their expertise would be beneficial for this project.

- Although the presentation "infers" a nuclear or solar heat source to produce high temperature steam, there appears to be little connection to these energy sources in future plans.
- Funding -- to develop from single coupons or short stacks to 200 KW prototypes with performance and durability will cost $25 to $100 million.

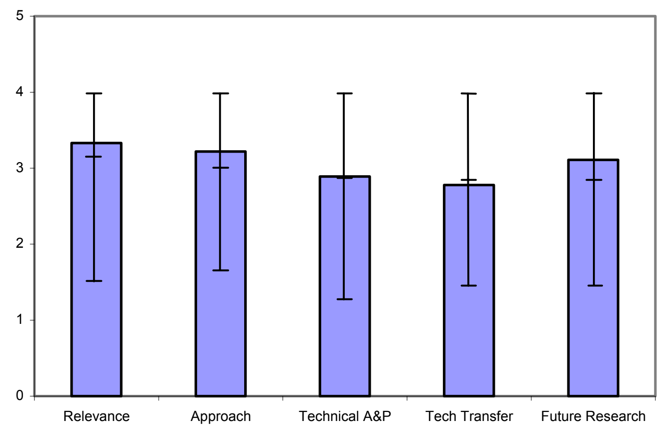
Specific recommendations and additions or deletions to the work scope

- This project should be led by industry with national lab providing high temperature materials expertise.
- Appears well done.
- A collaboration with NREL to develop the solar powered heat source concept appears appropriate.
- I assume the nuclear program will fuel extensive cell, cell stack and subsystem testing with emphasis on many pieces of hardware operating for significant hours prior to the buildup of prototype. If not this needs to be added.
- May need to consider some new/advanced ceramic materials for the electrolyte to achieve reductions in ohmic losses and to raise efficiency.

Project # HPD-15: Renewable Electrolysis Integrated System Development and Testing
Kroposki, Ben; National Renewable Energy Laboratory

Brief Summary of Project

Overall Project Score: 3.07



This National Renewable Energy Laboratory (NREL) project examines the issues with using renewable energy to produce hydrogen by electrolyzing water. Objectives are to characterize electrolyzer performance under variable input power conditions, test and evaluate the electrical interface with renewable (PV, Wind, Hydro, Geothermal, etc) and/or hybrid/grid power (dedicated hydrogen production, electricity/hydrogen cogenera -tion), design and develop shared power electronics packages and controllers to reduce cost and optimize system performance, develop and verify integrated renewable electrolysis systems (via performance modeling, simulation and testing; and addressing Safety, Codes and Standards requirements).

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Well designed approach.
- Good understanding of RD&D needs and project objectives.
- Emphasis on renewable energy sources to produce hydrogen.
- Linking renewables to provide output stabilization is a sensible focus.
- Incorporating renewables efficiently is vital to Hydrogen Initiative success.

Question 2: Approach to performing the research and development

This project was rated **3.22** on its approach.

- Doubt that improved electronics are going to get you to targets.
- They appear to be putting together known components - where are the potential breakthroughs?
- Power electronics RD&D is at the heart of this project, a key tech and cost barriers for electrolysis based systems.
- Good approach with detailed tasks based on realistic goals and objectives.
- NREL has the experience, facilities, and capabilities to make this work.
- Capital cost, efficiency, and durability are indeed the feasibility issues.
- Very structured, task oriented.
- Approach is addressing numerous barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.89** based on accomplishments.

- Maybe not fair to evaluate since early in project.
- Testing a known electrolyzer, known components.
- Collaborations need expanded - especially in power electronics.
- Project in early stages, but shows promise.
- Significant progress for a new project with reduced funding.
- Off to a good start.
- Steady rate of progress and accomplishments is evident.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.78** for technology transfer and collaboration.

- Project in early stage but interaction with appropriate collaborators off to a good start.
- Limited collaborations to date.
- There's value to having universities involved in such projects.
- Reasonable levels of industry and government collaboration are evident.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.11** for proposed future work.

- Evaluating all electrolyzer system (PEM/ Alkaline).
- Future work is "success" oriented, needs thought/planning on contingencies, other possible barriers needs timeline progress goals ($/kg).
- Good plans for future work in FY 04 and beyond.
- If they follow through effectively and productively this should turn out to be a good program.
- If energy source (e.g., wind) produces electricity for grid or electrolyzer, consider use of H_2 produced to run a fuel cell that places electricity (a less desirable option).
- Inefficient or confirm necessary to maintain net stand-by under turn down conditions.
- Clear plans for future work and goals are evident.

Strengths and weaknesses

Strengths
- Evaluating all electrolyzer systems (PEM/alkaline).
- Emphasis on achieving cost targets.
- Well thought out work.
- Leveraged with wind power funds.
- Very clear, precise presentation.
- Well organized, reflects a good project.
- Focused on the wind/solar power interface is very useful to the industry and often overlooked.

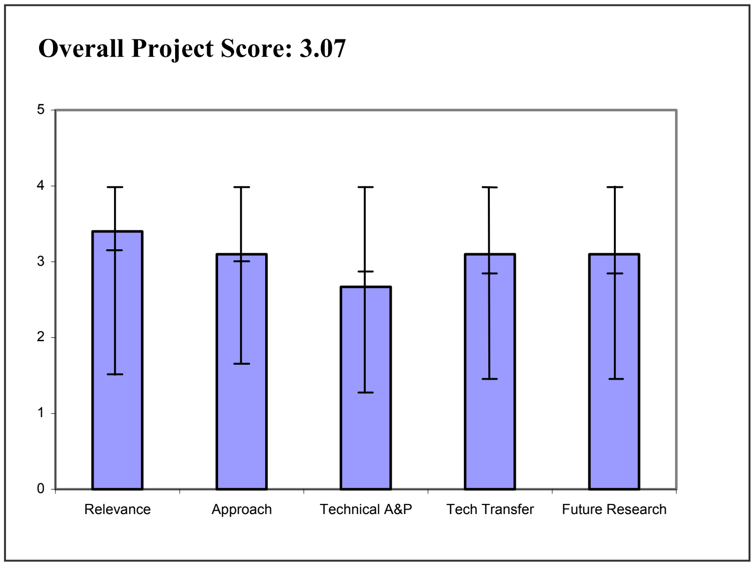
Weaknesses
- Doubt that they will be able to get from current >$13/kg to 2010 goal.
- The only indicated cost savings is some improved electronics and elimination of "battery ".
- Would have liked to see what goes into the current $13 cost and where the improvements will be made to reach the goal.
- Requires a storage battery to load level.

Specific recommendations and additions or deletions to the work scope

- Consider bringing biomass into the mix to provide the possibility of a load-leveled, all-renewable, battery-less process for making H_2.
- Need clarification of a technology/ intellectual property access plan.
- Other commercial organizations will want to use the power interface, and there should be a process to allow them to access this e.g. CRADA or others.
- Consider expanding scope to look at controls required to determine where initial energy, e.g., electric from wind, could be best utilized; direct to grid on for H_2 production - cost vs. revenue optimization.
- Need to study system optimization given intermittent operation of electrolyzer due to renewable energy duty cycle.

Project # HPD-16: Hydrogen Generation from Electrolysis

Cohen, Steve; TeledyneEnergy Systems Inc.



Brief Summary of Project

The goal of this Teledyne Energy Systems Inc. project is to advance water electrolysis technology and develop an Electrolytic Hydrogen Generator with the following features: hydrogen delivery at high-pressure (5,000 psig); relatively inexpensive hydrogen generation and pressurization; production capacity 10,000 scfd; high conversion efficiency; cost of less than $600/kW for 10,000 units per year; as well as reliability and durability with low maintenance cost.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- Addressing efficiency and cost targets at both component and systems levels.
- Making use of some excellent experience.
- Addresses important potential technical advances for electrolysis production of hydrogen.
- Relevant performance goals as goals/objectives.
- Good description of specific targets which are challenging.
- Near term in scope.
- Will proposed system meet cost/performance targets?
- Project recently initiated (March 04) making evaluation of status premature.
- Supports water electrolysis technology in general terms.

Question 2: Approach to performing the research and development

This project was rated **3.10** on its approach.

- A long established piece of commercial equipment.
- Going to higher pressure probably a good move.
- Approach has some risk with use of high pressures but excellent potential to meet the targets.
- Some questions as to why is this being done.. Stuart Energy already has functional optimized system.
- Well designed.
- Barriers clearly understood as well as goals.
- Realistic, experimental-based approach.
- Close to off the shelf.
- Once again, barriers to be addressed were discussed in general terms.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Too early to evaluate.
- New project, but extremely well thought out.
- Project in early stages but indicates substantial improvements to target.
- Project only 5 weeks old. Too early to expect results. Not realistic to rate this criteria.
- Not applicable.
- They seem to be on schedule for a new project.
- Looking forward to next year's progress review for this project.
- Project just starting.
- Not started yet.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.10** for technology transfer and collaboration.

- Collaborators provide relevant expertise to this program.
- Proposed interactions appear minimal at best.
- Appropriate involvement of related industry and state entity. (Demo site, public education/awareness).
- Good interactions - potential association with transit application is positive.
- Proposed interactions are appropriate.
- Most of the collaborations are parts/materials suppliers.
- Excellent collaboration efforts were described.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.10** for proposed future work.

- FY 04 work provides basis for systems design and trade studies.
- Would benefit from having FY 04 milestone for testing results to indicate go/no go on system development.
- No details outside of timeline provided.
- Project off to a good start and future expectations seem feasible.
- Reasonable plans - schedule should be accelerated if possible.
- Plan is to eventually build a "demonstration" system. Focus on optimizing electrolysis system.
- Plan is very well developed.

Strengths and weaknesses

Strengths
- Excellent understanding of issues at both component and systems level.
- Detailed analysis of efficiency and cost goals for project based on DOE targets.
- Trade-off studies for system optimization are important.
- Cost-pressure optimization is also positive.
- A company with lots of H-generation experience.
- 50% cost share by Teledyne.

- Strong industrial collaboration was evident.
- Experienced team developing and cost reducing a power technology.
- Good chance for success.

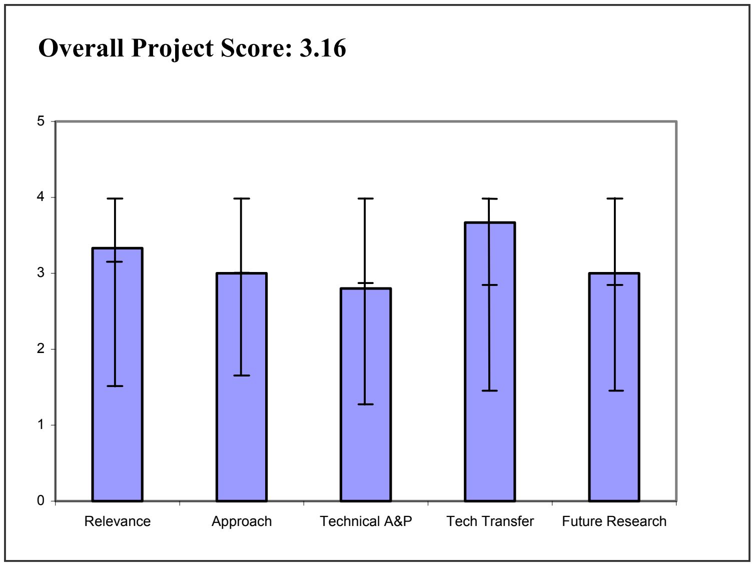
Weaknesses
- Appears to duplicate work at Stuart (questionable).
- Need to evaluate the cost impact of scaling production capacity to optimize unit costs.
- Liquid KOH at pressure is a challenge.

Specific recommendations and additions or deletions to the work scope

- Consider need to supply H_2 at 10,000+ psi based on expected need for fueling vehicles.
- Teledyne should try to take their H-gen systems to a new level with some "outside the box" developments.

Project # HPD-17: Development of Solar-Powered Thermo-Chemical Production of Hydrogen from Water
Schultz, Ken; University of Nevada

Brief Summary of Project



The goal of this Solar Thermo-Chemical Hydrogen (STCH) team project is to define economically feasible concepts for solar-powered production of hydrogen from water. Task I objectives are to: screen and select cycles and systems; establish a thermochemical water-splitting cycle database; develop solar receiver/reactor design concepts for top cycles; and analyze and select the best systems for development. In Task II they will build on earlier CU/NREL work to study metal oxide reduction cycles, design an improved ultra-high temperature solar-thermal reactor, and conduct fundamental studies using CU transport tube reactor and the NREL High-Flux Solar Furnace.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Determining the potential for solar H_2 production is important.
- Relationship to overall DOE objectives was not described.
- This program has sufficient scope and resources to get a credible go/no go decision on solar-based thermochemical H_2 production from H_2O.
- Solar, high temperature thermochemical cycles support the initiative in all aspects- crucial for long term sustainability.
- Important work on a long term portion of the DOE technology portfolio.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- This appears to be a very high-cost paper study with only limited experimental effort using existing facilities on thermochemical cycles that have been previously studied.
- Roles/responsibilities of partners should be better identified.
- The relative cost of this project appears high for the results targeted.
- Approach doesn't seem to be consistent with lower cost solar collectors.
- Criteria based and the chosen 16 criteria are well thought out.
- Screening methodology is pretty consistent with the other methods of screening used for other programs.
- Good application from learning gained in the nuclear program.
- Addressing targeted barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.80** based on accomplishments.

- Only limited accomplishments in 7 months.
- Seems to be off to a good start.
- The database assessment will have great value in the community.
- Leveraging research done by other groups.
- Adequate progress considering newness of the project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.67** for technology transfer and collaboration.

- Various interactions noted.
- Clearly involving wide variety of resources and organizations.
- Lots of collaboration and well chosen interfaces.
- Good collaboration among variety of parties.
- Web site to show findings and good efforts to make progress as transparent as possible.
- Good leveraging of other programs.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Too much paper study not enough experimental verification of the potential for solar-produced hydrogen.
- Almost all work is future work.
- An impressive plan - stick with it.
- Aggressive schedule to meet DOE cost objective.
- Appropriate for program stage and objectives.

Strengths and weaknesses

Strengths
- A strong capable team.
- Can lead to commercialization.
- Good presentation at review (strong spokesperson).
- Excellent methodology used to structure and rank research.
- Solar thermochemical is a very high potential production technique and this project should help to focus further/ future projects.
- Ambitious attempt at finding the optimal solution at this stage of the technology.
- Excellent collaboration.

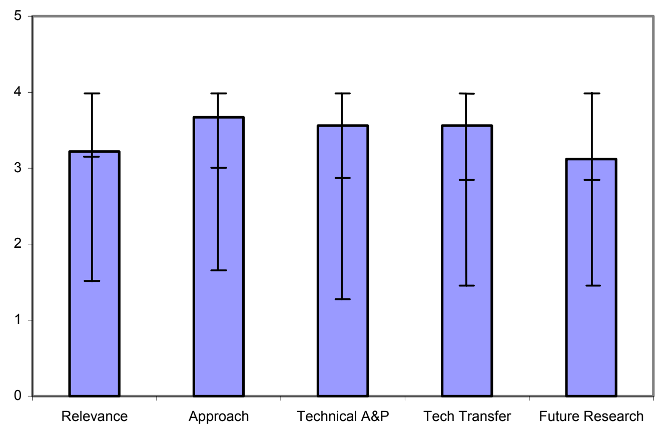
Weaknesses
- Team is not challenged to come to grips with the critical feasibility issues of solar hydrogen production.
- Why do the analysis study if two cycles, ZnO and Mn_2O_3 have been chosen?
- Seems to not be terribly innovative (draws heavily on previous work).

Specific recommendations and additions or deletions to the work scope

- This team should be challenged to produce more important results/conclusions.
- Do a 3-month literature study and get started on an experimental verification project to assess value and cost competitiveness of solar, thermochemical hydrogen production.

Project # HPD-18: Moving Toward Consistent Analysis in the Hydrogen Program: H_2A
Mann, Maggie; National Renewable Energy Laboratory

Overall Project Score: 3.43



Brief Summary of Project

The H_2A project team's overall goal in this project is to bring consistency and transparency to hydrogen analysis. Phase I goals include production and delivery analysis, consistent cost methodology and critical cost analyses, R&D portfolio analysis, and tool development for providing R&D direction.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.22** for its relevance to DOE objectives.

- Fits DOE Multiyear RD&D Plan goals.
- Tool will be available on DOE website for cash flow analysis-somewhat limited utility.
- Development and refining baseline analysis elements is a needed reference tool.
- Consistency is a critical need.
- Political and price scenarios should be explored.
- No clear relationship to overall DOE objectives shown, but clearly a useful tool to assist funding decisions.
- Scope of analysis impressive.
- Project is very important in identifying appropriate research directions.
- Consistent analysis basis will be beneficial.
- The core mission of this project is to provide consistency in cost/benefit analyses to determine if DOE goals, objectives and targets are met.
- Should provide a useful tool for apple vs. apple analysis.

Question 2: Approach to performing the research and development

This project was rated **3.67** on its approach.

- Appears to be a well thought through project.
- Good use of cash flow analysis tool.
- "Forecourt" was not defined until end of project review - should be defined upfront.
- Project "barriers" and goals clearly identified.
- Communication should be emphasized.
- Should publish guidelines for units and assumption statements.
- Good team building.
- Not perfect, but the plan does embrace issues and criteria effectively.
- It will evolve into a comprehensive analysis function that produces reliable results.
- Sound tools including cash flow analysis were proposed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.56** based on accomplishments.

- Good use of technical paper publication.
- Base case and sensitivity analysis has progressed well.
- Tool looks great -- should be mandatory for proposals.
- Needs price scenario selection.
- Great examples with type profiles by resource.
- Delivery should include solid storage and delivery of feed stock.
- Relatively new project that has made impressive studies so far.
- Good accomplishments so far.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.56** for technology transfer and collaboration.

- Universities are part of the H_2A team - could use a better effort with other university tech transfer (more diversity).
- Interactions and collaborations are comprehensive. Quite a team!
- Collaboration with energy economists and independents recommended.
- Team included wide range of interests.
- Good use of web.
- All appropriate groups of stakeholder appears to be represented.
- Project leverages stakeholders in analysis and makes project available to all.
- Sensibly chosen collaborators.
- Should look to add more collaborators to shore up deficiencies as they become obvious.
- The role of key industrial collaborators was not adequately discussed.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.12** for proposed future work.

- Will document assumptions.
- Future not clear (beyond 04).
- Should include DOE identified scenarios.
- Phase 2 is reported to be under discussion.
- H_2 delivery analysis should consult studies by industry (e.g., GM).
- Implementation of "peer-reviewed papers" was not discussed adequately.

Strengths and weaknesses

Strengths
- Good use of National Labs plus contractor; part of Multiyear RD&D Plan.
- Use of sensitivity analysis (chart) is good.
- Good cross section of team partners.
- Meets a critical need for consistency.
- Fine start with the spreadsheet tool -- should improve analysis of proposals.
- Results showing builds by production type very well done and very interesting.

- Clearly excellent, much needed tool.
- Seemingly well done.
- Practical methodology.
- Useful expression of results.
- This is the kind of work EERE should sponsor to assure that the R&D programs are appropriate.
- Very good effort to finally create a standard model.
- Good set of partners including industry.

Weaknesses
- Could use more scenario analysis (fuel costs).
- Does not address major price and political scenarios.
- Proposals will play out differently depending on scenario.
- Needs more support for units - the preference for standard industry units can not be ignored.
- Time value of results not clear.
- Sensitivity analysis cited but not clarified.
- This is much new jargon in the naming of things -- this should be clarified and minimized to avoid confusion and lack of appreciation concerning results.
- There's lots of room for oversight and neglect of key issues in this kind of analysis.
- Inclusion of a "conclusions" slide would be helpful.

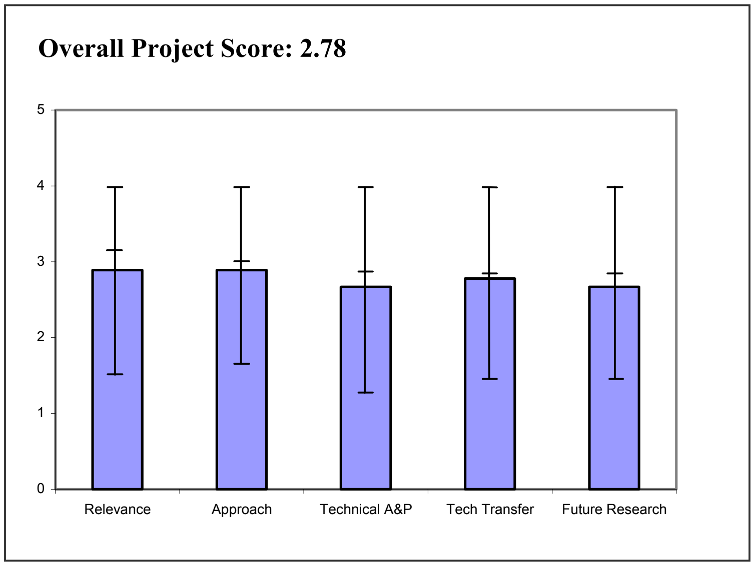
Specific recommendations and additions or deletions to the work scope

- Should look at / analyze safety for next piece, although safety was not an issue at this time.
- Develop consensus forecasts in major scenarios depicting different types of transitions, e.g. import reduction, fossil reduction, alternate energy breakthrough and maybe wild cards (global cooling, open global war, rapid growth, and depression).
- Include energy economist/ independent collaborators.
- Include both user preferred and program standard units e.g. both SCF and KG.
- An annotation on impact(s) would be helpful.
- Most important is to keep industry involved in identifying analysis needs and verifying models.
- Focus on usability/ transparency.
- Interface for other (non-economic) issues should be part of the project (i.e., WTW, emissions, etc.)
- Put all assumptions on the strongest possible grounding -- the results from this kind of analysis are often easy to criticize or take issue with.
- It would be nice to make the H_2A model user-friendly, if it is to be released for public use, for example, users should be allowed to pick its key parameters.
- Should be sure to widely disseminate along with providing training and support.
- Coordinating with education and outreach program will be beneficial if not already in place.

Project # HPD-19: Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0
Greene, David; Oak Ridge National Laboratory

Brief Summary of Project

This Oak Ridge National Laboratory (ORNL) team intends to rapidly create an integrated model of the transition to hydrogen as a transportation fuel using methods developed for the Transition Alternative Fuels and Vehicles (TAFV) Model. Objectives are: to produce a national-level model, HYTRANS v. 1; test HyTrans v. 1 and produce 2-3 scenarios of market evolution; produce a regional model; test and generate 2-3 regional transition scenarios; and publish model documentation and scenarios.



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.89** for its relevance to DOE objectives.

- Driven by National Academies study.
- Version 1 is limited in scope.
- Safety is covered under ORNL research and safety guidelines.
- A much needed project.
- Addresses National Academies recommendation.
- Goals/objectives of project are relevant.
- Excellent idea for execution.
- Includes non-H_2 alternatives: hybrid and electric.
- Poor relevant effort.
- Mission expression was poor.
- An import issue is being addressed by this project, but the level of effort may be subcritical to cover all aspects thoroughly.
- Should provide useful guidelines.

Question 2: Approach to performing the research and development

This project was rated **2.89** on its approach.

- Non linear optimization model.
- "Barrier" elements well thought out.
- Approach seems reasonable but ability of model to yield sophisticated (not obvious) results is not clear.
- Optimization has limits.
- Intuitive, goal driven, and heuristic models should be considered as a supplement.
- Price scenario should be included.
- No clarity on origin of input data.

- Admitted doesn’t understand current pipelines.
- Needs to study all possible production technologies and must be designed for flexible response as new concepts emerge.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Lots of data! More observations than project's plan - could use more specifics on project itself.
- Project in early stage but good progress to date.
- To date the model results seem to "confirm the obvious.”
- Most conclusions are evident to an informed observer without the model results.
- Impressive model structure and problem description.
- Claim that model "solves" chicken and egg question completely unsupported.
- Mathematical expressions confusing.
- Relatively new project; some results are starting to come out.
- Vehicle diversity and demand density concerns are valid targets for study.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.78** for technology transfer and collaboration.

- Did not hear this clearly expressed during presentation.
- Collaboration will need to spread to many other entities, e.g., industry.
- The planned advisory group and workshop should provide useful sophistication for the model.
- Economic, political, and independents should be involved.
- No clear communication intent.
- Some collaborations are in place; others may be needed to assure comprehensive coverage of all parameters.
- Discussions in this area were not adequate.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- Not specific enough.
- Very robust plan.
- Incorporating stationary demand and production is positive.
- Emphasis on "robust" solution is good.
- Survey work would be useful.
- FY 2004 and FY 2005 results at the next review should sharpen the evaluation of this approach to the point where its value can be better addressed.
- Schedule seems to be aggressive.

Strengths and weaknesses

Strengths
- Project seems to have uncovered other areas of research.
- Willingness to obtain external input/criticism for model improvement.

- Excellent idea.
- Nice application of mathematical optimization.
- Nice inclusion of competing technologies for current fleet inclusion.
- Very good start on a very complex problem.

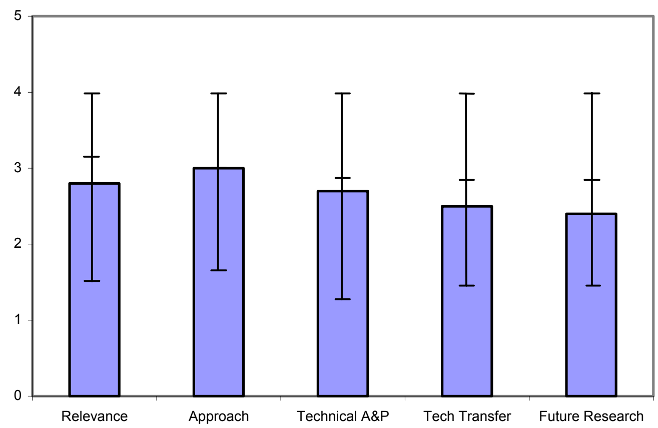
Weaknesses
- Chart with population density has no legend (US/green); not a lot of explanations "why" they did what they did.
- Without extensive model development in terms of sophistication, the results tend to be just confirmation of obvious conclusions.
- Optimization has inherent weaknesses -- particularly in the propensity to find ideal solutions.
- The transition will not be ideal -- will rather move forward with optimal steps.
- Possibility of future fleet of superlights/smarts, trucks, motorcycles, bicycles, and subways -- or even a revival of public transportation.
- Fails to justify money spent on project.
- This study brings some new jargon to the program. Be sure to clarify and define all such new terms at the next review.
- Would benefit from additional outside collaborations, e.g., Dept. of Defense, oil companies, investment banks, etc.

Specific recommendations and additions or deletions to the work scope

- PBFA is now called PBA should reflect change in slides.
- 2005 to 2050? Keep timeline within program plan.
- Incorporate as much sophistication into the model as possible.
- Explore use of suboptimal modeling -- goal driven, heuristic, and scenario modeling.
- Include economic, political, and independent collaboration.
- Surveying structuring may provide some useful insight.
- Cancel this effort.
- Theoretical models should be funded at low level to allow for corrections to the model.
- Heavy funding is not warranted until trends unfold in the marketplace.
- This project seems to have synergy with HPD-18 project.
- Should a formal bridge be built between the two projects?
- Interaction with industry and other government agencies (e.g., DOE) would be helpful.
- This tool could be vital for national security planning. Coordination with DOD threat analysis and scenario planning should be done; for example, given the inelasticity of prices small disruptions cause great volatility and uncertainty. Financial markets go to great lengths to hedge against volatility and place an economic value on this factor. Domestic H_2 may play a similar role.

Project # HPD-20: WinDS- H_2 Model and Analysis
Short, Walter; National Renewable Energy Laboratory

Overall Project Score: 2.68



Brief Summary of Project

In this analysis project the National Renewable Energy Laboratory (NREL) will identify the scenarios, time frames and regions of the U.S. in which wind turbines that generate both electricity and hydrogen are likely to become economical from a market perspective. Objectives are to optimize wind system concepts that produce both electricity and hydrogen, both today and in the future.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- Sounds like a good project - not sure how this project fits in with hydrogen! Primarily electricity production.
- Wind as renewable energy source is important.
- Hydrogen production by electrolysis is incidental to wind produced electricity.
- Hydrogen transport based on electrical distribution roots is not realistic - why not just produce H_2 at electrical distribution points.
- Wind shouldn't be done alone. Need to include solar, bio, and other non-fossil fuels electrolysis.
- Wind alone is not necessarily relevant.
- Clear expression of mission.
- Making a concentrated study of H_2 production from wind energy.
- The study is needed to put the prospects for wind utilization in proper perspective.
- Project recognizes unlikely use of electrolyzer and fuel cell at wind sites to store/shift energy.
- Allows resources to be refocused.
- A useful exercise.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Integrated with other work.
- No safety issues for this project.
- Hydrogen production/transport seems to be an "add on" to an existing wind model.
- It is not clear how this production model is based on where the wind is relevant to hydrogen production. It is just a wind produced - electricity methodology.
- Good comparison with other uses for wind, e.g., grid, local use, electrical storage systems.
- Lack of practicality checks.
- Reasonably well considered approach. The PI should endeavor to make the modeling/analysis as comprehensive in its consideration of the forcing issues as possible.

- Wind power production, future growth rate, and wind power subsidy: are these factors taken into consideration?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.70** based on accomplishments.

- No legend on "regions" slide.
- Just showed class 6 but project used 3-7- confusing to listener.
- Base case results slide should have wind "electric."
- New project evaluation "N/A" to some degree.
- Only limited results for almost a year of effort given wind model already existed.
- Cost/performance scenarios would have been more interesting if current status values were used in place of 2010 target values.
- Lessons can be applied to other intermittents.
- Excellent micro-modeling techniques might be useful in vehicle transition.
- Made deliverables - but didn't say to who or how used.
- Will get a better idea about the usefulness and credibility of this project at the next review.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Did not discuss this during presentation.
- Collaboration internal to NREL only.
- No interactions outside of DOE and NREL.
- Critique by industrial H_2 providers would have benefited early results.
- Needs to include other intermittent, source-related collaborations.
- No team building intent but seems necessary.
- No external collaborators.
- Some university in the USA must have a program of a closely related kind that this project could benefit from association with.
- May have been enhanced with collaboration from industry groups.
- Should seek industry inputs.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.40** for proposed future work.

- Work duplicates other efforts.
- Needs external input to define scenarios to be studied.
- Need to improve transport aspects, e.g., pipeline between regions, other that just cryo-trucking.
- Should apply to other renewables and explore synergies.
- Future plans lack specificity.
- Agree that proposed future work in this area is minimal/limited.
- Inclusion of a "biomass as a source of H_2" should proceed with caution, since its commercial - ready status is very different from wind power.
- The term "biomass" should be clearly defined.

Strengths and weaknesses

Strengths
- Great presentation of wind market and alternative uses for wind.
- Excellent use of micro-modeling.
- Model should be very useful in application to other intermittent and scenario analyses.
- Well thought out analysis.
- NREL is best suited to do this study.
- Straight forward conclusions.
- Good discussions in the "conclusions" slide.

Weaknesses
- Ran out of time - skipped slides.
- Why "analyze" to 2050?
- The fact that this was developed as a wind model and then H_2 production was added seems to limit the usefulness of the results.
- It seems hydrogen "face-lifted" to wind.
- Wind should not be studied independent of other intermittents.
- There are potential synergies with other intermittents, e.g., hydro, photoelectric, biomass (where wind sites are forests or farms). These synergies are significant.
- Overly simplistic representations of argument.
- Not clear how results from other related Production projects feed into this study. It was hard to follow because of the "flip flopping" between wind electric generation and hydrogen production.

Specific recommendations and additions or deletions to the work scope

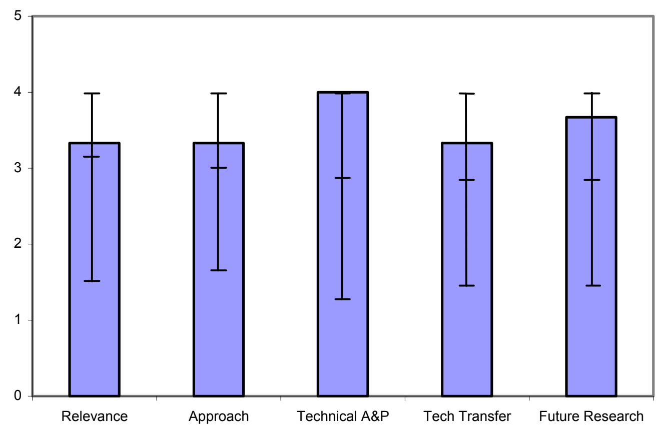
- It appears scope of project has been completed.
- Expand to include other intermittents.
- Explore synergies.
- Cancel this project.
- Explore synergy with solar and biomass methods of H_2 production to give a load leveled system.

Project # HPD-P1: Novel Catalytic Micro channel Fuel Processing Technology
Irving, Patricia; InnovaTek, Inc.

Brief Summary of Project

The goal of this project by InnovaTek, Inc. is to produce pure hydrogen from infrastructure fuels using cost-competitive, highly efficient catalytic steam reforming and membrane separation technology by: optimizing InnovaTek's proprietary steam reforming catalyst composition; optimizing the hydrogen-permeable membrane composition and operating procedures; developing efficient thermal management using micro channel heat exchangers and an internal burner; and integrating processes and components to achieve smallest size and most efficient thermal management.

Overall Project Score: 3.53



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Looks like a good approach for distributed hydrogen production.
- Clear relationship to DOE objective.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- The current first phase of this project has now been successfully completed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **4.00** based on accomplishments.

- It looks like they are making good progress in all areas.
- 3 ppm S diesel unrealistically low.
- Cost efficiency and longevity targets will be met.
- The now completed first stage development has led to a multi fuel process for generating H_2 utilizing: 1) a novel micro channel reactor with good heat transfer characteristics. 2) a sulfur resistant catalyst and 3) a effective H_2 membrane unit.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Much of the creative engineering work seems to have been done internally.
- Outside contracts have been utilized for marketing their product for which they appear to have customers.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.67** for proposed future work.

- Close to commercialization.
- The PI had outlined a good forward plan for a second phase of this project: mostly operating system integration work and economics refinement etc. for the construction of a commercial prototype.

Strengths and weaknesses

Strengths
- Impressive progress for a very small company.
- Technology can be useful short term and far into the future.
- Very creative innovative engineering work.

Weaknesses
- Will the company have the low cost, large scale manufacturing capability to put this fuel production unit completely in the market place? (A question for the stage 2 proposal).

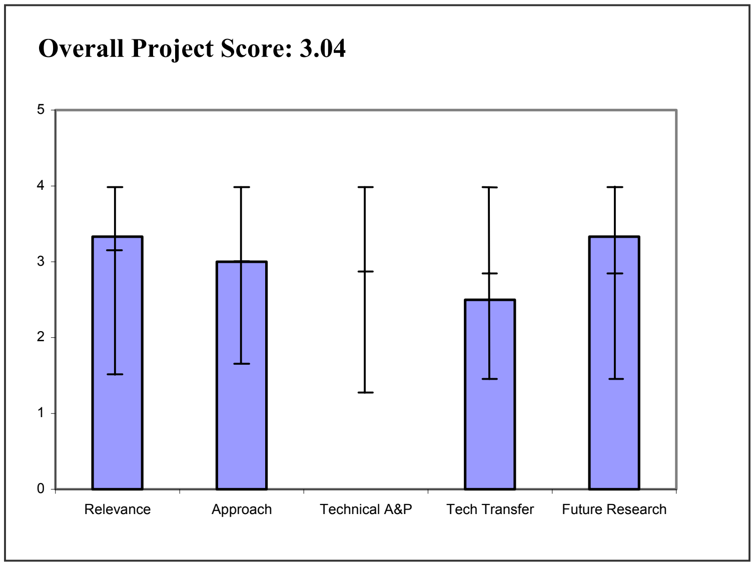
Specific recommendations and additions or deletions to the work scope

- A follow-up stage 1 should be seriously considered.

Project # HPD-P2: Startech Hydrogen Production
Lynch, David; Startech Environmental Corp.

Brief Summary of Project

Startech Environmental Corp. will field test integrated hydrogen production on a pilot scale using plasma gasification and ceramic membrane hydrogen separation, and evaluate commercial viability and scalability through extended operation under representative conditions.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Dual function-disposes of waste and provides moderate size H_2 production.
- To the extent that this technology actually encourages distributed H_2 production from biomass and non-natural gas feedstocks this project is very well targeted.
- Questions: feedstock availability; variety; on-site H_2 storage; safety; not sufficiently addressed.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Method appears attractive, all steps appear feasible, membrane porosity may be more reasonable than ICCM.
- Not clear whether the technology of plasma-based conversion works efficiently across a wide range (as claimed) of organic and fossil based inputs (feedstocks).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **N/A** based on accomplishments.

- The project has not yet been initiated.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Too early to evaluate.
- The project does not appear to involve participation with or integration with other industry or university performers or National Labs - at least that is the impression given by the posters and in oral comments by representatives.
- No apparent collaboration with other organizations, possibly none needed.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Concepts look good.
- Presentation could do a better job of explaining how, technically, the wide variety of potential feedstocks - particularly if a mixed feed, is converted into high purity hydrogen, as well as how slagging and other unwanted by-products are minimized.
- All work presented is future work.

Strengths and weaknesses

Strengths
- The project goals and the SOW are ambitious, yet quite feasible and achievable ultimately in commercial applications.
- Technically, the design and operation of the gasifier lends itself to 1) a wide range of feedstocks; 2) simple single stage gasification 3) low volume of ash, slag gaseous emissions etc., and 4) easy scalability for varied applications.

Weaknesses
- Not clear that a rigorous enough analytical program is in place to assess the impact on efficiency and H_2 volume and purity of using mixed feedstocks.
- More attention needs to be given to "real life" availability of feedstocks, issues of volumetric output and storage for a range of particular applications.

Specific recommendations and additions or deletions to the work scope

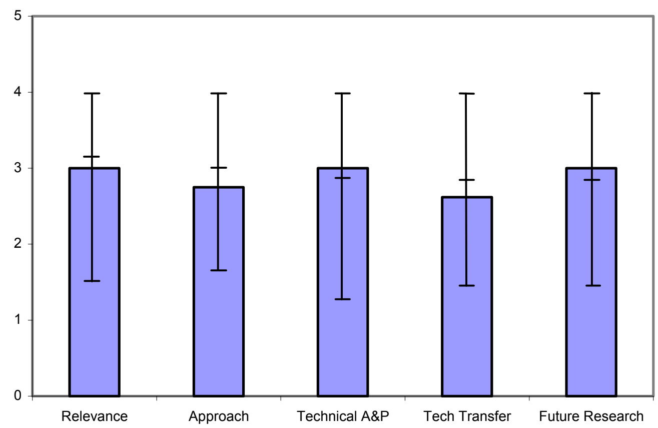
- Extend the non-technical reach to encompass the interface between gasifier performance and the broader system components of both feedstock issues and end-use applications.

Project # HPD-P3: Water-Gas Shift Membrane Reactor Studies
Killmeyer, Richard; National Energy Technology Laboratory

Brief Summary of Project

In this study project the National Energy Technology Laboratory (NETL) will evaluate water-gas shift (WGS) reaction kinetics and membrane flux using industrial gas mixtures and conditions, test the feasibility of enhancing the WGS at high temperature without added catalyst particles by using a membrane reactor, and determine the catalytic effect of metal shell materials (e.g., Inconel) and membrane surfaces (e.g., Pd) on the WGS reaction.

Overall Project Score: 2.87



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- This technology will be applicable to the barriers when better WGS membranes are available.
- Difficult to see direct relationship to DOE objectives.
- Objectives meet mission.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- This project tests water gas shift membranes, while other projects develop membranes.
- Need to show linkage to other projects with membrane development for WGS or have standard methods for evaluation: or predict impact of membranes.
- Little hydrogen above equilibrium seems to be produced. However, high temperature means high cost of operation and major capital costs-these should be estimated.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Small project.
- Baseline results.
- Good measurement - supports models, more realistic tests.
- Little production above equilibrium.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.62** for technology transfer and collaboration.

- Need better linkage with large Hydrogen Production/Delivery projects that could use WGS membrane tests.
- Only collaboration seems to be with the local university.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Provides incremental improvement only - if that.
- Not likely to provide a major breakthrough.

Strengths and weaknesses

Strengths
- Very good methods and equipment.
- Great concept; promising if hurdles can be overcome.

Weaknesses
- Linkage and/or overlap with other projects.
- Many potential problems that could prevent commercialization of technology.

Specific recommendations and additions or deletions to the work scope

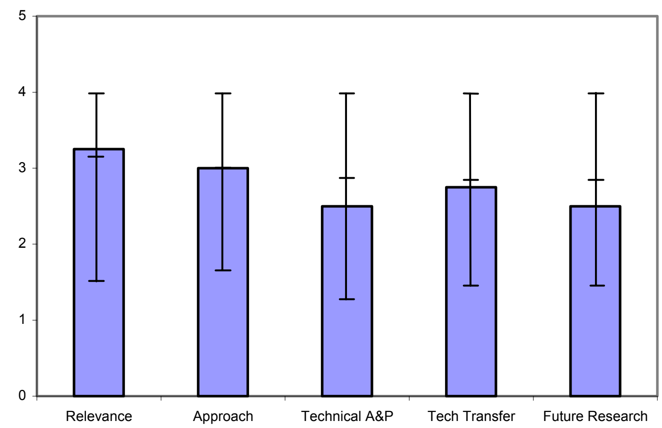
- Need to determine effect of contaminant in coal gasification stream early.
- Compare with conventional high-T shift followed by low-T shift.
- Consider Pd alloys for decreased cost.
- Perhaps help establish baseline measurements for production membranes and WGS membrane reactors.
- Estimated costs should be determined relative to estimated H_2 production.

Project # HPD-P4: Fluidizable Catalysts for Hydrogen Production from Complex Feedstocks
Magrini-Bair, Kim; National Renewable Energy Laboratory

Brief Summary of Project

The objective of this project is to develop and demonstrate technology to produce hydrogen from biomass at $2.90/kg by 2010 and to make it competitive with gasoline by 2015. The approach is to identify the best industrial reforming catalyst and catalyst support and to formulate, evaluate and optimize multifunctional, multicomponent catalysts. To date they have developed novel fluidizable reforming catalysts with CoorsTek ceramics with improved reforming activity.

Overall Project Score: 2.80



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Disposing of waste while generating H_2.
- Multiple feedstocks possible.
- Biomass/waste for "renewable" based hydrogen.
- Primary effort is biomass technology rather than 100% hydrogen production.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- A fairly modest goal -- improve (less attrition) catalyst.
- "Sister" project to HPD-P5 and -P7.
- Develop robust (strength-durable) catalyst for fluidization -- test commercial catalysts and supports.
- Focused on one issue -- attrition increases chance of success.
- Applies to multiple applications, but is this only or deactivation cause.
- Again, little thought for high hydrogen production.
- Focused on attrition. Is this the only problem or is catalyst deactivation a greater problem?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- A very long project FY 01-FY 09?
- Large budget decrease to small project.
- Hard to see "improvement" through the FY 03-04 data.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.75** for technology transfer and collaboration.

- Moderate - other than Coors- vendors, 1 article, 1 patent application.
- Increased industrial links: planned patent and license discussion.
- Chief aim is advanced biomass pyrolysis techniques not hydrogen production and therefore does not support the President's Initiative.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Project should be completed well before planned FY 09.
- What are targets and goals? "Evaluate" and "improve."
- Not likely to lead to major technology breakthroughs for hydrogen production.

Strengths and weaknesses

Strengths
- Broad approach - good testing facilities, potential for "rapid testing."
- Tests of multiple feeds is a plus.
- This project supports development of catalysts for advanced pyrolysis but does not really support hydrogen production.
- Project is well done.

Weaknesses
- Unsure if goal is good performance with little attrition and if so, what is the target.
- Data is from multiple feeds and conditions.
- Unsure what is the improvement seen in FY 03/FY 04, i.e., measured performance but was it "better," what was baseline, and how much improvement is targeted?
- You can test near catalysts forever. So what is the goal for here?
- Unlikely to provide a major breakthrough in hydrogen production.

Specific recommendations and additions or deletions to the work scope

- Continue this research focused on a vital part of the future fuel issue -- converting a variety of hydrocarbon wastes to low molecular weight fuels.
- Projects -P7, -P4, and -P5 should be combined to one project and one funding source.

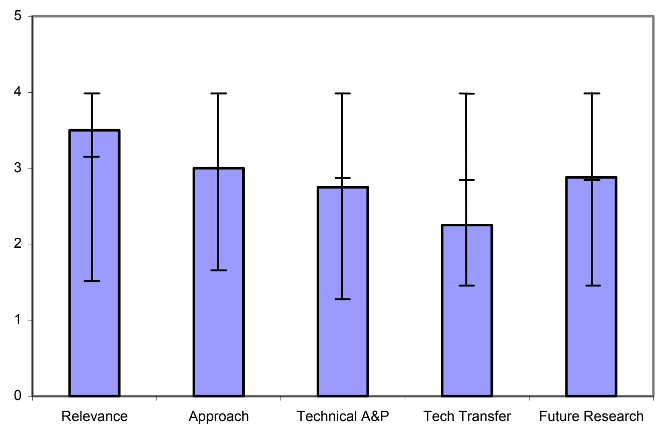
Project # HPD-P5: Hydrogen from Biomass: Process Research

Czernik, Stefan; National Renewable Energy Laboratory

Brief Summary of Project

This project explores the feasibility of producing hydrogen from renewable feedstock to increase flexibility and improve economics of a biomass to hydrogen process. The goal is to develop and demonstrate technology for producing hydrogen at 2.90/kg by 2010. The approach being used is pyrolysis or partial oxidation and steam reforming of biomass, plastics, and other solid organic residues.

Overall Project Score: 2.88



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Addressing two problems: hydrogen production and waste disposal.
- Strong clear linkage to multi-feed issues near to mid need.
- Valuable work.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good two stage process.
- Potential of co-product value from pyrolysis may improve costs and be useful in the transition but coproduct dependency limits the amount of hydrogen that can be produced when a lot is needed in the hydrogen economy.
- Although this project discusses hydrogen production by pyrolysis/reforming the other gases also formed are not indicated - a separations problem.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- A relatively small project.
- Still needs work to meet DOE targets.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.25** for technology transfer and collaboration.

- Collaboration not apparent.
- Need more links with industry especially power, H_2, etc.

- Need catalysts links across projects.
- Tech transfer does not appear to be a major consideration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.88** for proposed future work.

- Which catalysts are "best?"
- More of the same - just testing other biomass types.

Strengths and weaknesses

Strengths
- Tests, good experiments, near term.

Weaknesses
- This is a transition technology - needs to push to market in next 10 years.
- Sensitivity to co-product price as co-product market is saturated.

Specific recommendations and additions or deletions to the work scope

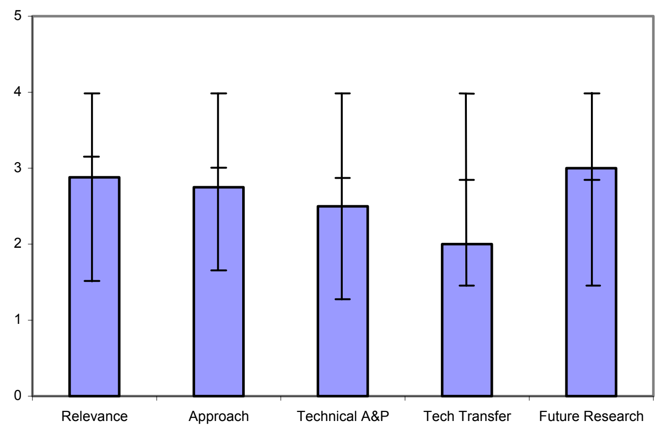
- Address mixed polymer wastes.
- How will PVC, nitrogen containing polymers be addressed?
- Is <1% catalyst attrition in 170 hours adequate?
- Can you claim a credit for disposing of wastes or does trap grease separated plastic have an economic value?
- Projects -P7, -P4, and -P5 are aspects of the same project and should be combined -- providing only one funding source for all.

Project # HPD-P6: Aqueous Phase Catalyzed Biomass Gasification
King, David; Pacific Northwest National Laboratory

Brief Summary of Project

Pacific Northwest National Laboratory (PNNL) will develop a cost-effective method for the distributed conversion of biomass feedstocks to hydrogen, using the following potential feedstocks: (1) ethanol, glycerol; (2) sugars, sugar alcohols (xylitol, sorbitol, glucose); and (3) less refined starting materials such as cellulose or hemicellulose. In addition, PNNL will provide technical and economic comparisons with alternate biomass conversion approaches.

Overall Project Score: 2.63



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- Valuable work.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- Stated funding inadequate for the outlined project.
- What is the feedstock availability?
- Looks like thermodynamics are unfavorable.
- Looks like reactor productivity too low needs to be increased.
- Combinatorial approach good.
- Aqueous gasification is very interesting.
- What is clear focus goal for this project?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- New start - appreciable data.
- Two small projects successfully linked.
- Limited progress due to limited time and money.
- Project limited financially.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- Need better links to catalyst and gasification industry.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- It will be good to "close" off longer carbon chain materials for steam reforming and allow focus on ethanol and glycerol and output of aqueous gasification.

Strengths and weaknesses

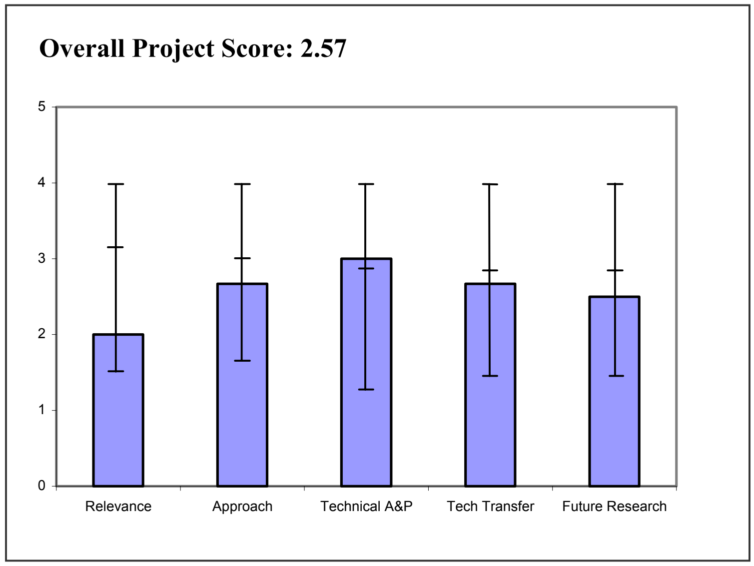
Strengths
- Good and potentially stronger combination of two projects.

Weaknesses
- "Real" biofeedstocks will not be pure sugars, alcohols. (If purified -- they are too valuable) but mixtures including slurries.
- How will aqueous-metal catalyzed-gasification work on slurries?
- No real biomass has been examined -- project is very new and underfunded/poorly funded.
- Other potential off gases are not addressed.

Specific recommendations and additions or deletions to the work scope

- Don't spend too much time on pure compounds, more on the real waste streams.
- Set goals for achievement -- more than "improve?"
- Process economic estimates are good but every small project cannot afford to do this - it becomes a management issue.
- Consider how to handle more realistic feeds (impure).

Project # HPD-P7: Hydrogen from Biomass: Catalytic Reforming of Pyrolysis Vapors
Evans, Bob; National Renewable Energy Laboratory



Brief Summary of Project

In this project, the National Renewable Energy Laboratory (NREL) evaluated the production of hydrogen from biomass by pyrolysis, steam reforming for $2.90/kg by 2010 and its barriers. Their milestone is to verify advanced catalysts and reactor configuration for fluid bed reforming of biomass pyrolysis liquid at pilot scale with catalyst attrition rates of < 0.01%/day by the fourth quarter of 2009.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- This is a technique for biomass pyrolysis - hydrogen production is only a byproduct.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- "Sister" project to HPD-P5 with similar issues.
- Two stage systems (pyrolysis then reforming) adds complexity.
- Relies on coproducts.
- Little hydrogen production.
- Appropriate for their objectives.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- A relatively small project that has been downsized from the original larger one.
- Appeared to have success in the economic study but it was unclear.
- What is/was baseline cost?
- What is improvement needed?
- Good engineering design for "pilot."
- Technical accomplishments are not related to hydrogen production advancement.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Strong collaboration with UGA, Clark Atlanta projects.
- Weak apparent links with industry that might ultimately commercialize the technology.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Actual tasks are goals for them.
- Appropriate for their objectives.

Strengths and weaknesses

Strengths
- Mid-term technology with co-products.
- Char co-product is value also -- carbon sequestered.

Weaknesses
- Transitional H_2 production entry -- is there a real midterm opportunity?
- Full use may/will saturate co-product markets.
- Economics driven by co-products.
- In reality, this is a carbon/phenolic process that produces hydrogen as a byproduct.
- This work has been funded for years with little advancement in the technology and few breakthroughs.

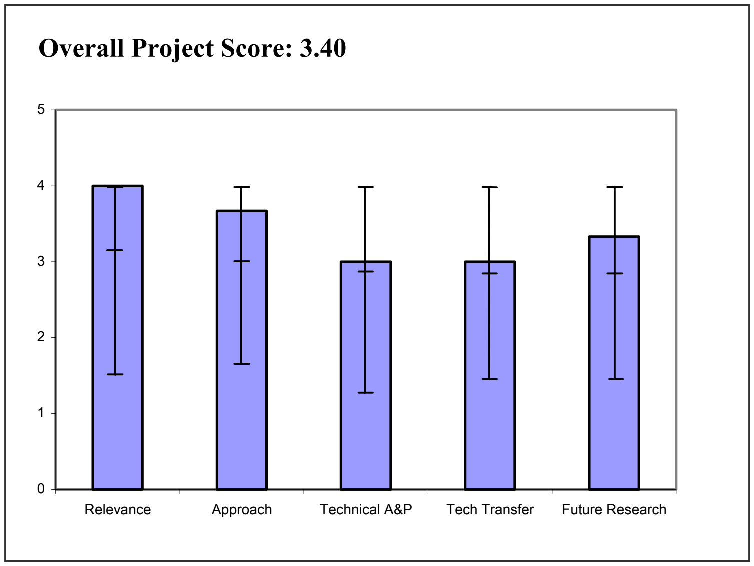
Specific recommendations and additions or deletions to the work scope

- More clearly state targets for improvement.
- Projects -P4, -P5 and -P7 should be combined with one overall project manager and 1 budget for all activities as they seem to be addressing different aspects of the same technology.
- Not an appropriate part of the hydrogen program.
- May be better fit with other DOE programs.

Project # HPD-P8: Creation of Designer Alga for Efficient and Robust Production of H_2
Lee, James; Oak Ridge National Laboratory

<u>**Brief Summary of Project**</u>

In this project, Oak Ridge National Laboratory (ORNL) will create a designer alga by designing and inserting a proton channel into the algal thylakoid membrane. This work will move toward overcoming the low rate of hydrogen production in photobiological systems.



<u>**Question 1: Relevance to overall DOE objectives**</u>

This project earned a score of **4.00** for its relevance to DOE objectives.

- Relevant to renewable H_2 goals.
- Claims that work will meet goals.
- One research project addresses 4 barriers to biological production of H_2.

<u>**Question 2: Approach to performing the research and development**</u>

This project was rated **3.67** on its approach.

- Very creative approach.
- Sharply focuses on various schemes for hydrogen channel.

<u>**Question 3: Technical accomplishments and progress toward project and DOE goals**</u>

This project was rated **3.00** based on accomplishments.

- Good results considering funding level.
- Although poorly funded, the project has made progress.
- Good performance given limited funding.

<u>**Question 4: Technology transfer/collaborations with industry, universities and other laboratories**</u>

This project was rated **3.00** for technology transfer and collaboration.

- Good collaborations within ORNL and with academics.
- Working with University of California, Berkeley, etc. to solve all algae issues.
- Investigator plans to work more closely with University of California, Berkley and NREL.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Plans are good, but funding is low for plans.
- Future research, bulk of project, is sharply focused to address 4 technical barriers.

Strengths and weaknesses

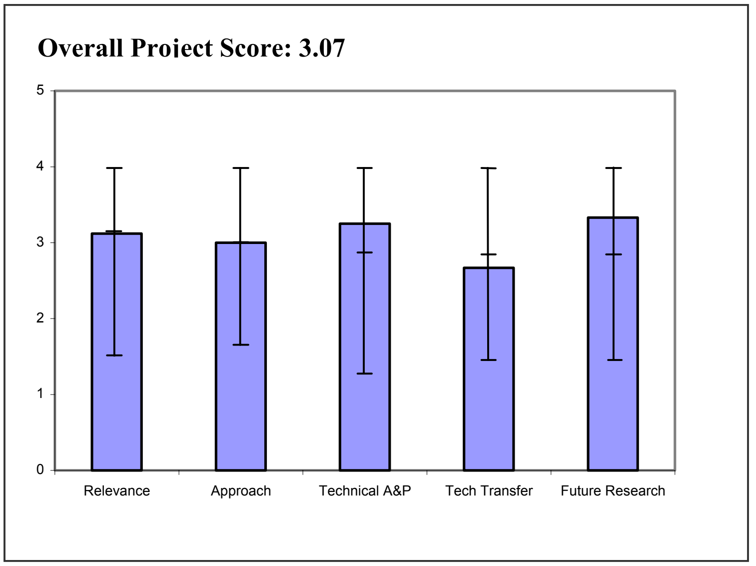
Strengths
- Integrated, well thought out approach to algal synthesis.
- The project is currently poised to develop and test a new/modified catabolic manipulation -- if successful, it could produce a significant breakthrough in biological hydrogen production.
- Innovative and high potential.

Weaknesses
- No cost breakdowns or estimates.
- No attention to balance of plant or implementation.
- Limited funding.

Specific recommendations and additions or deletions to the work scope

- Suggest that tie be formal with T. Melis having overall responsibility and control of the entire project.
- Have go/no-go decision point in two to two and a half years based on whether or not H_2 production increases.

Project # HPD-P9: Hydrogen Reactor Development and Design for Photofermentation and Photolytic Processes
Blake, Dan; National Renewable Energy Laboratory



Brief Summary of Project

This National Renewable Energy Laboratory (NREL) project's objectives for FY 04 are to identify three transparent material candidates, begin accelerated and outdoor weathering tests, and measure key properties for photolytic reactor applications. Solar production of hydrogen by photocatalytic or photobiological processes will require large area reactors with transparent coverings that have low hydrogen permeability.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.12** for its relevance to DOE objectives.

- Fairly routine work to evaluate coatings.
- Most of data should be tabulated.
- No real innovation.
- Development of coatings for reactors will be essential to production of efficient and durable reactors.
- Project timeline discusses fermentation - not an objective since light transmission is not an issue there.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good to begin small effort in this area of transparent materials for construction.
- Can be kept small for now.
- Making the right initial measurements.
- Reasonable approach for testing polymer photostability.
- Could probably be assigned to contract lab and done for less money.
- Project leverages extensive NREL experience in coating materials to rapidly advance the specific research needs of this project.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Small project - just started.
- Materials tested.
- Progress is excellent utilizing minimal budget.
- Excellent start - using previous data.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- None yet.
- Is some existing member of the program already set up to test permeability and flux?
- Not really needed here.
- Project makes use of strong network of test sites.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Good plan.
- Work should be expanded (more funding) or dropped.
- Work is a vital input to continued systems analysis of photoproduction systems.

Strengths and weaknesses

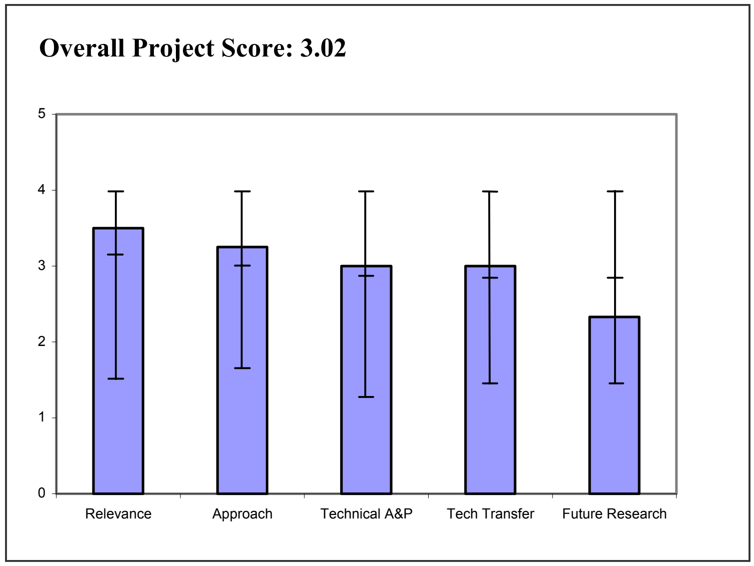
Strengths
- Essential for any photo conversion.
- Beginning to look at "coatings" -- may need to look at "maintenance" of surfaces.

Weaknesses
- Title is misleading as this is really "transparent materials of construction."
- It was unclear how much "existing" data could be used.
- Really more of a routine "analytical" project than a real research project.

Specific recommendations and additions or deletions to the work scope

- Better define "issues" -- target properties of H_2 and O_2 permeability strength, brittle, transparency (and aging).
- Discuss baseline material(s), if any.
- In later stages of this work the PI and staff should be strongly encouraged to work very closely with photobiological and solar electrochemical experts to ensure that the reactors for each type of application are appropriate for that specific application.

Project # HPD-P10: Photoelectrochemical H_2 Production Using New Combinatorial Chemically Derived Materials
McFarland, Eric; University of California, Santa Barbara



Brief Summary of Project

In this project, the University of California, Santa Barbara designed and built a system for automated electrochemical synthesis of combinatorial libraries of mixed metal oxides with the objective of finding an appropriate material to use in the photoelectrochemical splitting of water to produce hydrogen.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Renewable energy sources of H_2 are a principal objective of the Hydrogen Program.
- Development of a direct conversion of solar to H_2 without several PV and electrolyzer components would be a great benefit if it is safe and economically viable.
- Deserves work in basic materials science.
- Difficult to see relationship to major DOE objectives.
- Hydrogen production from renewable energy sources is critical to a hydrogen - based energy economy. Clearly, the discovery of new photocatalytic materials is a necessary precursor toward that goal if efficiency improvements are sought for electrochemical production of hydrogen.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Work is located in a highly developed chemistry research environment.
- Keeping the work products focused on H_2 production will be a continuing challenge as well as maintaining communication with entrepreneurial companies with knowledge and willingness to develop the good ideas further.
- The experimental work lacks the complementarity that should be achieved with the advent of theoretical/computational studies to validate results and to obtain a more fundamental understanding of the material properties.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Development of research tools as methods to test photochemical properties has been good and scientific data from materials assembled and tested with tools validates methods. But, like basic materials research in many fields, the breakthroughs are sparse.

- Economic estimates needed to judge viability of approach.
- Project team has done a thorough job at characterizing material properties (experimentally).
- The work encompasses a remarkable amount of engineering and methods development.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Needs some success that will generate impact; not unlike other materials research.
- Good mix of collaboration/interactions among universities and commercial companies.
- Project could benefit further from collaboration with notable US universities working in the field (e.g., U. of Arizona).

Question 5: Approach to and relevance of proposed future research

This project was rated **2.33** for proposed future work.

- Has designed tools and methods to do more.
- Didn't see evidence of big picture reviews for future work.
- These researchers know their field and can be trusted to direct their work but the cadre is small and dedicated and could grow inward if not exposed to outside collaborative/expertise occasionally.
- Contingency plans were not clearly described in the event that neither Fe-based or Zn-Co based materials meet the desired expectations.
- Need a better plan for exploring other systems.

Strengths and weaknesses

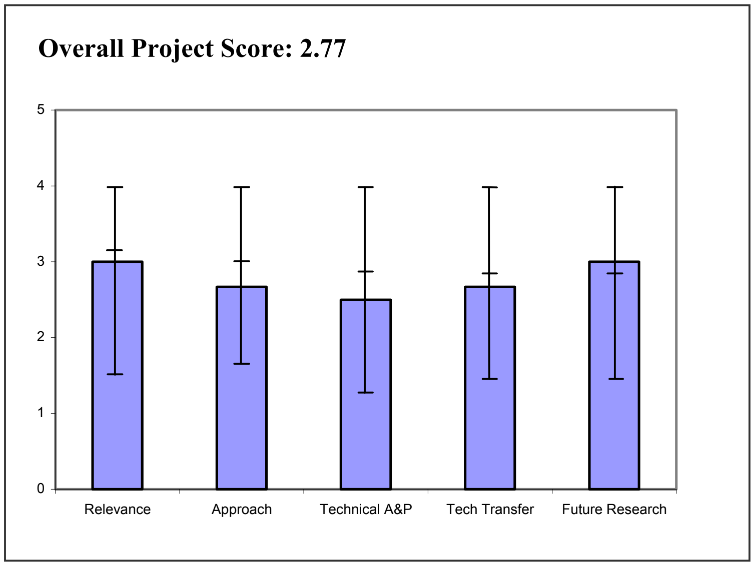
Strengths
- Materials science knowledge.
- Vision of importance of work.
- Research plan and premise of engineering effort are aimed at rapid screening and combinatorial alchemy of potential efficacious photocatalysts.
- Project team appears to be effective in fully characterizing the materials synthesized by the combinatorial methods/apparatus.

Weaknesses
- Basic materials research is not amenable to a fixed schedule.
- While the methods/apparatus are capable of producing a vast array of compositional variables, the overall effort seems to lack hypothesis-driven guidance or direction in terms of the composition-activity relationships, and theoretical component of overall effort is missing.

Specific recommendations and additions or deletions to the work scope

- Need to implement theoretical element of effort in order to compare experimental results with what theory can predict.
- *Ab initio* solid-state theory such as VASP, density functional theory, should be considered as a means of predicting band structure and photophysics.

Project # HPD-P11: High Efficiency Electrolysis Materials Research
Ingersoll, David; Sandia National Laboratories



Brief Summary of Project

Sandia National Laboratories (SNL) intends to improve the cell performance for electrolysis of water through improved catalysts and membranes. Specific objectives of the project are to prepare structured polymer thin films as novel low resistance, hydroxyl conducting membranes and evaluate their electrochemical performance as electrolyte/separator, prepare and electrochemically evaluate transition metal (e.g., Mo) macro cycle complex-based electrocatalysts, develop combinatorial catalyst discovery using direct assessment of electrochemical activity, and develop novel catalyst discovery through spatial correlation between localized electrochemical activity and catalyst composition/structure of more traditional electrocatalysts.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Improving the efficiency of electrolysis, assuming the principal energy source comes from a renewable form (e.g., solar) is important to the goals and objectives of the Hydrogen Program.
- The materials-related challenges, however, are great as they mirror those of the battery industry.
- Project is 1-2 months into work.
- Critical evaluation at this point may be premature.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- The synthetic scheme for Mo-based macrocyclic catalyst has significant technical barriers with regard to control of template quaternary structure and the simultaneous cross linking of monomer to form a highly conjugated, continuous porous structure.
- It is not even clear whether the PS template can be removed without destroying the macrocyclic framework.
- The synthetic pathway toward cross linking the monomer was not effectively described.
- It would seem prudent to first demonstrate using a readily polymerizable system that the approach toward forming a scaffold will work. Otherwise, the success of this project will be determined by what happens much later in the plan than earlier.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Not applicable.
- Too early in the project to judge.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Too early in the project to judge.
- Only "potential" or internal collaborations were identified.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Its almost all future.
- The critical, proof of principle experiments will be conducted through the remainder of FY 04.

Strengths and weaknesses

Strengths
- Project plan represents high-risk though novel approach toward the development of highly porous electrocatalytic materials for water electrolysis.
- If approach for synthesis of electrocatalyst is successful, a similar tactic may be used in the development of similar electrocatalytic membranes for fuel cells or for petrochemical processes.

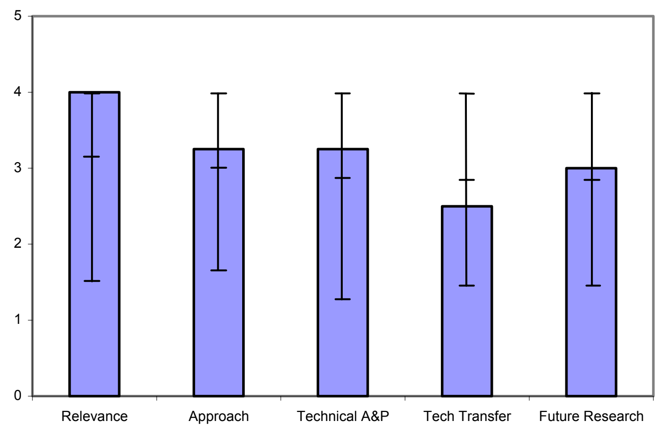
Weaknesses
- Experimental approach lacks details pertaining to the chemistry of cross-linking macrocyclic monomers.
- The success of the experimental approach relative to synthesis of electrocatalyst is determined too late in the program.
- No experiments have been planned to support proof of principle early in the project.

Specific recommendations and additions or deletions to the work scope

- Proof of principle experiments for the synthesis of electrocatalyst (cross-linked macrocycle) need to be conducted early in the project to determine whether or not PS template approach has any chance of success.
- A readily polymerizable system may be explored, such as a polyamide or a polyimide, to test approach.

Project # HPD-P12: Low-Cost, High-Pressure Hydrogen Generator
Cropley, Cecelia; Giner Electrochemical Systems, LLC

Overall Project Score: 3.20



Brief Summary of Project

Giner Electrochemical Systems, LLC has an overall project goal of developing and demonstrating a low cost, high-pressure water electrolyzer system, which will eliminate the need for a mechanical hydrogen compressor, increase electrolyzer hydrogen discharge pressure to 5,000 psig, and demonstrate a 3,300 scfd high pressure electrolyzer operating on a renewable energy source. Past Year (Jan 03- Mar 04) tasks included the development of lower cost materials and fabrication processes for stack components, fabricating and demonstrating an electrolyzer stack and system producing hydrogen at 2,000 psig, and designing and fabricating a test stand for 5,000 psig operation.

Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Electrolyzers will have a place in the hydrogen economy as a method of converting electricity from any source into H_2.
- May provide a commercial alternative for pressurization from rotating equipment.
- Compression is a big issue and this project addresses a high-potential way of addressing this issue.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Incremental approach is good.
- Component by component improvement in the electrolyzer will lead to steady progress in overall performance. A strong approach.
- Focused approach on demonstration of feasibility and reducing cost.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Stack cost reduction on track.
- Found lower cost materials, reduced compound count. But significantly impacted unit cost.
- Increased operating pressure two-fold good progress in first year. Another 2-fold in second year will be excellent.
- Significant progress to lowering cost and demonstrating feasibility at increased pressures.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Collaboration with other designers/fabricators may be helpful.
- GM has substantial ownership stake in Giner, so collaboration with GM is essentially not a collaboration.
- GM gets to keep the technology funded with government money.
- Outreach program is nice but also not a collaboration.
- Consider/confirm collaboration with other research programs, for example Europe and Japan.
- Little collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Schedule is aggressive, hard to see how it can be accomplished.
- Likely to reach goals but next steps are somewhat ill-defined in the poster. This is probably due more to confidentiality rather than any weaknesses in capabilities of the researchers.
- Builds on past research and addresses overcoming barriers.

Strengths and weaknesses

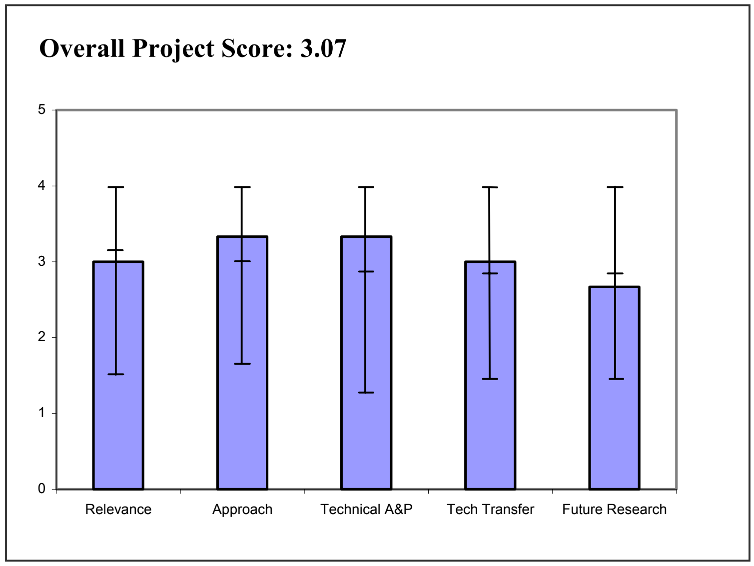
Strengths
- Giner Electrochemical is a top candidate for breakthrough technological advancement, having more experience than most others.
- Trying to go from ambient to 5000 psi with no mechanical compressors will lower cost of the unit and push the limit of what can be done with high pressure electrochemistry.
- Interesting opportunity to replace mechanical compression.

Weaknesses
- No collaborations.
- Should expand in non-critical areas rather than doing everything alone.
- Proposed future research short on specifics, hard to evaluate.
- No optional paths identified.
- Little collaboration with universities, etc.

Specific recommendations and additions or deletions to the work scope

- We really need to get to 10,000 psi hydrogen.
- Consider feasibility of achieving higher pressures.
- Work on catalyst loading impressive but makes little impact on system cost (compared with balance of plant costs).
- Many researchers are working on catalysis, so need not be included in scope of this project.

Project # HPD-P13: Hydride Based Hydrogen Compression
DaCosta, David; Ergenics



Brief Summary of Project

The goal of this project is to develop a hydride-hydrogen compressor that operates in conjunction with advanced hydrogen production technologies and improves the efficiency and economics of the compression process. The objectives are to: continue testing a single stage hydride thermal compressor that employs three purification technologies to determine threshold contamination levels for common impurities; investigate compressor capabilities to perform the dual function of compression with purification for impurities that adversely affect fuel cell operation (e.g. CO); and develop miniature hydride heat exchanger manufacturing methods that will reduce cost to approach the 2010 cost targets.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- This is outstanding work, the reason for only a good rating is that the development of metal hydride compressors is not critical in meeting the President's Hydrogen Initiative goals like storage and lower cost.
- Alternative method for H_2 compression to reduce energy needed is important.
- This system is needed and will be needed in the future as hydrogen applications become more significant.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- The approach over the past several years has been outstanding.
- A version is near commercial status and they expect to make their first sale this year.
- They have one remaining challenge of removing methane. The PI explained their approach of raising temperature on the first discharge, which should solve the problem.
- Good approach based on background of hydrides for H_2 storage.
- Improved durability in the presence of impurities is important.
- Size of compressor needs to be reduced.
- Cost needs to be reduced.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.33** based on accomplishments.

- The metal hydride compressor shows superior performance over other methods of gas compression for H_2.
- Demonstrated removal of CO and moisture stability are good achievements.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- The company is a small business and has not collaborated to a large extent.
- The justification for the outstanding rating is with some collaboration and internal expertise they are very close to going commercial.
- Needs to work with fuel cell partner.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- The PI indicates the project ends in this next year because they are close to success. They did not have a list for future research.
- The rating of good is based on the need for different sizes and pressure ranges to meet H_2 needs in compression in the future.
- Need to develop independent funding source for next phase.
- More cycling of material (hydride) is needed.
- Removal of CH_4 needs to be addressed.

Strengths and weaknesses

Strengths
- A near commercial success, the type DOE needs to keep their long range H_2 program on track.
- Necessary device for future hydrogen application.
- Ability to remove CO and H_2O from gas stream during compression.

Weaknesses
- Would have liked to see the company looking at different configurations of their concept of metal hydride compressors, so DOE in the out-years could continue to have success stories associated with funding.
- Bulky size -- needs to be smaller.
- Not enough cycling data.

Specific recommendations and additions or deletions to the work scope

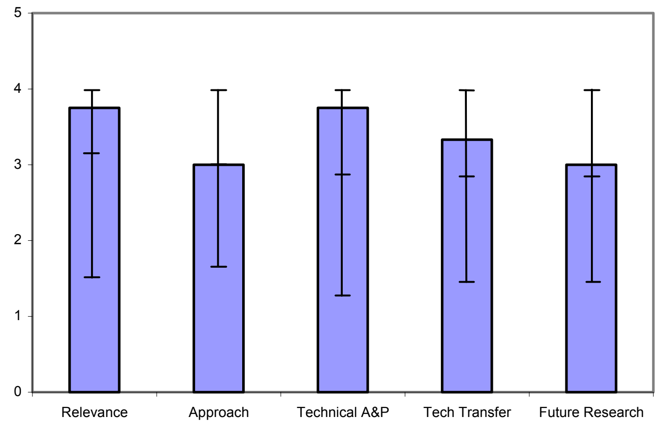
- The recommendation is for DOE to keep its involvement in metal hydride compressors and not have it end next year.
- Reviewer had difficulty addressing cost-benefit plan for hydride compressor.
- Different engineering design is needed for the cooling and heating system.

Project # HPD-P14: Technical and Economic Studies of Regional Transition Strategies Toward Widespread Use of H_2 Energy
Ogden, Joan; University of California, Davis

Brief Summary of Project

This University of California, Davis project will develop new simulation tools to evaluate alternative pathways toward widespread use of hydrogen under various demand scenarios and regional conditions. Tasks are to understand which factors are most important in finding viable transition strategies, to develop “rules of thumb” for future regional hydrogen infrastructure development, to conduct regional case studies of H_2 infrastructure transitions, and to work with the H_2A core group to develop models of hydrogen delivery systems.

Overall Project Score: 3.37



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.75** for its relevance to DOE objectives.

- Great communication and analysis tool.
- Very relevant for planning the transition.
- Identify how H_2 will enter the market best.
- Useful tool for analyzing the transition.
- Shareable excel model.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Very good but somewhat mechanical approach to demand.
- Needs a more robust demand model.
- Needs to consider other possible transitions- smaller vehicles.
- Not driven by price - price conservatism.
- Safety needs more attention.
- Well thought out and addressed barriers.
- Very good job of thoroughly thinking out the issues, starting simple and adding complexity.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.75** based on accomplishments.

- Model and engine very impressive for the budget; great work.
- Presenter was very impressive in understanding and dedication.
- Excellent progress considering the number of factors considered.
- Have produced a useful model that can evolve.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Seems to share progress and much inputs.
- Working with H_2A.
- Good use of a variety of resources.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Optimization seems misplaced.
- Build on existing work.
- A logical extension of the current work.

Strengths and weaknesses

Strengths
- Easily shareable basic model.
- Presenter has impressive understanding and dedication.
- Good slate of collaborators and good communication potential.
- Application of thorough, novel thinking.
- Probably one of the better modeling studies.

Weaknesses
- More attention needs to be placed on safety.
- Needs to consider other vehicle transition, a better understanding of demand and perhaps, price drivers.
- Optimization leads to ideal results.
- Model depends greatly on its assumptions.

Specific recommendations and additions or deletions to the work scope

- Drop optimization for now. Replace with system dynamics study to understand how to improve system.
- Deserves support at maintenance level not an expansion level to see how the hydrogen and fuel cell vehicle transition evolves.

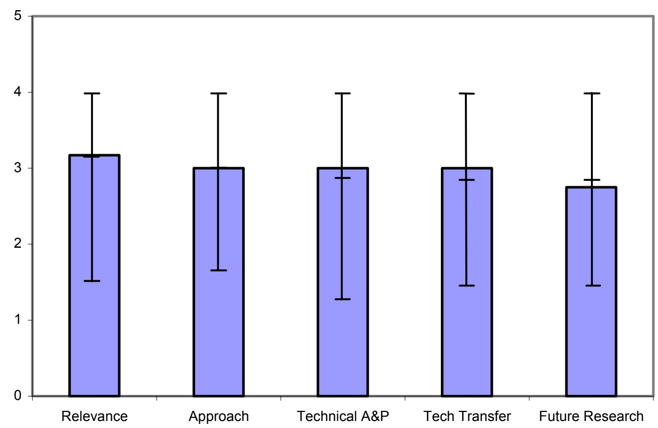
Project # HPD-P15: Hydrogen Production in a Greenhouse Gas Constrained Situation

Kartha, Sivan; Tellus Institute

Brief Summary of Project

Tellus Institute is examining in a detailed quantitative manner, plausible scenarios for a transition to a hydrogen economy. They will explicitly illustrate the staging and sequencing of major phases of the transition scenarios and their implications, quantify the greenhouse gas (GHG) reduction benefits of each of the transition scenarios, explore the spatial characteristics of the transition scenarios based on GIS analyses for four greater metropolitan areas of the USA (Boston, Denver, Houston, and Seattle), and account for relevant techno-economic and policy factors.

Overall Project Score: 2.98



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.17** for its relevance to DOE objectives.

- Model capable of key insights into dynamics of fleet transition.
- Focused on individual cities.
- Interesting compliment to other modeling efforts.
- End state focused.
- End state focus isn't quite as critical as transition.
- CO_2 impacts should be an important factor when considering a H_2 transition.
- Should produce a useful tool for assessing the transition.
- This study is important to the President's Initiative, since reducing CO_2 emissions is one of the big reasons for going to hydrogen. Pathway studies on CO_2 emissions from various types of hydrogen production are of great value to policy makers.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- These scenarios explored various scenarios.
- Assuming 90% fleet replacement by 2050.
- Needs to consider other cases besides National Energy Modeling System (NEMS) other economic /political scenarios.
- Not too much detail on internals of model.
- Approach seems good for examining infrastructure options in urban centers.
- Does current data warrant such detailed GIS mapping?
- Well thought out approach focused on modeling transition in a few cities.
- Appropriate for scope of the project.

- The PI appears to have uses the appropriate model and techniques so his findings can be integrated easily into DOE's internal assessments.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Model recall time keeps it from general use.
- Needs to track petroleum demand and other air transportation energy demand.
- Valuable tool for a municipality to get energy transition plans.
- GIS work adds little of analysis but is a serious point for municipalities.
- Not much info on progress in last year.
- Hard to evaluate.
- Significant progress toward project and DOE goals.
- Have produced some useful thinking on transition possibilities.
- The project appears to be near completion and is meeting the DOE goals for it.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Collaborations from specific cities should be brought into the loop.
- Coordination with H_2A is important.
- Work with a H_2A to develop assumptions- also with others on energy projections.
- Good use of H_2A results.
- I was not made aware of any collaborations with others.
- The good rating was based on the case of which this work could be transferred to DOE.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- More emphasis should be placed on alternative economic analysis.
- Environmental impact should be accompanied by energy and petroleum impact.
- Prices should be answer.
- Future direction not clear from poster.
- Focused on continuing previous work.
- Appropriate for completion of specified approach.
- The PI made only a fair case for continued support by citing that he would like to look at regional issues in more detail in the future.

Strengths and weaknesses

Strengths

- Well coordinated with NEMS.
- Addresses individual cities.
- Well thought out vehicle turnover model.
- Good GIS capability.
- PI knowledgeable in process used for program.

- Very focused on a few markets with detailed and various scenarios.
- Thorough work within the assumptions employed.
- Projection studies of this type are always risky; however, they do provide guidance to the decision and policy makers.
- This study did show limited to "no" CO_2 reduction when producing H_2 from fossil fuels.
- Comparative studies of this type allow planners to direct the available funds to the most appropriate production routes and distribution.

Weaknesses
- Too much dependence on NEMS.
- Municipalities should be part of collaboration.
- Not enough attention paid to energy and petroleum/gasoline offset.
- Project seems to be GIS capability in search of a mission.
- Limited number of cities investigated.
- Very dependent on assumptions, especially the definitions of the transition scenarios.
- Would have benefited from a more thorough vetting of transition scenarios as part of the collaborative process.
- Having ten to twenty year projections based on costs is troublesome to me. I would prefer to have these long range projections based on efficiency.
- The most efficient method of producing and transporting H_2 will be the best.
- Costs can be calculated or added into the model, if near term costing data is needed.

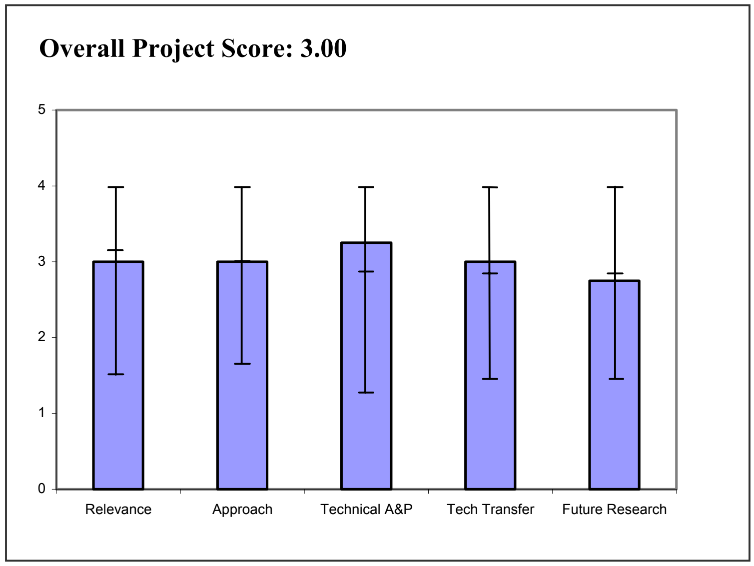
Specific recommendations and additions or deletions to the work scope

- Demonstrate to municipalities for comment and collaboration.
- Enable comparison with other fleet size/ vehicle evolution -- other economic political scenarios.
- Display petroleum/gasoline offsets in model results.
- DOE should continue to fund these comparative studies.
- These types of studies are needed for making sound decisions.

Project # HPD-P16: Fuel Choice for FCVs: Hydrogen Infrastructure Costs
Lasher, Stephen; TIAX

Brief Summary of Project

TIAX is conducting an assessment of the opportunities and risks for various fuel choices for FCVs –in particular comparing hydrogen to onboard reforming of gasoline. The assessment is also being used as a support to the refined R&D targets for direct-hydrogen FCVs based on an analysis of well-to-wheel energy use, GHG emissions, cost, and safety of direct-hydrogen FCVs and competing vehicle technologies.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Highly theoretical (by its nature).
- Useful to national effort but must be taken with a grain of salt.
- One of the few infrastructure economic modeling efforts.
- Studying how to best have hydrogen enter market-economics modeling.
- Should integrate more with ongoing DOE efforts (H_2A)-NEMS.
- Useful work to better understand the drivers for technology choices during the transition.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Difficult to tell a lot about details from poster.
- Investment return approach is valuable. Turns scenarios into cash value for potential investors.
- Good approach - would like to see scope expanded.
- Good recognition of the important components of assembling type of model.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Difficult to assess quality of output, but is in general agreement with similar models.
- Plans to address areas where less is known and not based on natural gas reforming.
- Have assembled and done some refining of a comprehensive model.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Results should be validated with or incorporated into H_2A effort.
- Industrial entities should confirm component accuracy.
- Good collaboration/interface with industry - could involve more university.
- Having solicited and responded to stakeholder comments from a variety of parties.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Usefulness unclear.
- Work with H_2A.
- Good opportunity as long as it is well integrated with other DOE modeling efforts.
- Appropriate for project status.

Strengths and weaknesses

Strengths
- Good start at modeling H_2 transition.
- Model needs to be opened to public for validation.
- Adapting to meet program need and reflect more scenarios.
- Look at transition period, which may well be more significant to the development of a hydrogen economy than the long-term market.
- Includes all the necessary key components to adequately model the transition.
- Good job of soliciting and incorporating outside comments.

Weaknesses
- Modeling has limited usefulness.
- As usual, too many variables.
- Currently limited scenarios.
- As goes for any model of this type, it's only as good as its assumptions.

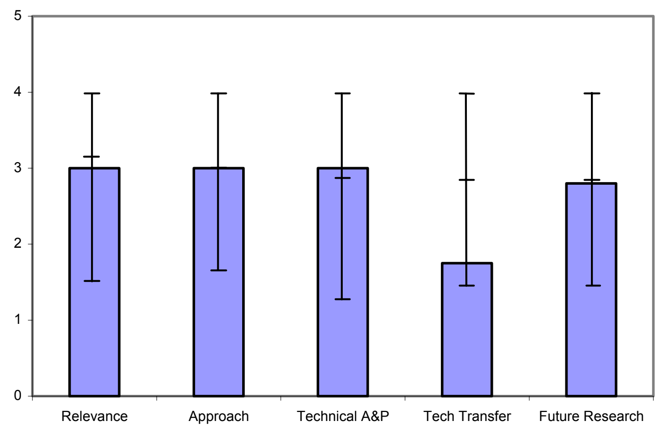
Specific recommendations and additions or deletions to the work scope

- This project should be funded at a relatively low level so that the model may be updated with new events.

Project # HPD-P17: New York State HI-Way Initiative

Hopewell, Paul; GE Global Research

Overall Project Score: 2.71



Brief Summary of Project

Under this DOE contract, the GE Global Research's Hydrogen Production Team is researching methods to achieve considerable reduction in alkaline electrolyzer system costs, compared to prevailing prices of available new equipment. They will do this by technological advances, production methods, materials of construction, or a combination of these methods. Appropriate physics-based performance and cost models will be used to allow detailed trade-off analyses to identify practicable performance and cost solutions.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Efficient electrolyzers are obviously in the plan.
- Reducing cost of electrolyzer and resulting H_2 product are specific goals of the program.
- Very important to lower electrolyzer cost.
- Useful work on a technology that has been identified as key.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- No obvious novel idea for electrolyzers. Little novelty.
- Seemed to be a pretty routine materials and design selection process rather than any real research into how to make step-changes in electrolyzer design.
- Targeted approach appears to maximized progress during limited timeframe.
- Goal is to understand cost drivers and systematically pursue materials substitution and process improvements to drive capital and products costs down.
- Seem to be addressing technical barriers in a focused and logical way.
- Address the key elements of the DOE technical barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- New project.
- Project is still beginning phases, hard to evaluate. However a good performance plan is evident.
- NA - Project began April 1, work started but no/few results available.

- Good progress - project began in April.
- Not applicable - new project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.75** for technology transfer and collaboration.

- May be too early to evaluate.
- Some stated collaboration with SUNY but actual value is not evident.
- No overt collaboration at tech transfer.
- Good use of collaboration - however much of the collaboration seems to be internal to GE.
- None identified, although it should be noted the project has just started.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.80** for proposed future work.

- Again, not sure of novelty of approach.
- Project scope is reasonably well defined.
- One year plan - bench scale demo at end of year and models.
- Further development outside this project.
- Future plans are less specific than they would ideally be however it is a very new project.
- Consistent with objectives and targets.

Strengths and weaknesses

Strengths
- Aligned with program.
- Presentation did not portray project objectives and specific scope well.
- Could not tell what was being done without aid of discussion with presenter.
- Goal is to use this project to seed a further development/ commercialization effort.
- Too early to comment.
- Really worthwhile project with excellent chance of lowering cost of electrolyzer costs.
- GE has good corporate range to address many of the barriers.
- Plan is for a comprehensive breakdown of electrolyzer manufacturing costs and how they can be reduced.

Weaknesses
- Pretty routine approach to making a step change.
- Safety approach limited to hazards assessment?
- Too early to comment.
- Not enough time on project to say.

Specific recommendations and additions or deletions to the work scope

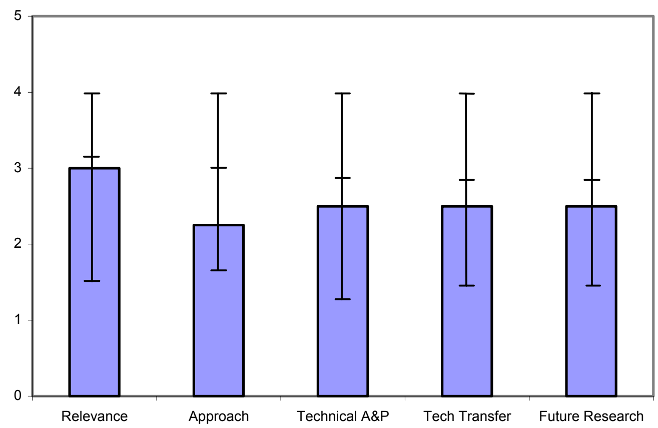
- None provided

Project # HPD-P18: EVermont Renewable Hydrogen Fueling Station
McKay, Chris; Northern Power Systems

Brief Summary of Project

Northern Power Systems is assisting the DOE in the development of hydrogen production technologies by building and testing a validation system. Objectives of the project are to: develop an advanced PEM electrolysis fueling station that utilizes renewable electricity sources; reduce cost of hydrogen production; improve electrolyzer efficiency; improve fueling station integration and controls; utilize hydrogen fueled vehicles for testing and validation; and show viability of distributed production pathway.

Overall Project Score: 2.55



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Objective is to rely on renewable sources.
- Flow chart integrates with electrical grid.
- How power output from wind will require use of grid.
- Grid for most locations is from non-renewable.
- Project allows partners to assemble integrated systems with (existing) advanced tech over current commercial offerings and get field-use validation.
- Demonstrates feasibility of H_2 production in near term.

Question 2: Approach to performing the research and development

This project was rated **2.25** on its approach.

- Other similar projects.
- No real new technology, but first integration of components in improved product.
- Re-assurable approach for electrolyzer-based fueling station demonstration.
- Not very R&D.
- Focuses on demonstration.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Too early in program to comment.
- Project cost is mostly a function of electrolyzer which is a separate effort.
- Project only began recently.
- Partnerships plan and budget established.

- Final contract not yet negotiated.
- Few technical barriers - though first of a kind.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Consider/confirm collaboration with other similar projects to share "lessons learned."
- Good proposed team with industry leaders, well integrated.
- Should involve more university participation.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Future work may be more commercial related as opposed to research.
- Plans appropriate for early stage of project - next year's review will be much more telling.
- Demonstration of H_2 distribution and production.

Strengths and weaknesses

Strengths
- Too early to evaluate.
- Near term demonstration of H_2 feasibility.

Weaknesses
- Too early to evaluate.
- Move demonstration in RD&D.

Specific recommendations and additions or deletions to the work scope

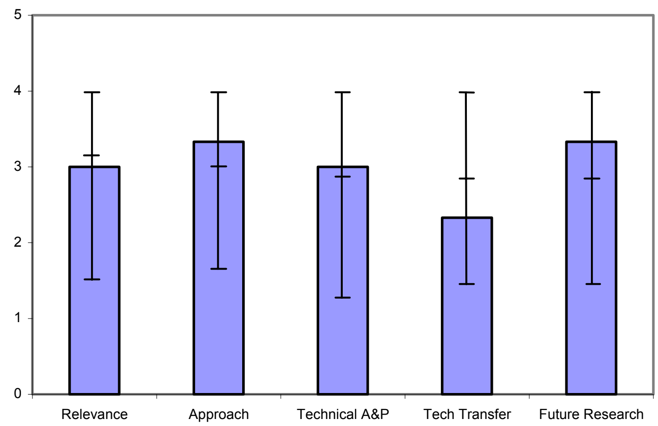
- None provided

Project # HPD-P20: Photopolymerization/Pyrolysis Route to Microstructured Membrane Development
Berchtold, Kathryn; Los Alamos National Laboratory

Brief Summary of Project

This Los Alamos National Laboratory (LANL) project will provide a rational approach to the design of synthesis processes for robust ceramic membranes with high gas permeability and gas selectivity at 1000C and higher. This novel route utilizes preceramic polymeric precursors while using established and economical polymer membrane fabrication techniques. The ceramic membrane is developed from the polymer membrane by a pyrolysis step adding another level of control over membrane permeability and selectivity.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Critical evolution at this time may be unwanted.
- This project may provide a new route to new materials for several different components.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Excellent approach to exploring new materials.
- Confirm integration testing with various fuels.
- Good sequencing of acquisition of fundamental knowledge of capabilities of the technique followed by a more structured experimental design.
- Completion of these steps will establish framework to explore more targeted applications.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Program not initiated until 04.
- Not applicable.
- Very good progress for such a new project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- Collaboration not described - possibly none needed.
- No indications of any collaboration but that is not really a problem at this stage of this type of work.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- It's almost all future work.
- Ambitious plan for the rest of the year.

Strengths and weaknesses

Strengths
- Novel approach that could yield novel materials.

Weaknesses
- May be attempting too much too quickly; some patience may be required in project management/ funding.

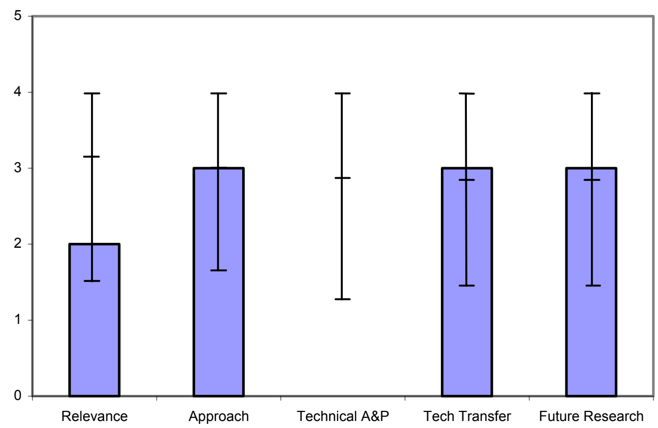
Specific recommendations and additions or deletions to the work scope

- As progress is made, collaboration opportunities should be identified.

Project # HPD-P21: Developing Improved Materials to Support the Hydrogen Economy

Shinkle, Robert; Edison Materials Technology Center

Overall Project Score: 2.75



Brief Summary of Project

Edison Materials Technology Center (EMTEC) will use Hydrogen Program goals to identify and fund projects with near term commercialization potential, using cross-cutting breakthrough materials technology and application-specific tailored nanomaterials. State of Ohio matching funds are pending.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- Difficult to see direct relationship to DOE objectives.
- Framework not inconsistent with the DOE plan; however, near term focus ignores the current state of the art considerations that drive the RD&D plan.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Framework is there to provide useful contribution; too early to tell if the promise will be fulfilled.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **N/A** based on accomplishments.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Not applicable.
- Project almost entirely collaborative - all of the work is essentially contracted out.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- All work is future.
- Proposal is to sponsor useful work.

Strengths and weaknesses

Strengths
- Indicate a willingness to work closely with DOE to maximize value added to existing program.

Weaknesses
- Too near-term focused; does not recognize the state of development of the vehicle and storage technology.
- Hard to see value added in having this contractor solicit and fund project proposals rather than DOE doing it directly.

Specific recommendations and additions or deletions to the work scope

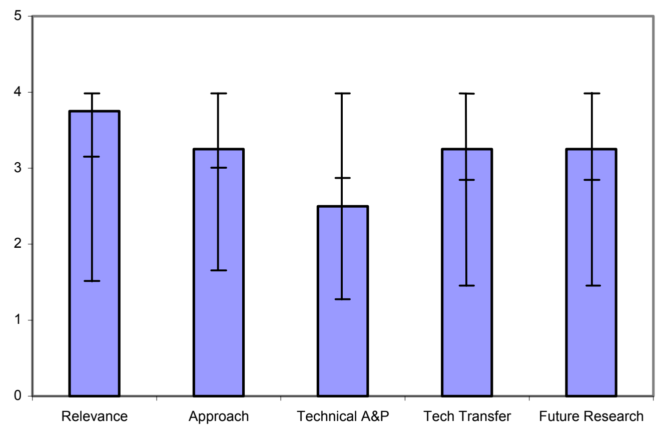
- A more focused scope on materials would make more sense.
- If multiple areas should be pursued, perhaps this should be multiple projects.
- Change focus to longer-term; no immediate need for hydrogen production technology for the hydrogen initiative.

Project # HPD-P23: Hydrogen Generation from Electrolysis
Maloney, Tom; Proton Energy Systems

Brief Summary of Project

Proton Energy Systems and its team will determine pathways to optimum electrolysis-based H_2 fueling through conceptual system design and component/system development. They will develop the requirements for the fueling system, optimize fueling system designs through systems analyses, and conduct R&D to improve component performance, cost, and/or durability.

Overall Project Score: 3.20



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.75** for its relevance to DOE objectives.

- An integrated system incorporating renewables is vital to meeting the goals.
- Demonstration of a complete electrolysis package.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Very well structured approach, good timeline, barriers being addressed.
- Have identified the key levers for optimizing this technology.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Project just starting. Results expected next year.
- Not applicable; project only just initiated.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Consider collaboration with other similar projects.
- A well integrated team incorporating renewables, production process, and mechanical (storage compression).
- Have identified key collaborators knowledgeable in specific area.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- Look forward to seeing more.
- Good plan.
- Consistent with project approach.

Strengths and weaknesses

Strengths
- Very well integrated process.
- Knowledge leveraging among partners.

Weaknesses
- None provided

Specific recommendations and additions or deletions to the work scope

- This work is properly focused on the wind to H_2 car fueling issue.
- This effort is important to the National energy effort.
- Would benefit from DFM analysis of the entire system in addition to the planned volume manufacture analysis.

Hydrogen Storage

Summary of Annual Merit Review Hydrogen Storage Subprogram

Summary of Reviewer Comments on Hydrogen Storage Subprogram:

Reviewers considered hydrogen storage R&D to be critical to the President's Hydrogen Fuel Initiative. The projects were considered to be appropriately diverse and strongly focused on addressing technical barriers and meeting targets. The Center of Excellence approach was praised as an example of effective R&D collaboration between National Laboratories, industry and academia.

The major criticism by the reviewers was the redirection of funds to Congressionally-directed projects and its impact on the program. As a result, none of the Grand Challenge awards were made in 2004 and a shift toward more exploratory research, a recommendation in the National Academies' Report, could not be implemented.

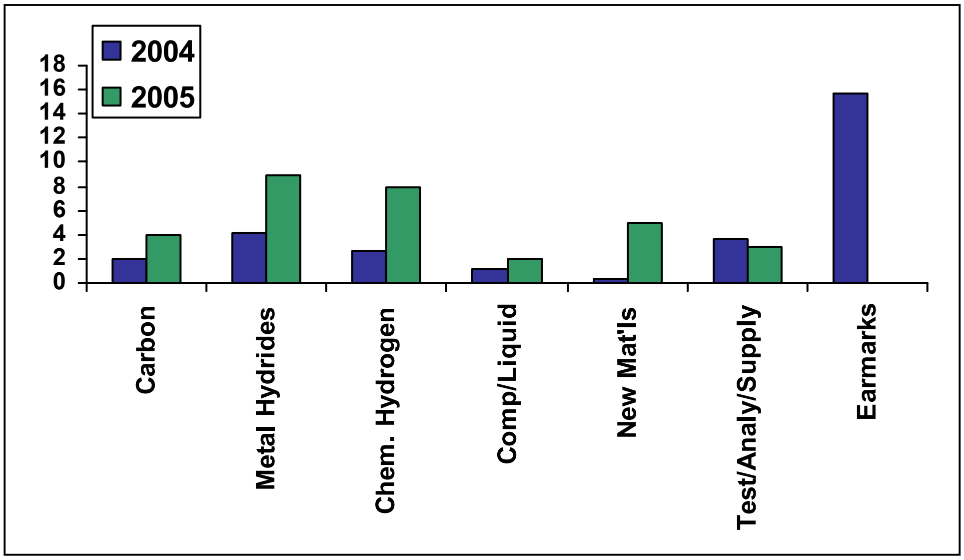
Additional recommendations were to conduct earlier analyses on alternate options and place greater emphasis on go/no go decision points. Most comments related specifically to continue funding of carbon nanotube R&D. DOE's position is that it is premature to eliminate or scale back work on carbon nanotube materials. Adequate research funding and time are needed to address reproducibility issues and to provide closure on controversial issues surrounding past work on carbon nanotubes in the technical community. A milestone is in place to reproducibly demonstrate 4 wt% storage in carbon nanotubes in 2005. A go/no-go decision point based on achieving 6 wt% storage is scheduled in 2006.

There was also a request for DOE to justify its emphasis on metal hydride R&D. Research on complex metal hydrides is part of DOE's hydrogen storage portfolio largely due to recent breakthroughs, particularly with sodium alanates. Although this material, with a less than 6 wt% theoretical capacity for the *material alone*, will not achieve the 6 wt% *system-level* target, a better mechanistic understanding of hydrogen storage in sodium alanate will likely advance the design and development of other higher-capacity complex metal hydrides.

Finally, the reviewers also commented on the need for cost reduction in the area of compressed hydrogen tanks. It should be noted that the National Academies' Report recommends that DOE terminate work on compressed and liquid hydrogen tanks for on-board storage because these technologies are near commercialization. However, since early hydrogen-powered vehicles will likely use high pressure tanks, the major barrier of cost must still be addressed. The DOE plans to shift away from funding work focused only on weight and volume targets for tanks. Future work on compressed/cryogenic tanks will focus on novel approaches for cost reduction and conformability, as well as on R&D for off-board storage applications. Advanced concepts for tanks such as heat dissipation in solid-state systems will also be explored.

Hydrogen Storage Funding by Technology:

The funding portfolio for hydrogen storage addresses primarily long-term materials R&D to meet 2010 and 2015 targets for on-board applications. The requested FY2005 funding profile, subject to Congressional appropriation, addresses the National Academies' Report recommendations and provides greater emphasis on new materials and concepts. Focused R&D through Centers of Excellence in metal hydrides, carbon-based materials and chemical hydrogen storage will also be implemented subject to congressional appropriations.



Majority of Reviewer Comments and Recommendations:

In general, the reviewer scores for the storage projects were average or low (the highest scoring project received only a 3.32 score). In many cases, this is because the projects are new and have minimal progress or technical accomplishments to report. Key recommendations are summarized below. DOE will act on reviewer recommendations as appropriate for the scope and coherency of the overall hydrogen storage research effort.

- **Tanks:** Focus on cost reduction. Define component volumes in the calculation of system volumetric capacity.
- **Chemical Hydrogen Storage:** Address life-cycle efficiency, particularly for off-board regeneration of spent fuel, early in the program. Emphasize go/no go decision points in the project research plans.
- **Metal Hydrides:** Refocus efforts on new materials with potential to meet the long term storage targets.
- **Carbon:** Implement go/no-go decision points. Shift emphasis from single walled carbon nanotubes and address the broader area of carbon-based materials and other high surface area adsorbents.
- **New Projects:** Some new projects need more focus and coordination. Greater emphasis on new approaches to meet long-term targets is positive in the DOE plan.

- **Testing and Analysis:** This is a critical area and there is a need for rapid storage capacity evaluation methods. Achieving reproducible and accurate results, accepted by the technical community, is an important first step.

For essentially all areas, defining a list of system components and their respective weights, volumes, and cost, is recommended.

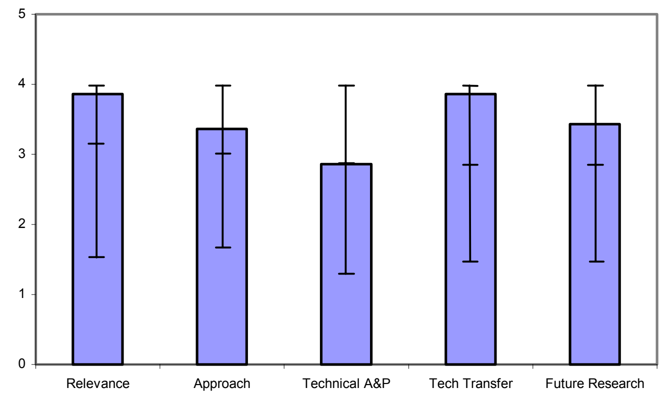
Project # ST-1: Hydrogen Storage Subprogram Overview

Milliken, JoAnn; DOE

Brief Summary of Presentation

The purpose of this Storage Subprogram Overview is to: describe goals/objectives; budget; barriers/targets; approach to R&D; technical accomplishments; interactions and collaborations; solicitations and awards; and future directions. As such, it sets the stage and puts into context the R&D and analysis projects which will be presented in this subprogram area during the Annual Merit Review.

Overall Project Score: 3.47



Question 1: Relevance to overall DOE Hydrogen objectives

This presentation earned a score of **3.86** for its relevance to DOE objectives.

- This Subprogram is extremely important to allow the President's Hydrogen Fuel Initiative to be realized. The projects included are diverse in their approaches to storing hydrogen (primarily on-board a vehicle).
- Program status presented clearly.
- Nice overview of future program directions.
- The presentation gave a good description of the program.
- Most of the funded projects have merit and align with the Hydrogen Fuel Initiative and Multi-year R&D Plan.
- On-board H_2 storage is absolutely critical to the President's program work. Without it, the mobile hydrogen economy will never come to fruition.
- Generally very good overview, but some further justification would have been useful, e.g., why the heavy emphasis on metal hydrides.

Question 2: Approach to performing the research and development

This presentation was rated **3.36** on its approach.

- This H_2 storage program is very focused on the technical barriers and stresses that all projects keep focused on the targets.
- New ideas/approaches are given fair attention.
- Early evaluation of the projects vs. targets would be beneficial considering redirection of resources if no-go.
- The approach of sponsoring a wide range of programs that study many different techniques is perfect.
- Seeking many inputs on what to work on and what goals to set is important too.
- Funding work that is too risky for others, but could serve if it works is even appropriate.
- I have doubts that carbon nanotubes will have chances of reaching the 4 wt% storage density target.
- May need to be slightly more ready to drop projects with serious doubts.

Question 3: Technical accomplishments and progress toward project and DOE goals

This presentation was rated **2.86** based on accomplishments.

- Low score due to funding issues and timing.
- Congressional earmarks affected the output.
- Progress in this program is very good. The nearer term technologies are fairly close to meeting 2010 targets. No technologies are close to meeting 2015 targets and capacity and conformability still remain as difficult barriers.
- Although, individual projects show different progress towards targets, overall accomplishments stated very clearly, progress towards goals is significant.
- Progress is really quite good.
- Nearing 2010 goals for physical storage methods in many dimensions, a significant advance.
- While solid storage materials are behind the more mature methods, there has been significant percentage increases.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.86** for technology transfer and collaboration.

- This program demonstrates an outstanding level of collaboration with many industry, academic, and government participants. Examples, such as Quantum, are working towards technology transfer for implementation in vehicles.
- Centers of Excellence is a good example how research collaboration should be done.
- Center approach will ensure collaboration, cooperation and coordination.
- Very good collaboration shown by the contractors and the DOE team as well.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.43** for proposed future work.

- Can implement earlier go/no-go decision point?
- The Grand Challenge should provide significant increases in quantity, quality and speed for advancing research in H_2 storage.
- Excellent focus on new storage materials to meet the targets.
- Future work is well distributed with emphasis in many important areas.
- There is a need for more work on cost of compressed and liquid storage methods to declare victory. While these were down played in the NRC report, it is hard to argue with the idea that most FCVs will initially use one of these methods if the cost can be reduced to an acceptable level.

Strengths and weaknesses

Strengths
- Strong leadership.
- Strong vision.
- Integrity.
- The DOE team is qualified, coherent, well-managed and doing a great job.
- Most funded projects have merit.
- Vital and well informed team of sufficient size to handle the job.

- Diverse approach.
- Go/no-go decision points to "window" programs based on promise.
- Ambitious customer oriented goals.
- Excellent program plan.
- Presenter appeared to be an exemplary program manager.

Weaknesses
- Be more flexible.
- Be more agile.
- Adopt the "fail-fast" principle.
- Available funds not enough to start new projects.
- Earmarks have a large negative impact.
- Projects chosen may not be the best ones.
- Some projects will have trouble moving forward.
- Material safety should be a major concern.
- Funding paced to government budget cycle.

Specific recommendations and additions or deletions to the work scope

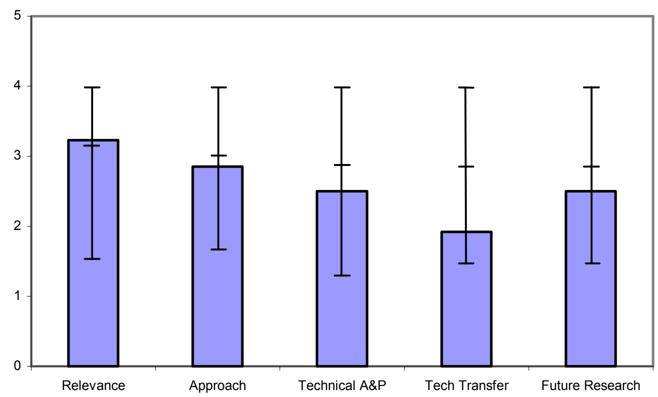
- Start the analysis of each alternative as soon as possible.
- The go/no-go decision should be made at earlier stage.
- Conserve resources.
- Spread the resources to a wider group.
- New technology routes may need to be assessed earlier in their development against their theoretical ability to reach technical and economical targets, and terminated if the answer is negative.
- More new-materials projects are needed.
- Funds on carbon nanotubes can be reduced.
- Work on sodium borohydride regeneration will not be fruitful. So, go/no-go decisions need to be set earlier.
- Need more money.
- Carbon Center and carbon nanotube work is weak. The progress in this area has been particularly disappointing, and the material themselves are all quite limited even in terms of their potential to meet volumetric density goals. This area should be a small effort, but does not warrant a separate Center of $4M in funding. Physical storage is proposed to go from $1M to $2M. Where is the extra $1M going to go? I'm very surprised to see no mention of ammonia in any of the existing projects, new projects, or the chemical hydride center.

Project # ST-2: Low Cost, High Efficiency, High Pressure Hydrogen Storage
Newell, Ken; Quantum Technologies, Inc.

Brief Summary of Project

Quantum Technologies' project goal is to deliver a cost-effective and safe high-pressure hydrogen storage system that will meet DOE targets. The technical plan entails a three-pronged approach: lowering the cost and weight of the storage system (via material optimization, process evaluation and use of lower cost carbon fibers); reducing the amount of material required through the use of sensor technology to monitor storage system health; and increasing the density of hydrogen by filling and storing at lower temperatures. This is a new project, started in 2004.

Overall Project Score: 2.60



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.23** for its relevance to DOE objectives.

- Unclear, particularly given NAS report and DOE goals if this R&D is a priority and will yield breakthroughs.
- Compressed gaseous storage is the only short or mid term technology known today that will support the successful introduction of hydrogen powered vehicles. More research into compressed gaseous storage systems is needed to address remaining issues such as cost and volume.
- This project provides a near term, on-board storage solution and supports activities in demonstration programs. It does have some issues in meeting longer term (2015) objectives.
- At best, compressed hydrogen will not achieve more than part of the 2010 targets. Safety and cost remain major issues.
- This work has some importance since compressed hydrogen is the main way for on-board storage currently.
- Objectives are on target.
- Methods are appropriate to study.
- This is the likely technology for first commercial vehicles so improving the technology is key to the President's plan.
- Good fit with near term goals for storage.
- Cost reduction is key for early success.
- Clearly relevant as a near term option for FC test vehicles; may not be the answer in the long run. Quantum seems to understand the implications and significance of balance of plant (BOP) considerations.
- Cost, specific volume and weight of the H_2 storage system are highly important.
- Will be near term technology.
- Critical to short term application.
- May be applicable to other storage methods.

- Obviously, this work can never achieve 2015 (or likely even 2010) goals. Also, there seems to be little progress on achieving even the 2005 cost goals. Nevertheless, this is currently the most-mature technology, and therefore compressed storage has a place in the DOE portfolio.

Question 2: Approach to performing the research and development

This project was rated **2.85** on its approach.

- Not clear why EIHP is reduced to 1.8 (sp). What is the cooling/refrigeration needed? What is "low cost?"
- Not clear: Fiber translation - how is it done?
- Consider measuring and modeling the effects that embedded sensors may have on fiber translations and other potential localized effects or defects.
- EIHP is okay, but what about US-DOT? Need to conduct future testing.
- Promising results in early evaluations.
- Getting a 3X increase in capability over a couple of years demonstrates that this is a good approach. The project seems to be quite focused on addressing the technical barriers. However, it isn't clear if the approaches outlined in the project will get close to meeting cost targets in the near term and density and volumetric targets in the long term (2015).
- Not clear how cost target can be achieved.
- Not clear whether or not storage system is compared to targets (or just tank?).
- Quantum is trying to improve density and reduce cost.
- This work is not integrated with other research.
- Technical barriers should be addressed in more depth.
- Studying various sensor technologies to improve safety.
- Attacking the right problems.
- Cost is clearly key at this point, and both carbon and processing costs are good ways to approach this.
- Sensors are also a good approach to help on cost.
- Good spread of different approaches for cutting costs/increasing H_2 capacity.
- Lower burst specs + sensors for tank health may have problems with codes & standards.
- The approach is right for what Quantum is trying to do.
- Are burst tests done with hydrogen?
- Nothing really exciting or new, rather a consequently continued development.
- What exactly are "low cost fibers"?
- Work is clearly structured.
- Focus on materials is good.
- Good approach at using lower cost fiber.
- Good consideration to BOP.
- Cost seems to be the largest problem, so this work should be more focused on it.
- The largest potential for cost reduction is in the area of lower-cost carbon fiber, but there seems to be little work in this regard in this project.
- Clearly explain how much potential there is for cost reduction and what types of processing routes there are (and new routes that might be explored) to produced lower-cost fibers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Stated that they started in Jan '04 but showed considerable previous work, so what actually was done in '04?
- How is it different from old work?
- Not enough details provided in presentation to be able to accurately assess accomplishments or progress.
- Status was reported for the tank itself but not for the entire system.
- Cost reported was not the DOE-recommended volume levels.
- PI did not seem to understand (or want to understand?) the criteria under which DOE requested that data and results be presented. Thus, it is difficult if not impossible to assess progress toward DOE technical goals - disappointing for a system that is the nearest to being production ready of any storage system.
- Close to 2005 interim targets except for cost (by order of magnitude +). 700 bar progress is encouraging.
- They met the 2005 density targets.
- It is a great challenge to meet the 2005 cost target.
- They claimed they met the 2015 fill rate target and at the same time they are still working on fill rate improvement.
- The presentation combined accomplishments and technology status in several slides. This was confusing.
- It is simply bad that they continue to quote numbers without the regulator as being system numbers. This is now unacceptable.
- Still, probably the best system to date as far as meeting 2005 2010 goals.
- Much better cycle durability understanding than anyone else.
- CoolFuel method appropriate and valuable.
- Cost improvements nice, though still not there.
- Reasonable progress.
- Low cost fiber results promising.
- Seem to be making good progress in what is clearly an uphill struggle to get close to DOE storage targets. Getting the burst pressure criterion reduced to 1.8-X would narrow the gap.
- Unclear if the status numbers include valves, regulators, PRDs, etc. My guess is that they do not.
- Had to realize a significant improvement.
- Insufficient information provided.
- Recently started, 2 months ago.
- Good analysis of cost drivers.
- Good progress on regulatory approvals and validation tests.
- Some reduction in cost achieved.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.92** for technology transfer and collaboration.

- The reason for low grade: it is a private company, so it is hard to share information but need to tap into other DOE-run projects.
- No discussion of collaborations or plans to technology transfer… other than a brief mention in passing that they are working with GM on its fuel cell program.
- Mentioned working with GM, but other collaboration not discussed. Is there additional collaboration with academia?
- No collaboration with other organizations?
- There was no indication of cooperation or technology transfer.

- Cooperating or collaborating with suppliers and customers is critical to realization of the initiative and 2010 goals..
- Limited collaborations.
- Minimal collaboration; substantial cost share by Quantum.
- Not presented. Quantum is very close to commercialization.
- No collaborations identified.
- None identified.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Not sure what they are, other than the targets.
- Need to elaborate more.
- Lowering the safety factor may be possible with embedded sensors, but must to done in context of real world cylinder issues: such as crash and impact damage (one time event) and long-term fatigue.
- Provided list of things to be accomplished but no details about approach or specificity of plans.
- Future work is focused on the most significant challenges, but timeline to overcome barriers (cost) not clear.
- This project looks more like engineering development than research.
- Focus on cost target needed.
- They need to show more information on the CoolFuel concept.
- No contingencies consideration.
- Focused in the right areas.
- Reasonable approach.
- Aggressive schedule for technology selection.
- Planned follow-on development work should provide a benchmark for pressurized H_2 storage.
- Rather a development plan than future research.
- Whose are new materials and new designs?
- What can be expected in the next 2-3 years?
- Too soon.
- Cover all aspects of.
- Very little specific detail in this regard.

Strengths and weaknesses

Strengths

- Good project, in use in demonstration vehicles. Appears to be able to get to 2010 interim goals except for cost.
- Appears to be close to meeting technical targets.
- Have the technology.
- Achieved some targets.
- The only project on compressed hydrogen.
- Multiple strategies for achieving improvements.
- Good/balanced program; Quantum isn't trying to deceive anyone about what the prospects are. Only near-term technology that could enable the introduction of fuel cell vehicles into the marketplace.
- Solid company with a broad background.
- High tech composite company.

Weaknesses

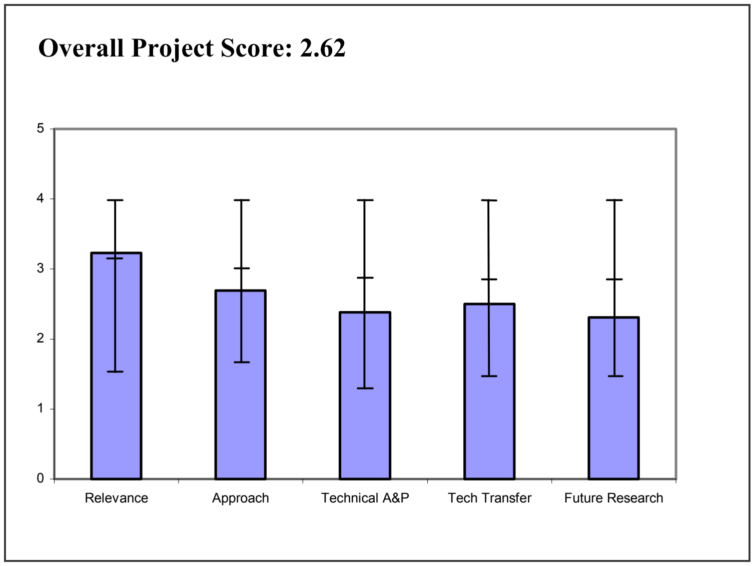
- It is commercially available now.
- Technology has reached its physical limits.
- Explain sources of data and hidden assumptions.
- Appears to be moderately mature relative to the rest of R&D efforts of DOE.
- Does not allow for much packaging and design flexibility. Looks more like development than research.
- Materials cost!
- Cost.
- Safety.
- Physical limits to gravimetric and volumetric densities.
- Status numbers do not appear to reflect the total system weight and volume.
- Everything seems to be proprietary.
- Did not include BOP in weight and volume claims.
- "Smart tanks" and "CoolFuel" not adequately described.
- The confusion surrounding the current status numbers is inexcusable. Quantum, of all the presenters, should understand the important difference between a system and a tank or a fuel. What's more, the volumetric density status is equal to that of 10000 psi hydrogen itself. This causes much skepticism of all of their claims. Also, the DOE status numbers that Milliken showed were all from Quantum, but Quantum's presentation had significantly different numbers. Again, this doesn't inspire confidence in their claims.

Specific recommendations and additions or deletions to the work scope

- Targets vs. status - should be evaluated on the basis of the system!!
- Could benefit from looking at manufacturing issues to ensure high volume reliability and consistency of technology.
- Work should focus on sensors also.
- PI needs to follow DOE guidelines for reporting status consistent with goals of program, e.g., costs at high volume, efficiency for entire systems (not just for tank) etc.
- Continue working on getting closer to the cost target. This is the best challenge for research.
- More information on the CoolFuel concept is needed to evaluate it.
- More work on safety is needed.
- Provide at least an estimate of the projected total storage system volume and weight per kg of H_2 at the next review.
- Consider pathways for solving the fiber supply issue and evaluate costs for large volume production of storage systems.
- Have safety review. Safety slide addressed their product - not their in-plant safety.
- More focus on 10K tank performance and cost reduction.
- Should develop target cost / strength /modulus properties for carbon fibers that would enable the 2005 and/or 2010 DOE targets. This information could be cascaded to other researchers exploring new processing routes to lower-cost fibers.

Project # ST-3: Optimum Utilization of Available Space in a Vehicle through Conformable Hydrogen Tanks

Aceves, Salvador; Lawrence Livermore National Laboratory



Brief Summary of Project

Lawrence Livermore National Laboratory's (LLNL) project goal is to develop conformable hydrogen tanks that will meet DOE targets. Conformable tanks have the potential to optimally utilize available space in a vehicle and thus greatly improve volumetric efficiency. Since conformable vessels are subjected to bending stresses, their approach entails two techniques (tank structures) for reducing these stresses, continuous fiber vessels and vessels made of replicants. This is a new project, started in 2004.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.23** for its relevance to DOE objectives.

- Offers substantive approach to compressed or liquid H_2 storage.
- Compressed gaseous storage is the only short or mid term technology known today that will support the successful introduction of hydrogen powered vehicles.
- More research into compressed gaseous storage systems is needed to address remaining issues such as cost and volume.
- Project is very important for allowing the necessary flexibility in vehicle packaging and design.
- Conformable tanks provide better packaging options than non-conformable tanks.
- A conformable tank may not hold pressure as much as a non-conformable tank.
- Good alignment with needs of storage. Especially deals with the boil off issue. Also innovative method to change the cost and production methods.
- Important objective for real world application.
- Addresses multiple targets.
- Novel approach.
- Addressing an important issue; could lead to design concepts that reduce the volume of the H_2 storage system.
- The subject of transformable (conformable) high pressure tanks is very important.
- Worthwhile goals.
- Complimentary to room temp, compressed gas development.
- It is difficult to see how the claims of achieving 2010, and even 2015 density goals can possibly be realized.
- Compressed hydrogen will not be the answer to on-board storage.
- Don't think it will meet the targets.

Question 2: Approach to performing the research and development

This project was rated **2.69** on its approach.

- Not sure how they could meet 2015 targets.
- Good analytical approach.
- Look forward to see how challenges of implementations are addressed.
- Novel approach to compressed gaseous (mostly) storage which addresses the issue of conformable tanks. Conformability is critical in vehicles for maximum packaging space efficiency.
- Evaluation of three approaches and down select to two is good. The project seems to be working to specifically address some of the technical barriers, but cost is a question and how to handle stresses on outside ribs of "bucking" design is not clear.
- Project desperately needs someone experienced in pressure container design.
- The timeline of the project is extended over 5 years. Most these are to do analysis. Building and testing is in 2009. I am not sure if this time is needed before testing.
- Little information was presented.
- The barriers were discussed as if they were solved.
- The novel theoretical work and the clever cryo-compressed work are both good approaches.
- Reasonable mix of theory and practice. Some consideration for manufacturability should be included.
- Should verify lap joint approach with composite producers if it hasn't been done already.
- Don't understand how much strain will be present at rib-skin joints.
- Need to do non-FEA modeling of buckling design. End effects will be significant.
- Lacking in thorough engineering detail, but the approach does project reasonable design ideas that accommodate shaping of the H_2 storage container.
- Leveraged with DARPA funds. Replicant approach could lead to breakthrough.
- Should be more focused --> "The project addresses most technical barriers."
- Focus on the subject of safe and transformable tank.
- Innovative.
- Low temperature compressed gas systems allow higher volume density to be achieved.
- Replicants approach still to be validated.
- Approach is certainly novel, but the motivation for this project should be more clearly spelled out. Seems like quite a few disjointed ideas.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.38** based on accomplishments.

- Good theoretical work but far from real life application.
- Moving well against own timeline.
- Could benefit from an accelerated rate overall to be viable by the 2015-2020 timeframe.
- Conformable vessel analysis was promising and has allowed the PI to narrow the range of alternatives. However, no details about the results were presented, possibly because the project has just started.
- Need more work to confirm that there is an ability to meet the targets (as reported) with conformable tanks.
- Making good progress, but still haven't totally figured out the bonding issue for the ribbed approach or how to handle stress on outside ribs of "bucking" design is not clear.
- Results presented are misleading.
- The project is new. No accomplishments yet.

- Accomplishments have been slow over the last year.
- FEA results are interesting.
- Reasonable progress for limited time project has been funded.
- Project began in FY 2004.
- The results are interesting and they do make sense, but a prototype(s) needs to be built to prove feasibility of the concept.
- Very early in the overall program.
- Just a few results can be seen.
- Results do not really show something outstanding; rather textbook-knowledge.
- Just only the "bucking" system is a bit disappointing.
- Relatively new project.
- Did eliminate one option - good.
- All results shown are modeling and analysis. I would like to see experimental results as well.
- Project is new, but even still seems to have been very little progress.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Active association with others is minimal on this program even though they have collaborations with others on similar topics.
- Collaboration with pressure container designer(s) needed.
- Collaboration with pressure container fabricators needed.
- High level of collaboration, including OEMs (ACC), academia (several) and a prototype supplier, as well as other government activities.
- There was a slide on interaction and cooperation.
- Is a project with DARPA on carbon fibers to be considered cooperation?
- Potentially very important to realization.
- Good mix of collaborators.
- Might try to work with commercial polymer manufacturer or good polymer chemists. Don't know relative value of prototypers vs. resin manufacturers.
- Collaborations with Purdue, Univ. of Calif., and Spencer Composites.
- Not shown.
- One patent and two scientific publications are too few.
- Several organizations identified.
- Very good collaborations.
- Good connection with ACC and DARPA.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.31** for proposed future work.

- Practical issues are not addressed.
- Modeling and analysis could benefit by including liner/permeation barriers in modeling before transition to build. Particularly with fatigue/pressure cycling.
- Moving in right direction. Could benefit from a transition to physical testing.
- Would like to see more detailed future plans.
- Future research plan should continue as stated but address source of issues mentioned above.
- Need to get on track with designs that might work.

- Need to get on track with designs that can be fabricated.
- Contingencies not considered.
- The plan does not seem to be impressing.
- Would like to see more actual testing to substantiate the theory and see it sooner in the plan.
- Future plans need to target the whole H_2 storage container and interfacing parts of the associated storage/delivery system.
- Analysis of concepts needs to be finished in '05.
- Covered FY 05.
- Needs more focus on experimental work.

Strengths and weaknesses

Strengths
- Innovative concept using old technology.
- Work uses a more unique approach vs evolutionary improvement.
- Important concept to packaging the fuel container similar to today's gas tanks. OEM's should be quite interested.
- Good concept to explore.
- May be unique in working on conformable tanks.
- Novel and innovative approaches.
- Novel approach.
- Potential to increase the conformability index for pressurized storage tanks.
- Innovative ideas.
- Innovative.
- Important work.
- Project is high risk, high payoff.

Weaknesses
- What are the strengths of LLNL?
- Domes are not built because of any weakness but because of high cost, you haven't addressed the cost of your approach as such, it's a weak concept!
- Not clear if this concept could ever be affordable or would overcome physics issues.
- Apparent lack of pressure container design experience.
- Not eliminating impractical concepts.
- Not enough details- cost, plan.
- No partners to enhance or supplement DOE funding.
- Long range. Fabrication costs may be large.
- Need to integrate experimental and theoretical approaches.
- High risk - but worth trying.
- Not clear that potential barrier and failure point have been identified with pathways to address them as R&D moves forward.

Specific recommendations and additions or deletions to the work scope

- Need to look at the cost issue.
- Should bring up the go/no-go decision to an earlier date.
- Budget information for the project life needs to be included.
- Need to show some progress in determining if these methods work in the real world, and need to show complete system capabilities of cryo systems by measurement.

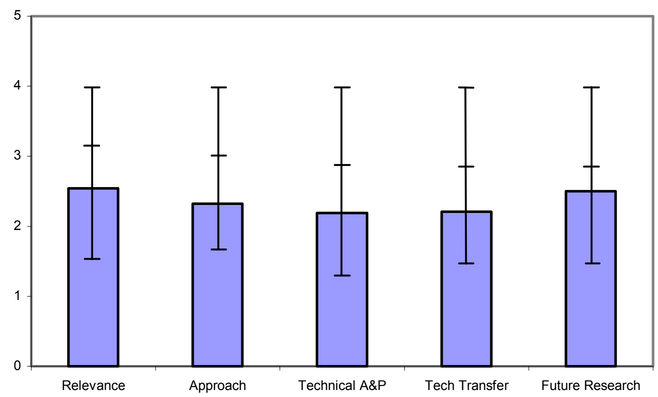
- Need to present exactly what is included in the estimated weight and volume density.
- Need to demonstrate that the concept is feasible in prototype hardware.
- Thiokol and/or another tank manufacturer should be involved in building and testing prototypes.
- Clear targets and a go/ no-go milestone for the replicant "technology" should be considered.
- Pursue collaborations with other organizations (e.g. Quantum, Dynatech) to understand the needs more clearly.
- Have independent verification of his claim that the cryo-pressure concept will meet 2015 targets.
- Would like to see more actual testing to substantiate the theory and see it sooner in the plan.

Project # ST-4: Radiolysis Process for the Regeneration of Sodium Borate to Sodium Borohydride
Wilding, Bruce; Idaho National Engineering and Environmental Laboratory

Brief Summary of Project

Idaho National Engineering and Environmental Laboratory's (INEEL) goal is to develop a viable method for regenerating sodium borohydride from sodium borate, to meet DOE's fuel cost target of \$1.50/kg H_2. Specific objectives are to: demonstrate radiological methods of converting borate to borohydride; validate earlier observations and results showing borate conversion; initiate processes for identifying, qualifying and quantifying conversion mechanisms; and estimate production capability of the process.

Overall Project Score: 2.35



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.54** for its relevance to DOE objectives.

- This sort of program is needed if a BH_4 based system is to be useful.
- It is not clear if BH_4 systems are viable, but this method might make it possible.
- May have use in production of hydrogen.
- Uses a domestic energy source, presently under-utilized, toward hydrogen storage problem.
- Truly independent of fossil energy.
- Compressed gaseous storage is the only short to mid term technology known today that will support the successful introduction of hydrogen powered vehicles.
- More research into compressed gaseous storage systems is needed to address remaining issues such as cost and volume.
- The radioactive energy is not free, even if it came from waste.
- Sodium borohydride can't be regenerated directly from sodium borate.
- There are several processes that can be used. Which one is adopted here?
- I could not see the relation between generating sodium borohydride from sodium borate and hydrogen production mentioned in the presentation. The regeneration process consumes hydrogen.
- Little information is given.
- Any progress in hydride regeneration will be significant.
- Very speculative work - relevance is tentative at best.
- Willing to give this a chance to show relevance since it is a very new project.
- Not one of the better Storage projects in terms of relevance.
- There will be many roadblocks to coupling H_2 production/distribution with nuclear facilities of any kind.
- Important because of promising H_2 storage densities (on the material level).
- Unlikely to produce anything useful.
- Are people really going to want to rely on spent nuclear fuel to regenerate storage material?
- Approach is specific to borate regeneration. However, it is important to study this method.

Question 2: Approach to performing the research and development

This project was rated **2.32** on its approach.

- Not sure if the barriers were explained.
- Early in project but it appears to have an interesting proposal/approach worthy of further evaluation/research.
- No evidence of the formation of borohydride via radiolysis.
- The project does not seem to be well designed.
- No integration to other research.
- No indication of technical or financial feasibility.
- How was the 53% conversion efficiency measured?
- The approach is not especially robust, but given the extremely low budget they may have little choice. The concept is interesting but they need to run more definitive experiments soon.
- Project is unique; INEEL uniquely qualified.
- Potential impact on chemical storage solution to hydrogen storage problem is immense.
- First priority should be verifying formation of borohydride.
- Need to form enough material to isolate and perform XRD or other unambiguous method.
- Lots of possible chemistry occurring. You're hitting the system with a huge hammer - lost of ways for things to shatter to produce hydrogen! Is boron catalyzing water decomposition? Are there other gas phase products?
- I am very skeptical about using such a high energy process to drive the reaction since all the chemicals (both products and reactants) get destroyed to some extent at these energies.
- Not obvious that the analytical methods are providing interpretable information. I'd like to see error bars on the production data.
- Approach is too broad. Lots of work already done on additives.
- Focus on radiation.
- Approach not clearly explained - new project.
- Don't understand experimental set-up.
- Very important to determine viability of this method.
- Need better analysis and measurement techniques.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.19** based on accomplishments.

- May be too early but they have to improve their analytical techniques.
- Need to confirm that borohydride is produced and that conversion is possible.
- The project is new.
- Very hard to assess progress, especially given the small time they have had to do it. They certainly can make hydrogen.
- Calculation of throughput per reactor is valuable progress.
- Spectroscopic evidence of BH_4^- in solution huge step forward.
- First synthesis of BH_4^- without electrochemical basis.
- Must replicate the result. Reproducible regeneration would be outstanding.
- Too early to evaluate.
- Too early to hold this against the project since it is very new.
- The NMR data were poorly presented and not clearly described.

- What happens when sodium borohydride (wet or dry) is irradiated? Basic chemistry is not well understood.
- Even though the project is new there is more knowledge on sodium borohydride publicly available than INEEL indicates to know.
- Trouble finding borohydride and replicating earlier results.
- Barriers identified - new project.
- What are the options/alternatives?
- Promising results.
- Good progress for new project.
- Most important to determine whether borohydride is actually being formed (e.g., with XRD or other characterization tools).
- Also, need to be clear about forward/reverse reaction: in what conditions is the reaction expected to go each direction?
- Why use water as the solvent when this is known to promote the reaction to borate?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.21** for technology transfer and collaboration.

- Need to find a good partner with strong analytical chemistry background.
- Collaboration with industry leader is good. Question whether collaboration with Idaho State University is adding any value.
- Little collaboration planned.
- Little opportunity for collaboration but they have paired with two logical partners, aligned with needs of program in BH_4 recycling.
- Must strengthen collaborations. Some problem with measuring yield/detecting product likely solved by others in chemical hydride field.
- Pursue Millennium Cell collaboration as well as collaboration to verify $NaBH_4$ formation.
- Making appropriate commercial contacts.
- Collaboration with Millennium Cell and Idaho St. Univ.
- The quality and depth of the chemistry being done on this project could be enhanced by a stronger analytical component.
- Only Millennium Cell and Idaho State University.
- Where are other valuable cooperation on chemical background knowledge?
- Collaboration with industry and university.
- Should couple more closely with other organizations to expand measurements and analysis.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Proposed focus on aqueous media will not address the stabilization of borohydride issue.
- Correct factors to look at.
- All effort must be made to reproduce spectroscopic proof of BH_4.
- Identification of mechanism also important.
- No contingency if result is not reproduced.
- Supposedly it's to perform duplicates; test catalysts; study conversion mechanisms; explore other chemistries; test different radiation sources. More specifics on some of these planned directions would make it easier to judge the prospects for success.

- The proposed future work appears to be unfocused.
- Improving efficiency and yield, catalyst effect, conversion mechanisms.
- Future work is the majority of the project - especially impact of different mechanisms.
- Good focus on improved efficiency and yield.
- Good to expand to other materials.
- Not clear how catalyst would be involved.

Strengths and weaknesses

Strengths
- Interesting approach that can have applications in other areas.
- Intrinsically inexpensive way of converting borate to borohydride.
- Uses essentially waste energy.
- Novel approach that may work for other materials.
- May have identified first non-electrochemical route to borohydride - a noteworthy accomplishment.
- Identification of direct conversion of nuclear energy to hydrogen storage solution critical step in hydrogen economy.
- Novel approach.
- May have some value in use of reactor 'waste'.
- Reactor types - use of waste.
- Very unique approach.
- Unique capability.
- Approach offers alternative to chemical and electrochemical process.

Weaknesses
- Limited resources to do the right analytical chemistry.
- Unknown cost or commercialization viability.
- Intriguing proposal, but can it deliver? Need to confirm generation of borohydride and if so, then need to confirm repeatability in number of cycles that might be seen in use in vehicles.
- Use of aqueous solutions is a barrier towards stability of borohydride.
- Poorly equipped to analyze results.
- At least 3 ways BH_4 could be destroyed.
- Collaboration may increase rate of research.
- No obvious contingency plans.
- Not broadly applicable to hydrogen economy. Only successful if borohydride specifically is proven out.
- Chemical selectivity using the proposed radiation approach may be difficult. That's why incontrovertible proof of BH_4^- formation is crucial.
- EERE should raise the expectation bar with respect to the quality of the science coming from this project.
- Regenerating spent borate into borohydride requires the addition of hydrogen.
- It appears that the hydrogen comes from the radiolysis of water.
- Funding level not addressed.
- Poor presentation. Little information. The presentation was difficult to follow.
- Did not show which chemical and nuclear reactions produce borohydride.
- Did not show cross section and mean free paths.
- Experimental setup unclear.
- Chemical reactions involved need to be mentioned.

- There is a fundamental gap on knowledge about sodium borohydride.
- Seems like a real long shot.

Specific recommendations and additions or deletions to the work scope

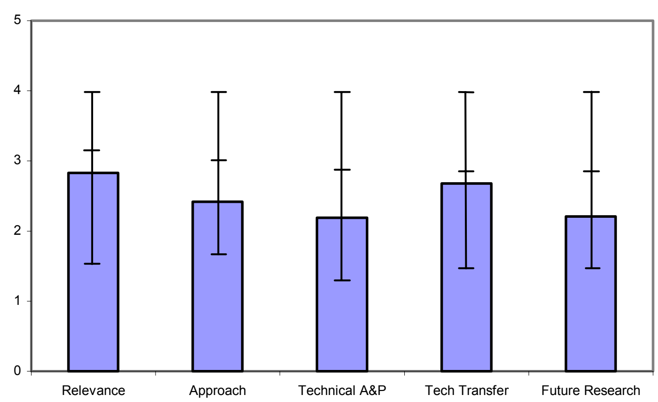
- This project depends on sodium borohydride being a storage alternative. It should be therefore directed to work with other projects that work in this area.
- Should be subject to an early go/no-go decision.
- Re-direct or terminate the project.
- Research should focus on the objective.
- Work on getting the equipment they need to analyze output solution.
- Focus on understanding the chemistry.
- I concur that stopping back reaction is key - but as there are three ways this may happen (radiation makes excited BH_4 that reacts faster than ground state, second photon breaks BH_4 created, radiation converts water to highly reactive species that react with any existing BH_4) this will be challenging. Identifying sodium borohydride is crucial.
- If this is not a vital way to recycle BH_4 at low cost, then consider trading it to the production team because they clearly make hydrogen, seemingly very effectively.
- Broaden scope of project to other solvent/hydride systems. All hydrides are expensive, but can often be interchanged. Example: A cheap synthesis of LiH leads to cheap MgH_2 and $NaBH_4$. Thus, all chemical hydride technologies would benefit from success of this program.
- Need clear statement of what is being attempted; what general mechanism is being used; and some model to predict costs/efficiency.
- Project needs serious go/no-go milestones.
- Strengthen the physical and analytical chemistry aspects to include a broader range of measurement tools to sort out the mechanism.
- Molecular spectroscopy might be useful.
- Run borohydride solution as a blank to determine the effect of radiolysis on the borohydride.
- Might fit better under production and delivery rather than storage.
- Achieve more know-how on sodium-borohydride (solubility and other topics).
- The project title indicates regeneration of sodium borohydride, the presentation is about the H_2 release.
- Bring this work closer to the Center of Excellence and clearly focus.
- Must strengthen collaborations. Some problem with measuring yield/detecting product likely solved by others in chemical hydride field.

Project # ST-5: Low Cost, Off-Board Regeneration of Sodium Borohydride
Wu, Ying; Millennium Cell, Inc.

Brief Summary of Project

Millennium Cell's project is focused on the development of a reliable regeneration process for sodium borate ($NaBO_2$) to sodium borohydride ($NaBH_4$) that meets DOE cost targets. The technical approach is to identify electrolytic processes that reduce cost, focusing on direct borate reduction and high efficiency sodium reduction. A key tool is to use hydrogen gas to reduce cell voltage and improve regeneration efficiency. **This is a new project, started in 2004.**

Overall Project Score: 2.47



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.83** for its relevance to DOE objectives.

- Chemical storage is one of several possible storage technologies that will meet the targets necessary for the successful introduction of hydrogen powered vehicles.
- No prior knowledge if electrolysis can be used to regenerate sodium borohydride from sodium borate.
- How to stop the spontaneous back reaction?
- Information on the kinetics of the reaction, thermodynamics?
- The only barrier they can overcome, if successful, is the cost barrier.
- This project does not address other targets.
- Potentially could meet 2010 goal; however I would note the recycle proposed seems very unlikely.
- Regeneration is crucial for metal hydrides.
- Why plan on 7.5 kg stored H_2 in slide 5?
- $NaBH_4$ seems to be a very questionable solution to H_2 for cars.
- Unclear whether a sodium borohydride-based storage system can meet DOE's 2015 weight and volume goals for on-board H_2 storage and delivery "systems."
- Chemical borohydrides promise decent storage efficiency (on the material level).
- Unlikely to be successful- overall energy efficiency likely to be poor.
- Regeneration of borate critical to use if borohydride for storage.
- Unlikely to meet cost goals due to life-cycle analysis.
- Projections about gravimetric densities for future systems seem overly optimistic.

Question 2: Approach to performing the research and development

This project was rated **2.42** on its approach.

- They understand/explain the barriers well.
- Major barrier is the cost of electrolysis.
- Energy efficiency is an issue.

- The cost forecast in slide 4 in not realistic at all.
- Material safety is not addressed.
- System density is optimistic.
- The electrolysis approach is not very likely to be energy efficient.
- While reducing the number of steps is a good idea, the use of electrochemistry as a tool seems unlikely to be efficient.
- Typically electrochemistry is powerful but inefficient.
- Electricity is generally an expensive "reagent" for fuel production due to generation efficiency. H_2 assisted voltages are interesting. Have they all been verified experimentally? Are all chemical paths verified? Is energy to melt NaOH included in energy cost? What will capital costs be for operations involving corrosive materials?
- Need to look at process designs and preliminary energy and costs.
- Electrolytic approaches to chemical processing are generally inefficient. I'd like to see some efficiency predictions for this concept.
- Clearly formulated approach.
- There is no way to achieve $1.50/gallon gasoline equivalent with sodium borohydride by 2010.
- Cost roadmap is very questionable.
- Very questionable that electrolysis leads to more efficient Na - production.
- Electrolytic approach has potential for reducing energy costs of regeneration.
- Unclear on cost of H_2 used in process.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.19** based on accomplishments.

- Too early in project to be able to assess if project has potential to be successful.
- Evaluation of status vs. targets - system basis -- very good!
- Still energy efficiency/cost is a challenge.
- A new project.
- Have reduced voltage by 4. However they do not understand the actual energy efficiency including hydrogen consumption.
- Too early to evaluate.
- Early in project.
- What voltage gives a sufficient reduction current density?
- How many hydrogen energy equivalents go into the regeneration process?
- Too early in the program.
- Recently started.
- New project but some electrolytic results.
- New project; no progress yet.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.68** for technology transfer and collaboration.

- Reasonable variety of collaborators in industry, research and academia.
- Superb collaboration team.
- Project is not critical but off board regeneration to enable the potential of chemical hydrides is important to the plan.
- May need additional consultants outside Princeton community.

- Good start - appropriate for this stage of project.
- Collaboration with Air Products, INEEL, Princeton Univ., and Ionotec.
- The cooperation partners are not well-linked into the research.
- Air Products.
- Would be desirable to have a major $NaBH_4$ supplier.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.21** for proposed future work.

- Do life-cycle energy calculations . . . it's not that difficult.
- Use the most optimistic assumption and tell us what the efficiency is.
- "Tweaking" the electrolytic regeneration would not address the energy efficiency cost issues.
- It looks as if few electrolysis paths will be evaluated.
- The one step reaction is not very likely.
- The plan to improve Na production more probable to work technically, though as noted, economic success is less likely.
- Reasonable approach.
- Don't understand "Rule out false positives" slide 14.
- Very strong statement for electrochemical research.
- A project like this could go on forever. We definitely need a go/no-go timeline here.
- Too unfocused and unspecific.
- Too early.
- Score based on effort towards regeneration. Should include work on onboard system density as well.

Strengths and weaknesses

Strengths
- Consideration of actual gravimetric capacity is based on entire storage system.
- Millennium Cell has a strong background in sodium borohydride for vehicle operation.
- Strong on use of output of the program.
- Some improvement in Na processing is likely.
- New approaches to difficult problem of borohydride regeneration.
- Team is very familiar with basic chemicals being studied.
- Know $NaBH_4$.

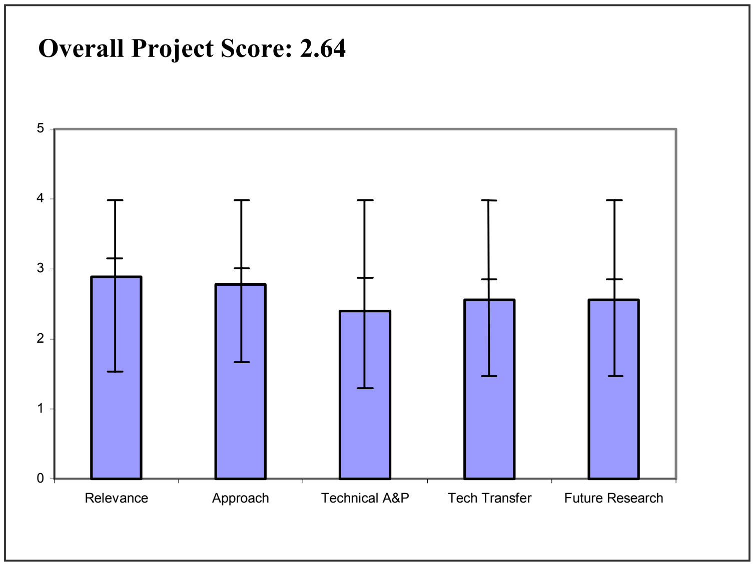
Weaknesses
- Uphill thermodynamic barriers.
- Unlikely to achieve cost targets.
- No discussion of onboard problems (precipitation, corrosion).
- Focus on electrolytic regeneration.
- Not sure if they have enough resources to perform sodium borohydride regeneration.
- Highly speculative one step process efficiency.
- The company is too small to accomplish the required fundamental research (i.e. find a better way to generate Na metal - other firms have worked on this for many years).
- Not a big chemical process company.
- Storage efficiency is still an issue.
- Use of average system weight not good. Should use highest weight/volume condition.
- Electrochemical efficiency evaluation should have been done before project started.

Specific recommendations and additions or deletions to the work scope

- At last review meeting, PI was asked to provide specific estimates on overall energy efficiency of regeneration cycle: theoretical and measured - none provided. Must provide estimates at next review.
- This program should be subject to closer review.
- Push the go/no go decision forward.
- May need to consider changing the direction form electrolytic regeneration of borate to borohydride to using a completely different approach for the regeneration.
- They need to have partners whose core business is in $NaBH_4$ regeneration from sodium borate.
- Perform experiments that might disprove the one step process early so resources are not wasted if this is indeed an unlikely path.
- Figure out the energy cost of hydrogen in the Na process so you know exactly where you have to lower the voltage to equal the existing process.
- Need a project plan with milestones.
- Need to demonstrate direct reduction in one step.
- Need to develop an accurate estimate of the full fuel cycle efficiency and cost.
- Need to include the energy contained in the H_2 at the anode in the efficiency calculations.
- Might fit better under production and delivery rather than storage.
- Consider realigning this program with the work executed at the Chemical Hydride Center of Excellence.
- Needs overall energy balance - need to include energy required to make input H_2 and electricity.

Project # ST-6: Chemical Hydride Slurry for Hydrogen Production and Storage
McClaine, Andy; Safe Hydrogen, LLC

Brief Summary of Project



The objective of Safe Hydrogen's project is to demonstrate the viability of magnesium hydride slurry as a cost effective, safe, and high-density hydrogen storage medium. The pumpable, high density slurry offers infrastructure advantages, and high system energy density with high vehicle range. The focus of the project will be on regeneration of the spent slurry and conversion of magnesium hydroxide to magnesium hydride to meet DOE cost targets for off-board regeneration. Work will also be done on mixer, slurry, and system development to meet DOE capacity targets. **This is a new project, started in 2004.**

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.89** for its relevance to DOE objectives.

- Chemical storage is one of several possible storage technologies that will meet the targets necessary for the successful introduction of hydrogen powered vehicles.
- An attempt to develop a storage material and system.
- Concept looks good and has advantages.
- Preliminary density information not provided.
- Efficiency of the processes needs to be described in a better way.
- The project sounds good and worth pursuing.
- Cost estimates could be optimistic.
- While a safe system is useful to the plan, this material has almost no chance of making the target for 2010 and so it relevance is limited.
- Reasonable applicability to chemical hydride goals.
- Key is regeneration costs.
- Very relevant - success in the project would be a big step to get to the President's hydrogen economy objective.
- Safe Hydrogen projects that the slurry can make cost targets, but is this based on total system volume and weight, including the companion water system?
- Clear presentation of the estimated total system weight and volume is needed to determine whether the technology can meet the DOE targets.
- May turn out better than Na.
- Not clear if method will reach any of the DOE targets.
- Should not quote these "eye-popping" numbers for "slurry" density. This is misleading; at the least should always include water with these numbers, and at the most should include the entire system.

Question 2: Approach to performing the research and development

This project was rated **2.78** on its approach.

- Intriguing approach but concerns about magnesium hydride slurry being viable from a cost perspective and from feasibility of coating to preclude exposure to water.
- Ought to continue to determine if there may indeed be a way to make the system viable.
- The project is designed reasonably.
- Some of the technical barriers are addressed.
- No integration with other research.
- Reasonable timeline and milestones.
- In general the process followed is good: they are looking at the function on the vehicle and recycle. Only the end product efficiency is not appropriate.
- Would like to see details on economic estimates for H_2 costs.
- Preliminary estimates are rarely too conservative.
- Project is well-focused and relies on a significant data base of known chemistry.
- What volume and weight percent of the slurry is oil?
- Cost share by Safe Hydrogen is about 30%.
- On-board system has been demonstrated; off-board regeneration is the focus of the effort.
- Carbothermic process could use coal as the energy for regeneration.
- High energy costs of regeneration. Proposed process still too high.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.40** based on accomplishments.

- New project. Too early to assess properly.
- New project.
- Have not started the program so hard to appraise.
- Too early to evaluate.
- Early in project but it appears well-organized and prepared to work on barriers.
- Just getting started. It will be interesting to see what they accomplish by next year's review.
- Just started.
- New project.
- New project; no progress yet.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.56** for technology transfer and collaboration.

- Limited collaborations, per se. Lists various activities that will be doing testing or evaluation.
- Coordinated with logical partners.
- Given that the parent process to use the slurry is unlikely to meet consumer energy density requirements, it is hard to say this is essential to the plan.
- Should partner with commercial Mg producers. They must be looking at SOM process as well.
- Fairly adequate for this stage of work.
- There are four strategically selected collaborators that reinforce the project in crucial areas.
- Good team.
- Add large scale Mg supplier as consultant.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.56** for proposed future work.

- Would like to see more specificity and details of future plans for research and how challenges will be met such as: oil coating the material, retention of the coating through the life of the system, etc.
- No consideration for contingencies.
- Reasonable timeline and milestones.
- Research plan is suitable for goals.
- Carbothermic reduction would be great. Could you share literature on earlier use with Tech Team? Why was it abandoned?
- Makes pretty good sense.
- The future plan is very general. It just shows that they plan to cover all the bases with minimal detail about how that will happen.
- Just started.
- Critical issue is regeneration. Not enough emphasis on this.

Strengths and weaknesses

Strengths
- A good concept.
- Using a fluid fuel is attractive.
- Significant experience with end product and needs.
- Interesting approach.
- Relies on relatively well-known chemistry.
- Builds on previous DOE work that demonstrated the feasibility of the on-board H_2 generation process with LiH-oil slurry.
- Mg should be a more tractable system.
- Good team.
- Turned in safety 1-pager.
- Generally good presentation.

Weaknesses
- Question whether the system will be able to meet the goals for the DOE program despite the claims of the PI. Will need to see data.
- The main issue for this approach is the need for liquid water as a second fuel. This makes it more difficult to achieve the density targets.
- Need a waste tank on board.
- Thermodynamics and kinetics are not addressed.
- Little experience in the recycle chemistry business.
- Parent system to use slurry unlikely to go on a vehicle.
- As with all chemical hydride systems, regeneration costs will be the critical value.
- Didn't get the feeling that this project has a whole lot of science attached to it.
- Don’t see how you can get to any of the density targets onboard or meet cost targets for system or for fuel.

Specific recommendations and additions or deletions to the work scope

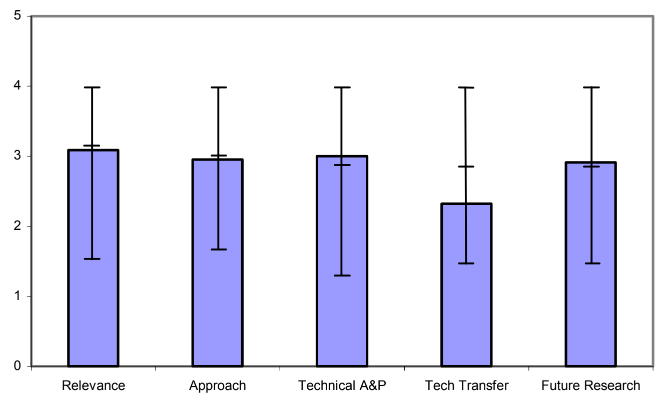
- Need to make a list of system components and materials along with their masses and volumes.
- Need to look at the usage system early on. If this cannot work, then not much point in going further.
- Add some meaningful milestones to projects timeline slide 9.
- A full systems analysis is needed here that includes all the parts of the fuel storage and delivery infrastructure for a passenger vehicle.
- Consider partnering with commercial Mg producers. They must be looking at SOM process as well.

Project # ST-7: Hydrogen Storage by the Reversible Hydrogenation of Liquid and Solid Substrates
Pez, Guido / Cooper, Alan; Air Products and Chemicals, Inc.

Brief Summary of Project

The overall project objectives are to develop carbon-based solid and liquid hydrogen storage materials with material-based capacities of >6 wt% and >45 g H_2/L and a hydrogen storage system prototype with 6 wt% and 45 g H_2/L capacity in the range of –40 to 90-120C and less than 1000 psi H_2 pressure. Primary technical objectives are the discovery of novel materials using experimental and computational methods and demonstration of reversible hydrogen storage with liquid substrates. **This is a new project, started in 2004.**

Overall Project Score: 2.85



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.09** for its relevance to DOE objectives.

- Chemical storage is one of several possible storage technologies that will meet the targets necessary for the successful introduction of hydrogen powered vehicles.
- Materials with more than 6% are very valuable to meeting plan goals.
- Promising approach to utilize existing infrastructure. Could minimize transition costs.
- The only storage project that I would call critical to Initiative.
- Very relevant and being carried out by a company that understands the business of bulk chemicals.
- Difficult to evaluate all merits since the liquids are not disclosed.
- This is still a material discovery system.
- Material and system targets are the same (slide 2).
- Confusing (claiming they have the material and at the same time saying they will work to select it).
- Liquid fuel has advantages.
- Still need a waste tank.
- Ambitious about many things.
- Is it that easy to recover the regeneration heat and also to use the fuel cell heat to release hydrogen?
- Little information was provided.
- Almost no data.
- Material safety?
- At best, this project (if fully successful with known LQ* materials) will only meet half of the 2015 targets; also it is probably true that a full system approach to figuring out the actual storage values will leave LQ* H_2 at a level well under half of the 2015 target.
- 6-7 wt% good for 2010 target.
- Liquid-based system at low pressure should not add too much.
- Interesting concept; unfortunately, without knowing more, it is difficult to accurately assess the relevance of the work.

- Assuming that I can guess the types of liquids that are being considered, it seems unlikely that they will ever achieve more 6 wt% or so. (In a system, this certainly would not satisfy the 2010 goal.)
- What about volumetric densities of these fluids?

Question 2: Approach to performing the research and development

This project was rated **2.95** on its approach.

- Appears to have a unique approach to a total hydrogen fuel delivery system. It will be interesting to see if it proves out.
- Potentially low cost and safe media for H_2-storage.
- Good mix of experiment and computational approaches. Use of exothermic hydriding step gives a real advantage over other materials. How big is the synthetic challenge?
- Only chemical hydride project that avoids huge regeneration costs in both $ and energy.
- Talk was slightly compromised by company protection of proprietary data but approach came through as well planned.
- Not sure what research objectives are.
- Not sure how it meets 2010 or 2015 targets . . . need component list.
- No information on cost.
- Can utilize commercially available hydrogenation process.
- No evidence of technical feasibility.
- Secret materials claims not supported.
- Barriers addressed vaguely.
- They understand the needs, but they are not very clear about exactly what they intend to do.
- Hopefully the confidence they have in their predictive methods are valid in this instance, for the moment it is hard to rate them.
- I'd suggest more emphasis on the search for the best possible LQ*. None of the ones we know about are good enough. Hopefully, we'll hear a success story about the new "bent bond" material at the next review.
- Analytical capability is impressive.
- Well focused but includes solids as well. Best success possible with liquid case.
- Again, without knowing more, cannot really assess.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Considering short period, showed good progress.
- Although early in the project, early results seem promising.
- New project (results not expected to date).
- Good upfront estimates of potential performance limits and material/process costs.
- New project.
- Described material has moderately good properties, which is good progress in a short time.
- Clearly the material needs to be brought to a lower release temperature.
- Very good progress for a new project.
- Early in project but a number of chemicals which might work have been identified.
- Timelines have real decision points!
- Too early to tell if substantive progress towards a practical system is being made in this project.
- Recently started.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.32** for technology transfer and collaboration.

- Need to bring in a catalyst company.
- Collaborations and technology transfers seem limited.
- Appear to be mostly preliminary discussions with no substantive commitment for support. But it is early in the program.
- The collaboration slide show limited contacts.
- Could be important if the materials are cheap and work at low temperature.
- The collaboration team is largely predicted, may be due to the fact they are not started, but one would hope they have this wrapped up by now.
- Reasonable collaborations for project involving proprietary material.
- Tech transfer is fully adequate for their stage.
- A strategically chosen set of collaborators, including fuel cell manufacturers, SWRI, and the C-H Storage Materials Working Group.
- Just started. Limited so far.
- Could use more interactions with other chemist and engineering groups.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.91** for proposed future work.

- Need to move quickly and efficiently through the downselect process in the first year to zero in on the most viable technical approach(es).
- Project is vague.
- No contingencies considered.
- Rating based on timeline, because we have no idea if they are really approaching the problems on a chemical level in a systematic and optimized way.
- Good approach.
- Very exciting project.
- Company knows what it is doing.
- The future work summary was too vague.
- Air Products needs to be forthcoming about the specific kinds of LQ*s and catalysts they are looking at.
- Just started.
- Productive modeling to lead experimental efforts.

Strengths and weaknesses

Strengths

- Potentially low infrastructure cost but we don't know what it is.
- Safety.
- New material discovery.
- Potentially low cost and safe material for storage.
- Possibility of use of existing infrastructure for refueling.
- Possibility of regeneration (hydrogenation) using existing commercial facilities.
- Having a liquid fuel is desirable.

- Experienced team with good tools.
- Appear to have a line on a material.
- Chemical hydride project that uses existing infrastructure with minimal changes.
- Overcomes recycling dilemma that plagues other hydride systems.
- Outstanding- company knows what it is doing.
- By far the best of the Storage projects.
- Successful completion would result in a useful product that could be put into use at a reasonable cost and is likely to be accepted by the public.
- A 30% cost share by Air Products shows some commitment.
- Competence of Air Products.

Weaknesses
- Unsubstantiated claims on efficiencies - why can't you estimate them?
- Unclear on net cost of H_2/kg and assumptions
- Difficult to meet 2015 target as this approach is at near H_2 capacity of petroleum-based materials.
- Liquid not disclosed.
- Generation of waste streams.
- Secret material. If they discovered the material or the process, they can file a patent which would protect their rights.
- Little data and information provided.
- Not clear if they found the material or they are still searching.
- Materials are not known so safety of the material(s) may be an issue that needs to be assessed.
- Waste tank is needed (this waste seems to be solid which would not be easy to remove.)
- Does not seem to suitably use the $1M per year.
- Possible synthetic challenges.
- I'll believe the cost projections when I see performance given in terms of "net" energy per unit of system weight and volume.
- Very expensive project. Presentation does not adequately describe what DOE gets for the cost.
- Heat available from the fuel cell is limited (T=80 degrees C). Even if this can be utilized, this will result in condensing the water in the exhaust stream, which can be an issue.

Specific recommendations and additions or deletions to the work scope

- Continue with the plan.
- Should have different density and cost targets for the material and for the system.
- Should give detailed account to DOE team so they can evaluate the chances better than we can.
- Need to consider the purity of H_2 out of the system.
- Deselect to one or two systems after ~ 1 year.
- I'd suggest more emphasis on the search for the best possible LQ*. None of the ones we know about are good enough. Hopefully, we'll hear a success story about the new "bent bond" material at the next review.
- Need to move quickly and efficiently through the downselect process in the first year to zero in on the most viable technical approach(es).
- Provide estimates on efficiency.

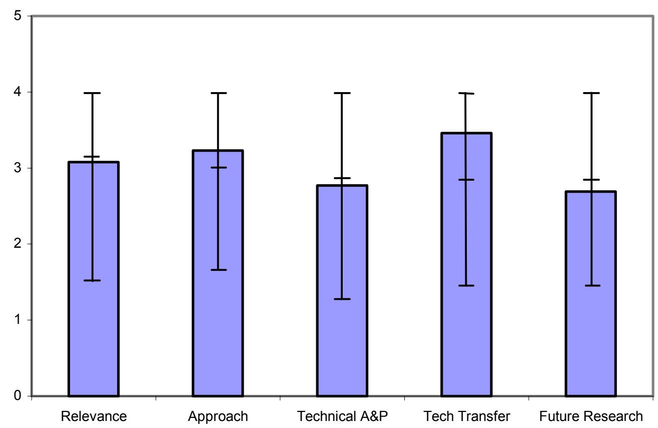
Project # ST-8: Doped Sodium Alanates: Fundamental Studies and Development of Related Hydrogen Storage Materials

Jensen, Craig; University of Hawaii, Manoa

Brief Summary of Project

The University of Hawaii is developing catalytically enhanced hydrogen storage materials capable of being used in vehicular applications. The objectives of the research are to determine the chemical nature and mechanism of the species that is responsible for the enhanced kinetics of Ti-doped $NaAlH_4$ and to apply the insights gained from fundamental studies of Ti-doped $NaAlH_4$ to the design and synthesis of hydrogen storage materials that will meet DOE hydrogen storage system targets.

Overall Project Score: 3.05



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.08** for its relevance to DOE objectives.

- The use of reversible hydrides is important to the Hydrogen Fuel Initiative.
- Metal hydrides are one of several high potential storage technologies that would support/enable a hydrogen transportation system.
- The PI has unique knowledge and experience in this area.
- The PI's claim of a new material with 7% wt density is not supported with data.
- System targets are not addressed. All research and numbers are material based.
- I believe it will be difficult to reach the DOE targets with these materials (alanates).
- Material safety (except lab safety) is not addressed.
- This work is aimed straight at a major need in the program.
- Good progress in addressing important issues to realize the goals of Hydrogen Program.
- Innovative and thorough.
- Relevant to alanates and other potential complex hydrides.
- The focal point for this research is another system that has no credible chance of meeting appropriate 2015 target for weight and volume.
- The justification to continue this work is to develop an understanding of a "model" system that could be applied to different materials.
- Contributes very well to the basic understanding of $NaAlH_4$, the state-of-the-art H_2-storage hydride.
- Some chance of 6 wt% - not 9 wt%.
- Work could lead to higher capacity materials.
- Pure sodium alanate unable (or at least unlikely) to achieve 2010 goals; thus, improvements on this material are key.
- Unlocking key to the dopant material in $NaAlH_4$ may give clues about making other materials reversible.

Question 2: Approach to performing the research and development

This project was rated **3.23** on its approach.

- The work is innovative.
- Progress is being made.
- Failure to address specific barriers related to the use of sodium alanate with respect to 2010 or 2015 targets.
- Approach appears to be a bit scattered. The results are confusing and interpretation of the data a stretch.
- PI seems to take great care in trying to understand and to explain the results of the analysis and to leave no stone unturned in identifying and evaluating alternative compounds.
- Too strong a focus on characterization of materials that do not meet targets (e.g. 2010 or 2015).
- A significant number of studies on doped alanates have shown little promise to date.
- Technical barriers were addressed vaguely.
- Technical feasibility is not guaranteed.
- Did not address the cost of alanates (doped and undoped).
- Safety of these materials will be a major concern even if other obstacles were overcome.
- Using many techniques to evaluate the material.
- Asking appropriate questions and getting answers experimentally. Not much PI could improve on here.
- Excellent example of a program developed to address the programmatic goals using the best available techniques and outreach with collaborators that can bring the experience needed to get at the core issues.
- Mechanistic information important to understanding and developing other complex hydrides. Group has developed good understanding of this system as well as improving performance.
- Seems that the state of mechanistic understanding is actually more uncertain than presented last year (May 2003). That is not a negative, but points to the complexity of the material system and the need for rethinking and new experiments.
- Leaves few stones unturned in the choosing of measurement and characterization techniques.
- The detailed battery of experimental techniques employed is highly commended.
- Going for fundamental understanding.
- Great diagnostic instrumentation.
- Application of wide array of analytical methods to understand mechanisms in material. Good capability for synthesis and material treatment.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.77** based on accomplishments.

- It is hard to determine new work from previous work or literature data.
- Lots of data, but very confusing results and interpretation. Need to get all data/results gathered and formulate consistent theory and test theory.
- PI is learning more about the chemistry and physics of metallic lattices and storage materials but seems to be making slow progress toward a technical solution that can meet the DOE storage targets.
- I did not understand why a patent on a model is filed.
- It seems that it is not known which model is more accurate to represent the doping chemistry. What is the plan to resolve this issue?
- Some results were not reproducible. Need to know why.

- Answers to some reviewer questions were not solid, such as "it likes to be there" in response to one.
- The preliminary 7 wt% storage capacity with the new discovery needs to be supported by evidence.
- Why are different measurement methods needed?
- Creation of the Ti-substituted material is a major advance IF it has good properties. The method alone is of value; though we cannot evaluate that as it was not discussed.
- Diagnostic results are not as definitive as might be wished; hard to tell for certain what is happening to the titanium as far as its true location or its actual molecular function. Still, a lot of new results that may someday help answer these questions.
- Progress is clearly being made; but it is unclear whether key barriers will be overcome, as in all storage programs due to the level of technical achievements needed.
- Good work. A little disappointing that mechanism is not clearer, but that is the way nature works sometimes.
- Lots of data but no convincing answer to the "Ti" question.
- The project appears to be a "good" return on investment.
- Tying the "mechanistic" studies and various experimental data together has been a little slow.
- After almost 4 years, project is barely into second objective "development of related hydrogen storage materials."
- Gained large amount of information from wide array of experiments. Initial results on "7 wt%" material promising.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.46** for technology transfer and collaboration.

- Lack of a partner with practical/end-use experience.
- Work with international and lab partners shows collaboration, but no tech transfer. Collaboration appears to focus on data, not on interpretation.
- The PI seems to be doing extensive collaboration and exchange of ideas to try to confirm or to better understand his experimental results.
- There is wide cooperation and technical publications.
- Well aligned and well connected.
- The outreach has been excellent and this PI is a highly sought after collaborator.
- Great utilization of resources to attack problems.
- Replete with collaborations - too numerous to list. That is the most positive aspect of this project.
- A highly detailed and valuable spectrum of international scientific collaborations. Transfer of information and practical implications to industry not quite as clear.
- Lots of high quality collaborators.
- Effective interaction with collaborators has resulted in good data and a number of publications.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.69** for proposed future work.

- As the speaker stated, it appears that this technology has reached its end.
- Unsure of continuation. Need to analyze where project stands and make a go/no-go decision now.
- Future direction needs to be clarified further. What other options are available if the model fails?
- Correct research to be doing.
- Have very specific plans for the next 2 years.

- The future focus should be on systems that do have a credible chance of meeting appropriate 2015 targets for weight and volume.
- Some hint of a better performing material but no details – "trust me" approach.
- Need to complete mechanistic understandings and move into new materials development. Seems to be understood.
- Not very detailed description beyond FY-04.
- Much research has focused on applying a wide variety of experimental techniques to determining the role of Ti. The evidence is contradictory, but the bulk vs. surface role of Ti would be immediately settled if the higher-density brine-free material could be synthesized and storage measured. This would also be working toward the DOE goals. Therefore, synthesizing and testing these higher-density materials (based on the hypothesized bulk substitution) should be the absolute top priority for this project. This definitely should be sorted out before next year's meeting.

Strengths and weaknesses

Strengths
- Lots of data and empirical observations.
- Research is world class and well respected.
- Good experimental and testing techniques.
- Significant knowledge on doped alanates.
- Unique knowledge in this area.
- Well conceived. Innovative. Focused.
- This project has been and continues to be at the forefront of important scientific questions that get at the heart of the technical issues that need to be addressed for the hydrogen storage problem to be resolved. The value of this project per dollar invested is extremely high.
- The presentation included technical aspects and technical questions that got to the core barriers that need to be addressed for this problem to be solved.
- Good work to attack mechanism and go after improved materials.
- Collaboration structure is a strength.
- Excellent scientific base and collaborations.
- Diagnostics excellent.

Weaknesses
- Failure of the material. Poor on application or storage device development.
- Low credibility: the speaker should not use the forum to propagate unsubstantiated claims.
- Interpretation of data is confusing. May need to rethink research plan to arrive at conclusive results.
- The PI tantalizes us with statement that he may have a storage media with 7 wt% capacity but does not provide enough detail or information to understand and to confirm or refute the results. We need to find a way around any confidentiality or proprietary issues to allow the results to be confirmed or excluded.
- The doped alanates will not meet the capacity and storage targets. Storage capacity presented for material (not for storage system).
- Results of proprietary methods were not verified. Non-supported claim of a new material with 7 wt% storage capacity.
- No system-based numbers. Safety and cost are not considered.
- Substitution model not proven.
- The presentation was difficult to follow.
- The PI may be a little too enamored of the Na substitution theory of Ti.
- The systems chosen for study represent a weakness.

- Resolution of exact mechanisms perhaps slower than expected. Not clear how this will quickly lead to DOE goals.

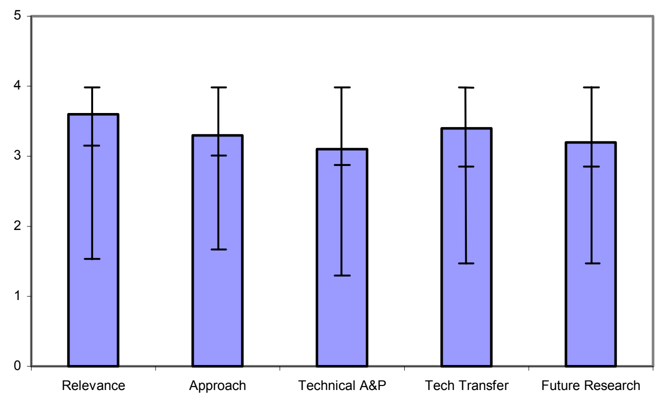
Specific recommendations and additions or deletions to the work scope

- Examine data in more detail to look for consistencies. Also, consider effects of ball milling. Per PI, ball milling enhances initial absorption but not reverse. Could "dopants" simply stabilize physical structure toward hydride/dehydride rates.
- Consider re-focusing from alanates towards the discovery of novel "breakthrough" materials (other than alanates).
- Find ways to confirm results. Add system perspective. Add cost and safety information.
- Fully characterize the new material if it shows decent gravimetric capacity and release temperature. Definitely prove where the Ti goes.
- Either prove that doped alanates have a chance of meeting meaningful (auto industry accepted) targets for H_2 storage or move on to systems that do. The sooner the better.
- Closer collaboration with commercial hydride producer.
- Focus on the new materials.
- This program should end as quickly as possible.
- Synthesizing and testing the higher-density materials (based on the hypothesized bulk substitution) should be the absolute top priority for this project. This definitely should be sorted out before next year's meeting.

Project # ST-9: Hydride Development for Hydrogen Storage
Wang, Jim; Sandia National Laboratories, Livermore

Brief Summary of Project

Overall Project Score: 3.32



Sandia National Laboratories (SNL) is seeking to develop new complex hydride materials capable of achieving at least 6 wt% system hydrogen capacity, to improve kinetics of absorption and desorption and thermodynamic plateau pressures, and to improve processing and doping techniques that will lower cost. Current materials under study include: advanced complex hydrides; destabilized binary hydrides; novel intermetallic hydrides; and other reversible hydride-based materials. In addition to new materials discovery, work continues in fundamental modeling, materials synthesis and modification, testing of hydrogen storage and delivery characteristics and engineering science and process development.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.60** for its relevance to DOE objectives.

- Important project to look for solid-state chemical hydrides. Need to investigate these classes of materials thoroughly.
- Metal hydride research is one of several possible high potential storage technologies that would support/enable a hydrogen transportation system.
- The research programs cover various chemical hydrides and new materials. Structured presentation with useful information. Amides may be the way to go. Safety and cost issues need to be identified. Having SNL to lead the Complex Hydrides Center of Excellence was the right choice.
- This project provides an important component towards meeting the capability to develop a hydrogen storage material that meets the targets and is contributing towards identifying what material will eventually meet those criteria.
- Good match to DOE goals.
- System with 6 wt% stored reversibly doesn't meet the DOE performance targets. New materials are needed.
- Good focus on new materials.
- Focused on the right problems. This is a high-resource project but is likely the best program in the entire DOE portfolio.

Question 2: Approach to performing the research and development

This project was rated **3.30** on its approach.

- Good systematic approach backed by careful scientific thought.

- Evaluating a large number of complex hybrids - which is likely to be required to find the optimum few for further assessment.
- Good focus on new material discovery. Good testing facilities. Good upfront estimates of the potential of new materials (amides, etc.).
- Projects are well-designed to answer important questions. A system approach has to follow material discovery.
- The new facility they are building/have built is very good as are the approaches towards identifying new storage materials.
- MgLi amides promising new materials. Did they come from LANL or Singapore? Need to ensure no duplication of work at other labs. Mechanistic work in progress for amides? Ti-alanate calculation promising result for mechanism elucidation.
- A program this size ought to be able to make meaningful progress in a couple of years. The approach is well orchestrated.
- Careful. Safety excellent. Excellent facilities.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.10** based on accomplishments.

- Promising results of Mg-Li-amides. Reasonable model for Na-alanates; further test this model with appropriate experiments.
- Difficult to assess technical accomplishments because insufficient analytical or experimental data was presented. Presentation was too superficial for valuable assessment of this area.
- Potential of new materials has not been demonstrated yet. Good system engineering estimates.
- Gravimetric density seems to be the metric used to measure the storage capacity of materials.
- This project has a lot accomplished with a lot of people contributing to it - the difficulty here is how to measure accomplishments of over 20 people and $1.7M per year with projects of $200K and a couple of graduate students.
- Reasonable progress. Good discovery on amides. Limited mechanistic progress on alanates given size of effort. Engineering work with conductivity is important for device fabrication.
- Major effort expended in setting up state-of-the-art measurement facilities (e.g., an in situ XRD system). They seem to have what they need in place to get going at a respectable pace.
- Good start.
- Li amide work is very interesting, as is the work on the Ti mechanism in alanates. Future progress along these lines is highly anticipated.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.40** for technology transfer and collaboration.

- Lots of collaborations; and research exchange with Univ. of Singapore very good.
- Numerous collaborations were cited but it is unclear to this reviewer how extensive or in-depth the collaborations actually were.
- Excellent collaborations and teamwork.
- The number of interactions and collaborations that they identify is quite impressive; this reviewer hopes they are as intensive as they are numerous.
- Good work with others.
- Lots of strategically chosen collaborators. UTRC prototype demonstration project should be incorporated into the Center.
- Visiting scientist. Good list of collaborations.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.20** for proposed future work.

- Overall program plans look promising. Still too early in the project to evaluate technical feasibility of many of the proposed ideas.
- I am expecting good results from the DOE Center of Excellence and various collaborations led by this lab.
- Proposed work is a new project. A center of excellence that has all the appropriate milestones, etc.
- Would like to have more information on approaches planned to carry out 2004 plans.
- The plans for future work seem to be clearly directed at meeting the DOE targets for "weight" and "volume."
- Good plan for the next few years.

Strengths and weaknesses

Strengths
- Strong engineering discipline combined with detailed scientific rigors.
- Systematic approach backed by good scientific approach.
- Excellent comprehensive approach to new storage system design including discovery of new materials via the second project.
- The presentation was well prepared and easy to follow. It looks like they have enough resources to get a job done. Unique in working on the amides. Accomplishments are easy to see.
- This project involves a lot of people with diverse backgrounds that provides a broad scientific base that can be brought together to solve new problems and explore new opportunities.
- Good team. Excellent facility development.
- Broad focus that includes "nano" concepts and embraces a wide variety of systems.
- Competent organization. Large group of in-house and outside participants. (Turned in safety 1-pager.)

Weaknesses
- The output of a team is compared with resources that they receive. Not enough progress made toward development of an onboard storage module.
- PI did not allocate his time well. My perception was that the PI spent far too much time talking about safety, organization/staffing and test facilities and equipment plans that there was insufficient time for detailed discussions about the content related portions of the report.
- Primarily empirical approach to new material discovery. Need more systematic approach.
- Material target only. It looks that hydrogen release from the Li amide requires high pressure. Cost estimation is not covered.
- Difficulty of geographic separation. Collaboration and may result in duplication of effort and facilities.
- Thermal conductivity of the alanates is low, making for difficult heat transfer to release hydrogen.

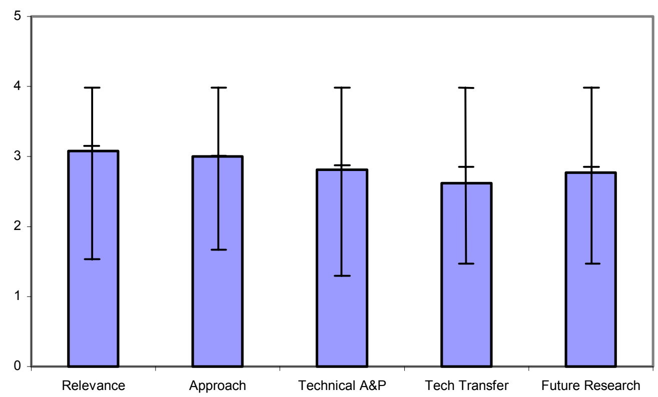
Specific recommendations and additions or deletions to the work scope

- Work with U. Hawaii (C. Jensen) to evaluate alanate results. Sandia model seems reasonable. Is it consistent with all data? What experiments are needed to evaluate materials versus this model?
- System-based studies are needed.

- This project should definitely continue.
- Make sure the performance metrics include considerations of (1) "whole storage system" weights and volumes and (2) "net" energy delivered to the vehicle.
- Schedule down select of materials and no-go for those that will not meet targets.
- Should consider investment in Na-alanates given uncertainties in this approach. Continue work in this area, but do not sacrifice other ideas for this chemistry.

Project # ST-10a: Development of a High Density Hydrogen Storage System Prototype Using Doped Sodium Alanate Complex Hydrides
Anton, Don; United Technologies Research Center

Overall Project Score: 2.86



Brief Summary of Project

United Technologies Research Center (UTRC) is working to design, develop, and evaluate a prototype hydrogen storage system using $NaAlH_4$-based complex hydrides with an ultimate goal of 5-kg hydrogen capacity. The hydrogen storage system will be suitable for a PEM fuel cell powered mid-size automobile application. UTRC's approach is to develop improved sodium alanate based materials and to design and fabricate a 1-kg hydrogen system for initial testing. UTRC will attempt to improve the charging and discharging rates of the $NaAlH_4$-based materials by increasing the reversible weight fraction of hydrogen stored to 7.5%, enhancing the hydrogen evolution rate to meet steady-state demand, and increasing the regeneration rates to achieve the five-minute refill requirement. Based on the 1-kg prototype's performance, a decision will be made with regard to building and testing a 5-kg hydrogen prototype. They will also determine the safety and risk factors associated with the enhanced material compositions.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.08** for its relevance to DOE objectives.

- Metal hydride research is one of several possible high potential storage technologies that would support/enable a hydrogen transportation system.
- No need to develop a system without having a basic material meeting the targets.
- The only team working on developing a storage *system* (currently). Good and informative presentation. Honest about data, without making unsupported claims.
- Engineering work is needed to show what tank "overhead" truly is.
- Device construction is crucial to identify issues involved with alanates and future hydrides. Information is probably available within auto makers, but needs to be public.
- Lots of money is being spent on a system that can not meet meaningful weight and volume target values for H_2 storage. However, the lessons learned from engineering a prototype system will be very valuable to the program.
- Good and detailed focus on a practical vehicular (PEMFC) H_2 - storage tank. Science and engineering good.
- Good to do a full system even though it will not meet goals.
- The only project in the portfolio focused on system issues relevant to solid-state storage. This is an important issue that deserves more attention from the DOE.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Not sure how they will overcome the barrier. Not clear why they want to continue when their own analysis- shows short-term failure.
- Noteworthy that project is conducted by a commercial company that plans to build a near-production size system. This differentiates this project from others in the area.
- System cannot meet the targets.
- Approach remains good.
- The approach to study catalyzed aluminum hydrides and design systems/approaches that can handle any hydride is very good.
- Comprehensive approach to multiple problems. Use of commercial H_2 is good to approximate real world. Would like to see high purity for comparison. Integrated approach to building device is strong.
- Methodology is standard; the project could use a stronger science component and a broader range of physicochemical measurement methods.
- Good combination of modeling and experimental work. Detailed safety studies are a plus. First effort to develop a full-scale (5-kg H_2) composite vessel.
- Good careful job.
- Broad approach using experiments, modeling, safety tests, and engineering.
- Some flaws in their approach. Modeling work seems very weak, and does not bode well for future project (complex hydrides materials discovery project). For example: The "prediction" from modeling the efficacy of catalyst additions is based on many underlying assumptions which were not mentioned (the idea of bulk substitution being most obvious). And, the most important thing is that the predictions do not work (again, not mentioned). Cerium (Ce) is not a better catalyst than Ti. And, from their model, the impurity with the highest heat of solution would produce the highest energetic effect, and therefore be predicted to be the best catalyst. However, it would also be the most energetically unlikely to form (again, not mentioned).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.81** based on accomplishments.

- Difficult to evaluate the accomplishments because the PI moved so quickly through the presentation. He skipped several key slides such as gravimetric and volumetric efficiencies. PI should not assume that the reviewers attended other technical sessions and should report relevant results here; sacrificing other portions of the presentation to include key results, accomplishments and status.
- The slide showing barriers and targets should also include a column for performance to those targets as well as the go/no-go.
- Much work is being done, question is will it meet goals. Goals seem unlikely to be met even though they are less than DOE current goal for 2005. Some of the progress shown was also shown last year, so I do not count that this year. Improved materials are not as good as those demonstrated previously by other teams. Significant progress on engineering though.
- The accomplishments may be better than the score of fair but it is not possible to tell from data that is withheld from the review team - this is a basic flaw in the review process and a strategy for the project management.
- 1-kg hydrogen system progressing well.
- Most of the progress made is not encouraging for alanates. The matter of storage medium degradation due to persistent impurities in the reload hydrogen is not a trivial one.

- Extensive progress on many fronts (especially engineering/system). Safety studies excellent (but a bit intimidating). Tank design done well, with very important heat transfer modeling. About to begin testing.
- Good progress toward classifying safety properties. Developed new doping process although material performance not generally improved by new process.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.62** for technology transfer and collaboration.

- While difficult, there should be more collaboration with Sandia National Labs.
- Certainly a critical program. Connections are good.
- This project has good collaborations and interactions with others, - academic and industrial.
- Over a half dozen collaborators - mostly industrial types. If the project is moved into the Sandia center, the science component should be improved.
- Many good collaborations with supporting organizations. Good team.
- Too much proprietary (data and results).
- Thermodynamic databases they are developing are important and this type of heat management that they enable will be important to future efforts in the area. DOE is paying for this development, and needs to insure that these databases will be available to others in the field. (This is not proprietary fuel cell related information.)
- System-level modeling is quite important, but was described as proprietary IP. Again, this will be important work that the DOE will have to re-fund over and over in the future if every company declares this as proprietary. Perhaps these researchers could extract the sensitive fuel cell information from their systems model and leave these as inputs to the model and provide a non-proprietary version of this systems model?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.77** for proposed future work.

- The future plans do not address the challenges.
- Timeline chart was not readable.
- Plans look suitable. Hope they pan out.
- Approach of foregoing 5-kg hydrogen system and improving the 1-kg program is a good modification of the work plan.
- It's not clear how catalysts are going to help alanates meet DOE targets for 2015.
- Good plan to finish work.
- Revised plan to redesign 1-kg hydrogen bed is a good idea. Premature to build 5-kg hydrogen bed.

Strengths and weaknesses

Strengths
- Very honest presentation - this project should be supported.
- The only team building and testing a hydrogen storage system. Safety issues are considered.
- Only real engineering program currently active. Powerful team.
- The capability to handle any hydride is important and well thought out. The safety experiments are excellent and help everyone.

- The redirection towards new work to take advantage of new materials and recognition of the need to redesign the vessel to enable the gravimetric requirements to be met is completely appropriate.
- Good, well-integrated engineering approach. Repeating 1-kg hydrogen device allows learning from v1.0 device.
- The team assembled to engineer and build the prototype system is impressive.
- Very systematic and professional, combining modeling, engineering, and experimental.
- UTRC is a quality outfit.

Weaknesses

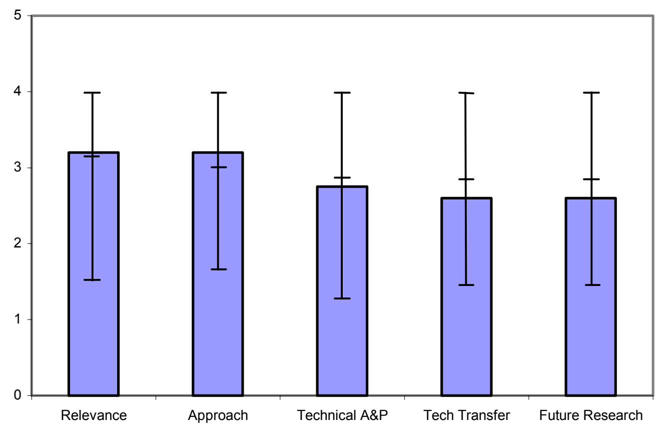
- Experimental approach - why a composite tank? Unclear what the new targets are when they admit they will not meet some of them.
- To reiterate, the PI should size the presentation to fit the time allocated and should not move quickly past key status or results on the assumption that reviewers were at other meetings where the results were able to be discussed in more detail.
- How to design the system such that it can be used with other metal hydrides?
- Will not meet 2005 targets. However, the project is a good exercise.
- Why are the results of the system level modeling sensitive IP? I assume the models and the details are proprietary. If this is an internal effort, it does not need to be mentioned here.
- Approaches taken on material do not seem to equal those taken by others.
- Non-disclosure of new materials and their structures inhibits advances of the scientific community as a whole and especially in such an important area where the state-of-the-art is still a pretty long way from reaching the goals. Such non-disclosure only suppresses the ideas of others who could come up with "the magic bullet."
- Alanates probably have limits and may never make DOE (FreedomCAR) goals. But should try.

Specific recommendations and additions or deletions to the work scope

- Re-scope the project by setting new priorities: Science objectives (e.g., material, transport phenomena); engineering objectives; storage module/vessel development objectives.
- Suggest redirecting resources towards the development of other reversible H_2 sorbents that can potentially meet targets.
- Focus on improving the engineering aspects.
- Continue project with redirection efforts.
- Computational details need to be examined - UTC vs. Hawaii results needs to be rationalized.
- This is a "demo" project; anything that could be done to put the project on a more scientific approach might get the demonstration closer to something that auto makers will consider attractive. Inlet H_2 purity should be studied further to determine the effect on durability over repeated cycles.
- No changes.
- Try to get system to not be proprietary.
- This project needs "competition." Right now, they are the only ones working on this, and are going to be unable to meet the (very conservative) go/no-go decision points. However, without some other group working on this, it is difficult to tell whether this project simply is not executing a clever engineering design, or whether this is a more fundamental problem which will befall anyone in the field. A second project in this area would at least provide a point of comparison.
- Thermodynamic databases they are developing are important. DOE is paying for this development, and needs to insure that these databases will be available to others in the field.
- System-level modeling is quite important, but was described as proprietary IP. Again, this will be important work that the DOE will have to re-fund over and over in the future if every company declares this as proprietary.

Project # ST-10b: Complex Hydride Compounds with Enhanced Hydrogen Storage Capacity[1]
Anton, Don; United Technologies Research Center

Overall Project Score: 2.87



Brief Summary of Project

United Technologies Research Center (UTRC) will develop a new complex hydride compound(s) capable of achieving greater than 7.5 wt% hydrogen capacity and 500 cycle-reversibility with 100% efficiency. The focus will be on $Na_yM_{+ix}(AlH_4)_{y+ix}$, in the quaternary phase space between sodium hydride (NaH), alane (AlH_3), transition metal or rare earth (M) hydrides (MH_z, where z= 1-3) and molecular hydrogen (H_2). The team will accelerate the discovery of new complex hydride compounds and guide experimentation with first principles modeling. The team will conduct three levels of performance evaluations to select compositions for further development, optimize dehydrogenation and hydrogenation catalysis with spectroscopic mechanistic studies and first-principles screening simulations, develop manufacturing processes to reduce cost and scale-up production, and develop business analyses for the commercialization of hydrogen storage systems integrated with fuel cell power plants. **This is a new project, started in 2004.**

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- This project is an important component in a program to find and develop materials for storing hydrogen and supports the Initiative's goals and objectives. This is true of both the old project and the new one.
- Good project in terms of looking for hydrogen storage materials.
- Need to find better materials.
- New materials important. Obvious match.
- Fundamental work is also useful both to them and others.
- Logical survey of "new" alanates.
- This project is an important component in a program to find and develop materials for storing hydrogen and supports the initiative's goals and objectives.

Question 2: Approach to performing the research and development

This project was rated **3.20** on its approach.

- Project has just started. High wt% storage material is important; not enough progress yet to determine if this project will get there. Does show potential.

[1] Note: In some cases, reviewers evaluated both ST-10a and ST-10b on the same evaluation form.

- The approach to study catalyzed aluminum hydrides and design systems/approaches that can handle any hydride is very good. (Both the old and the new projects).
- Good target set for basis system (not just material).
- Good discovery approach.
- This project attempts to bring the science component to the project in searching for enhanced performance (of the materials).
- Approach looks great. Good mix of theory and experiment. Molten state synthesis is interesting. Has it been tried for $NaAlH_4$?
- "New alanate" search will be quite systematic.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- The discovery project just started so no progress to report.
- New project's strength is that it is built on the experience from the old project and would be rated very good.
- Since project has just started, it is difficult to assess progress.
- Not enough innovation in selecting new materials for year 1 evaluations (still alanates).
- The slide showing barriers and targets should also include a column for performance to those targets as well as the go/no-go.
- Materials development program is a new start, so no accomplishments to report.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- This project has good collaborations and interactions with others.
- Probably will be proprietary problems here.
- Good team- exploits strengths of each partner.
- Reasonable mix of universities, research facilities, and industry.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- Future plans continue on the past successes and are quite good.
- Time line chart was not clear. Future plan was discussed briefly.
- New program is ambitious.
- Seems logical and well thought out.
- Continues with previously successful combination of modeling and experiment.

Strengths and weaknesses

Strengths
- Systematic approach to new material search. Good synthetic capabilities already in place.
- UTRC is a quality place.

Weaknesses

- Not clear how this program differs form other projects in the field. Widen the search beyond alanates.
- Intrinsic costs of materials not considered. Still focused on alanates.
- From the presentation, it appeared that the modeling efforts were independent of experiment in terms of some kind of verification that the modeling data is predicting properties that are correct. If this is not included it needs to be included, or you could wind up chasing non-existent artifacts.

Specific recommendations and additions or deletions to the work scope

- Approach of doping sodium aluminate material is consistent with other efforts at University of Hawaii and Sandia National Labs. DOE should work with contractors to promote synergy and minimize undo overlap.
- Consider broadening to include non-alanate materials.
- Material cost needs to be addressed.
- This project seems to rely heavily on atomistic modeling capabilities, and this group simply does not have the relevant expertise. (For instance, it is clear that they don't even know how to spell "first-principle" - this is not a quibble, but just an indication that this group is not expert in this topic.) DOE should consider having them work with established experts in this area, or possibly changing the research direction of their new project.
- DOE should consider how this project relates to or coordinates with the Sandia Complex Hydrides Center of Excellence.
- Need to ensure that modeling efforts are not independent of experiment- need validation that the modeling is predicting properties correctly.

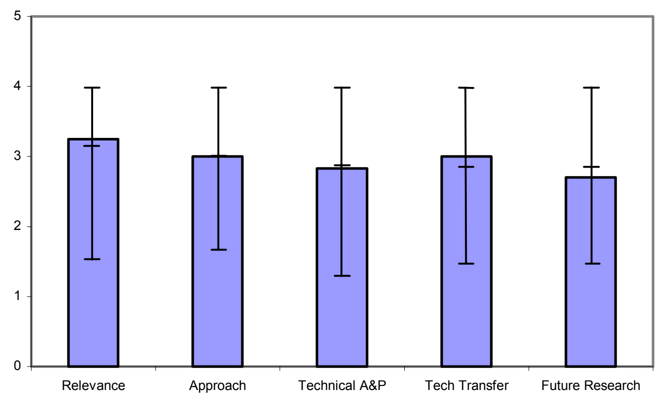
Project # ST-11: Discovery of Novel Complex Metal Hydrides for Hydrogen Storage through Molecular Modeling and Combinatorial Methods

Lesch, David (PI); Sachtler, Adriaan presenting; University of Pennsylvania

Brief Summary of Project

The objective of the proposed project is to discover novel complex metal hydrides for hydrogen storage that contain 6 wt% or more of hydrogen and can reversibly desorb hydrogen between -40 and 90C. The project will combine molecular modeling with high throughput combinatorial material synthesis, testing and characterization, large-scale materials testing, and system engineering studies to produce prototype, commercializable hydrogen storage systems.
This is a new project, started in 2004.

Overall Project Score: 2.96



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Metal hydrides are a possible high potential opportunity for hydrogen storage that can support the hydrogen transportation vision long-term.
- Has potential to be more relevant if project progresses as expected by UOP.
- Good technique and balanced program to achieve what is desired.
- Well aimed at critical problems.
- The goals as outlined, support the hydrogen objectives and contribute a very important discovery/computational aspect to address this initiative.
- Good match.
- UOP seems to understand the "target" issues in terms of "system weight," "system volume," and "net" energy delivered. Go/no-go decision making is in the plan.
- Aiming at DOE targets, as required.
- Need better materials.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Appear to be taking a logical approach to addressing the issues.
- Need to be more specific than "2010" targets as objectives.
- Having go/no-go points is a good step.
- Good focus on new materials search.
- Balanced approach of experiment and theory.
- Combinatorial on large scale samples is good.
- Need better definition of how they will analyze at high rates.

- Cost is identified as a technical barrier - it's not - it's an economic barrier that results from some underlying technical barriers that should be clearly identified.
- Combinatorial approach is promising. Would like more info on screens. Development of classical computational methods that yield useful results is challenging, but will be a great aid in rapid computational screening. Will combinatorial approach be used for synthesis and screening, or just screening?
- The approach looks efficient - combinatorial synthesis, TPD based screening, and theory coupled in to help elucidate results and define pathways for further research. More details on the high-throughput combinatorial screening technique are needed to assess the efficacy of this approach.
- Modeling/combinatorial dual approach good.
- Safety and environmental matters well-covered.
- Vague on materials to be studied. A few alanates at first. Not clear about possible overlaps with other DOE projects (e.g. ST-10).
- Screening - mass production.
- Will the combinatorial approach lead to rapid development of new material?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.83** based on accomplishments.

- Program just started so difficult to evaluate technical accomplishments or progress.
- New project. Good plan overall.
- Project is new but they had the labs ready and began modeling work.
- New program. Too early!
- Good progress has been made for being in existence for about 3 weeks.
- Just getting started with this big program. Large cost share by UOP shows commitment.
- Just starting this month but experimental equipment is already put in place.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Appears to have a good mix of industry, university and research facilities.
- Project has a good level of collaboration by including National Nabs, academia and industry.
- Good set of partners.
- Program is critical to realization of goals.
- The partnerships that are established are quite good and all should contribute towards its success.
- Good combination of participants.
- Collaborating with Ford (an auto company - that's good), UCLA, Univ. of Hawaii (a major university player), and Striatus.
- Good experienced partners.
- 4 on team - limited now.
- Good team assembled but no interaction outside of team to draw on years of experience/results of other teams.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.70** for proposed future work.

- Lays out comprehensive research plan for each year accompanied by go/no-go criteria for assessing value of research and whether or not to proceed to next phase of research.
- Project is just starting, so can't really evaluate future research based on past progress. May want to include more contingency planning if research doesn't yield expected results.
- Good balanced plan.
- New project so it has to be watched to see how it develops - while no past progress in this program it is based on progress in other areas.
- Still building facilities. Future plans lacking in detail for such a large project.
- This reviewer finds the future (especially materials) rather vague. Presenter apparently not very experienced in hydrides. Not well thought through (materials and methods).
- New start.

Strengths and weaknesses

Strengths
- Approach sounds good.
- Good cross-section of expertise and collaborators.
- Systematic approach to new materials discovery. Development of predictive tools for new materials properties.
- Good team. Technical approach is well-defined. Cost estimates to be performed.
- Balanced approach.
- Coupling discovery science and computation is fundamentally a good idea and an important component of a technology discovery/development program. One question that comes up is whether the discovery method they are designing can "discover" known existing systems.
- Ambitious project. Challenging tasks in early years to develop combinatorial and computational methods.
- Substantial in kind contribution and an auto manufacturer for a partner.
- Marriage of modeling and combinatorial experimental work.
- They have auto manufacturer (Ford) involved.

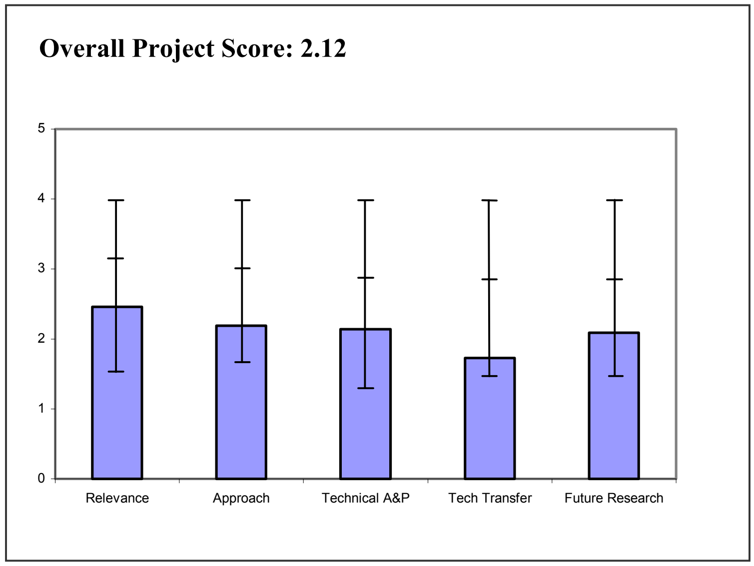
Weaknesses
- It may not be possible to actually synthesize many of the predicted materials.
- Too early to tell - but the need for high throughput screening needs to be carefully thought out because that is both needed to test the high throughput preparation and couple it to the human interface. This can be and often is the downfall to many discovery science activities and it was not clearly defined - at least at this early stage in the project.
- Will the science base be strong enough to push this project past the obstacles limiting the search for a usable hydrogen storage material that meets automotive industry requirements?
- More work on alanates! This seems to be an overworked field. Possible duplications with other DOE projects (e.g. ST-10).

Specific recommendations and additions or deletions to the work scope

- While not possible this year, for next year's review, show progress towards targets and goals.
- This is a new program that should be continued.
- Come to the FY 2005 Review with clearly laid out plans for FY 2006 and beyond.
- Consider immediate move to year 2 materials.
- DOE should consider how this project relates to or coordinates with the Sandia Complex Hydrides Center of Excellence.

Project # ST-12: Sub-Nanostructured Non-Transition Metal Complex Grids for Hydrogen Storage
Talu, Orhan (PI), Surendra, Tewari Presenting; Cleveland State University

Brief Summary of Project



The objectives of this project are to grow sub-nanostructured metal grids (less than 1 nm thick) with about 50% microporosity (less than 1 nm wide), measure hydrogen uptake/release, and evaluate these novel metal grids for hydrogen storage applications. The premise is that the overall hydrogen dissociation reaction rate will be higher (because the external metal surface area is enhanced), and the diffusion time constants will be lower (because the diffusion path is greatly reduced). In addition, conduction in the highly interconnected metal grid and convection in the micropore space may enhance heat transfer. The nanostructured metal grids will be grown from pure and alloyed non-transition metals and the phase diagram is anticipated to be different from the bulk phase diagrams because of the quantum effects that may arise at these length scales. **This is a new project, started in 2004.**

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.46** for its relevance to DOE objectives.

- Innovative concept but not sure how it will address and support the Hydrogen Initiative.
- Metal hydrides are a possible high potential opportunity for hydrogen storage that can support the hydrogen transportation vision long term.
- It is not clear that this project directly aligns to supporting the President's Initiative.
- Benefits not clear. Claims in slide 2 are not supported. No scientific evidence it can be done. May not be successful. Will not meet volumetric targets. What is the cost of making the structure? This concept may be useful for other applications.
- Potentially relevant in areas other than storage, but would be a major contribution if it works for storage - opening a new "front" in the effort to achieve the goals.
- The goal of building metal grids to reduce the diffusional barriers associated with transport of hydrogen has the potential to overcome or help overcome some of the issues with implementing the President's goals.
- Novel approach for making micrometals.
- This team really hasn't done its homework. Calculations should have been presented to show what the possible storage volumes for hydrogen might be for the 3-D grid structures. Stable grid structures may not be possible and may not come close to meeting DOE volumetric storage goals. Calculations would have been helpful. Despite the negative sounding comments, the project is far out and probably needs some time before a judgment can be made.
- Does not give any theoretical estimate as to what level of gravimetric and volumetric hydrogen storage capacity might result, vis-à-vis DOE targets.
- Trying new approach for high performance materials.

- Initial work is long way from developing storage material. This is really a material science project to develop a metal grid based on zeolites. Not really a hydride project.
- This idea seems unlikely (in the extreme) to work. We do need ground-breaking new ideas admittedly, but it is unclear how such an approach will help enable DOE goals, even if it works.

Question 2: Approach to performing the research and development

This project was rated **2.19** on its approach.

- Interesting approach to try to grow film on a metal substrate. Looking forward to future work and results to see if theoretical concept will bear fruit.
- Approach and tasks identified, but with the project just starting, it is difficult to evaluate feasibility and whether or not the expected results are possible.
- No evaluations of theoretical capacity, intrinsic costs. Approach is unlikely to work.
- Interesting approach. Many ways it could fail do not seem adequately addressed (e.g. grid collapse when zeolite removed, pore plugging too early, poor substrate zeolite contact, grid made but H_2 adsorption insufficient). Need to plan work around. May be under-staffed - remains to be seen.
- The approach proposed appears reasonably sound; however, since this is a new project, we'll have to wait and see how things go. The big question here is whether these metal grids even have the possibility of meeting the volume and weight targets set out for the storage needs of industry.
- Initial synthesis will be challenging. Maintaining structure will be even more difficult. Should consider mesoporous (MCM-41, etc.) materials in addition to zeolites. High risk project. Needs appropriate go/no-go decision points. Gas adsorption and XRD may be better techniques for characterization than HRTEM. They work much better for zeolites and should be better for the inverse lattices as well.
- Based on all the "hoping" and "trying" statements in the review presentation, I sense that the investigators for this project might be flying in the dark. It's not likely that a few metal atoms per faujasite super cage will connect up into a 3-D grid when the support is dissolved away. Also, zeolites are not good electrolytes or electrodes, so I'm not sure what kind of electrochemical exchange methods one could use effectively with them.
- New approach. New ideas needed. Details are lacking. I suspect only kinetic improvements can be expected, unlikely to improve capacity.
- High risk, high payoff.
- Unlikely that structure would stay intact with cycling.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.14** based on accomplishments.

- Project just funded. Too early to assess technical accomplishment or progress. Will want to watch closely if the researchers will be able to create the structure they think they can.
- Project is just starting, so can't really evaluate progress.
- New project. Too early.
- Some progress has been made since the project's inception and the milestones are reasonable.
- This is a new start - no results yet to provide any confidence that the methodology will work.
- New project. No progress to report.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.73** for technology transfer and collaboration.

- Need to work or find a partner with end user or an application in mind.
- No discussion of collaboration in presentation.
- From the presentation, this project appears to only include work at Cleveland State. If this is a collaborative project, it should be identified.
- Not clearly connected to other work. Partly supports the plan.
- This area of the project needs strengthening that should occur as the project matures, but at this point there are no apparent collaborations.
- Should work with Nenoff of Sandia or Pall Corporation for help with metal supported zeolites. Could cut months off the project and focus on goals rather than substrate preparation.
- No meaningful collaborations. Recommend someone with experience in the manipulation and modification of molecular sieve structures. The general approach has been used by other investigators going back to the 1980s.
- No collaborations cited by PI. Need help with practical hydride materials.
- Few if any partners identified.
- None identified.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.09** for proposed future work.

- PI describes detailed research plans; but question whether the first year's goal is sufficient/adequate.
- Not clear that the future work identified will provide the intended results. Does appear to be basic research.
- The plan looks adequate for now, if there is weakness it is on handling surprises that may arise in terms of grid collapse.
- This is a recently funded project and builds on the previous experience of the investigators in adsorption phenomena.
- Not optimistic. Wait and see what they present at the FY 2005 review.
- Some plans in place. Almost nothing on practical hydrides to be put in grid form. I get the impression presenter has very little background in state-of-the-art hydrogen storage materials.
- Has proposed plan.
- New start.

Strengths and weaknesses

Strengths
- Innovative novel concept.
- Good method for electrode development.
- Bright idea of making a "micro porous hydride material" to overcome diffusional barriers in the hydrogen storage system.
- Innovative.
- Novel approach to highly dispersed metals.
- New idea. Should improve kinetics and heat transfer.
- New approach.

Weaknesses

- Lack specific H_2 storage application.
- The metal grid is potentially subject to H_2 attack, thus collapsing the grid.
- Not enough focus on goals and targets.
- Metal grids (if Li, for example) would leach out together with zeolite matrix. "Microporous hydrides" will get converted to bulk crystalline material (thermodynamics).
- Highly speculative. Unlikely to make mass target.
- The lack or recognition (response to a question) that Pd has been ion exchanged into faujasites and reduced is surprising since this is the basis of probably 50% of the world's hydrocracking catalysts and a good percentage of its aromatic hydrogenating capacity.
- High risk. Need collaborations with people skilled in characterizing microporous materials.
- The presentation was not very clear about what underpinned the thinking that the proposed approach had validity. We know what the structural dimensions of the faujasite structure are and how many metal atoms we are likely to pack into that structure. Surely, some projections could be made from this information.
- Sub-nano grids seem unlikely to improve hydrogen storage (gravimetric or volumetric). Unlikely to reach DOE capacity goals.
- May not work.
- Don't see any potential for achieving high capacity material or even better understanding of storage materials. Small structure only impacts kinetics. Difficulties in depositing multi-component alloys. Appear to be limited to conducting systems.

Specific recommendations and additions or deletions to the work scope

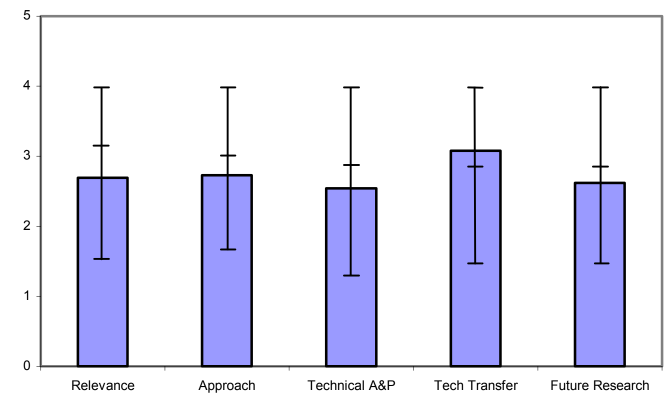
- Should be considered for funding in a different program, not H_2 storage. Need to look for end application as a scope.
- Should work with Nenoff of Sandia or Pall Corporation for help with metal supported zeolites. Could cut months off the project and focus on goals rather than substrate preparation.
- While not possible this year, for next year's review, show progress to targets and goals.
- Quickly do thermodynamic calculations to see if "hydride grids" will get converted to bulk upon recycling. Redirect or terminate the project scope.
- Focus as soon as possible on light materials. Note: this would be a great project for NSF/BES to fund. May have a role in battery materials; plan a route to transfer the work to the appropriate part of FreedomCAR or DOE if storage of hydrogen is small.
- This is a new project and should continue.
- It would be interesting and possibly of value to the project staff to see the results of a literature search that probes the prior work done by others to use molecular sieve materials as a means of making nanoscale materials/structures, such as quantum dots.

Project # ST-13: Hydrogen Storage in Carbon-based Materials
Heben, Mike; National Renewable Energy Laboratory

Brief Summary of Project

The focus of National Renewable Energy Laboratory's (NREL) work is on hydrogen storage in carbon-based materials such as single-wall nanotubes (SWNTs). The objectives are to determine the extent to which hybrid SWNTs can reversibly store hydrogen, to discover the mechanism of hydrogen storage in these materials, and to develop low cost, reproducible, and potentially scalable processes for producing SWNTs. The main focus in 2004 was on *reproducibly* measuring hydrogen storage capacity in hybrid SWNTs at room temperature and pressure.

Overall Project Score: 2.73



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.69** for its relevance to DOE objectives.

- Addresses 2010 target. Broad potential impact for both vehicle and stationary applications, but significant hurdles.
- Good science. If successful the program is well aligned.
- Carbon nanotubes are a possible storage technology that has been subject to much publicity and hype.
- Satisfies the need to explore and develop advanced materials for solid-state storage.
- Worth a thorough exploration of carbon.
- Class of materials may be applicable to storage applications.
- There is a critical need for the DOE storage program to determine whether there is indeed any commercially viable potential in nanotube technology. If so, the rating would be significantly higher, but as long as there is skepticism within the technical community, the rating needs to be lower given the definitions herein.
- Are carbon nanotubes capable of being a cost-effective way of storing hydrogen?
- High storage density may not be achieved.
- What is the plan to achieve the 4% SWNT capacity?
- What about system-based density?
- Odds of this being possible are not great anymore, which detracts from the alignment rating.
- Targets for carbon materials seem to be falling short of DOE storage targets.
- Hard to be positive about this project. Most observers have little or no confidence that carbon-based materials will come close to the DOE targets for "system weight," "system volume," and "net" energy delivered. This is, in effect, a last chance for carbon.
- Unclear at this point how this work will ever achieve DOE goals. This is basic science work that should probably be in the BES portfolio, but probably not in EERE focused on achieving more applied goals.

Question 2: Approach to performing the research and development

This project was rated **2.73** on its approach.

- Fundamental approach to understand adsorption/desorption mechanisms and apply to materials design is good.
- Measurement technique development and independent validation of storage results are extremely important to success of project and technology transition.
- Consideration of all carbon-based materials is good.
- There is a significant discussion of measurement accuracy and analysis.
- All the characterization work and lab verification work is top notch. The problem is that with good technique they do not make good material.
- Focus on TPD is a good idea.
- Computational studies should provide useful insights, e.g., about consequences of molecular strain.
- Looks good.
- Effort has broadened from earlier work.
- The researchers in this area are clearly top caliber and creative.
- Accuracy of measurement seems to be established.
- It had to take outside influence to address the problem.
- The technical approach has been good but apparently has recently been confined to confirming past results.
- Not clear in this project presentation on how it will get to 4 and 6 wt%.
- Intrinsic cost of nanotubes may be a "show-stopper."
- No evidence this will be technically feasible.
- There has been an avoidance of making samples that could be externally verified if successful. While tedious, in an environment where most scholars doubt the effect is real, this is a requirement.
- Some of the critical parameters for hydrogen sorption behavior in SWNTS could have (and should have) been identified earlier in the program; for example, the stochastic nature of the alloy doping. The approach toward addressing these issues is now on the right path forward and have confidence that significant fundamental understanding will be achieved.
- Real focus needs to be reproducible production of large (gram) quantities of material that adsorb significant quantities of H_2.
- Should also verify production of "good" nanotubes using low cost synthesis method.
- Laser synthesis will never make cost targets.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.54** based on accomplishments.

- Good validation of measurement reliability.
- Recommendation of low T/ low P options for new materials a great idea.
- Computational focus excellent, and interesting initial results for Fe role in H_2 spillover.
- The reproducibility is addressed. The results are disappointing.
- It is critical that results (especially claims of 8 wt-% storage) be reproduced and independently verified.
- Work done by the lab and the PI appears to be technically sound and rather rough, but the need for reproducibility and independent verification is critical.
- While equipment accuracy appears to be well-established, project is still yielding less than 3 wt%.

- Arguments on technical credibility of the measurements and reproducibility are not entirely convincing.
- Not much technical progress since last year given funding level. Lab review was essential, but not lengthy.
- Calculations are interesting though not yet compelling for explaining SWNT results.
- Now that the analytical capabilities have been validated and the reported results for hydrogen capacity are credible, the important materials-related efforts in this program can now proceed with diligence.
- Good work in resolving measurement issues.
- Need to go after materials synthesis in earnest.
- Need to make better progress in the area of reproducible synthesis.
- The role of catalysts/dopants needs better understanding. Is any of the information from the alanate work transferable to carbon?
- Still do not understand conditions for high capacity H adsorption on nanotubes.
- Demonstrating the reliability of their measurements was key; however, it is disappointing that all samples where reliability was demonstrated fall at or below the storage level of the alloy itself.
- How long has it been since the NREL group has made a sample that stores more than 4 wt%? Their milestone to "reproducibility" demonstrate this capacity or greater by FY 05 seems to be a crucial point at which a decision about the viability of this topic should be made.
- Why 2 of 9 samples showed high H_2 intake in SWNTs?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.08** for technology transfer and collaboration.

- Broad range of university collaborations with disparate opinions on best methods to make nanotubes with desired properties.
- Excellent leadership in organizing symposia.
- If successful, industry collaborations will occur to transition technology.
- Extensive collaboration through debate and discussion with other activities trying to reproduce or verify results obtained by the PI.
- Appears to be highly collaborative with academia and other National labs, but not with industry.
- If this project is to go further, it should also start to address how the technology could be transferred to industry.
- Alignment and collaboration adequate.
- Since the capability for synthesizing and catalyzing SWNTs is fairly unique to NREL, collaboration at this level is understandably weak.
- However, it is apparent that a substantial amount of outside collaboration has transpired relative to analytical measurements, theoretical chemistry, and characterization of materials.
- Sharing of candidate SWNT materials for verification of sorption behavior needs to occur.
- Great utilization of external resources.
- Many collaborations.
- Spearheading "carbon materials working group" and closely tied to SwRI - that's a plus.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.62** for proposed future work.

- Specific follow on areas identified for each class of materials they are working in based on last year's results.
- Plans seem reasonable, but future progress will depend mostly on ability to repeat and then independently verify past claims/results.
- The current plans are not justified by current results.
- It is not clear how the future research identified will meet targets.
- Put more focus beyond carbon nanotubes.
- Tests are nicely planned, but the focus on reproduction seems weak: this needs to be the over-riding focus.
- New focus on cryo is interesting and should also be pursued as the secondary line of work.
- Technical challenges are now clearly understood and a plan to move forward with the business of materials science has been outlined.
- Other methods of catalyzation need to be explored.
- Hopefully, TPD development work will be a reliable screening tool.
- Would like to have heard more about what NREL has in mind for research on "other" carbon-based materials, such as MOFs.
- Could be speeding up.

Strengths and weaknesses

Strengths
- Good science and team at NREL.
- Top notch team.
- Hydrogen storage center award- good news. Will be great to finally get independent validation of results reported by various groups for storage.
- Storage under mild conditions (low PT).
- Leading-edge research to develop advanced nano-scale materials for solid state hydrogen storage.
- Experimental approach should provide sufficient data to gauge whether or not SWNTs will be efficacious in meeting DOE performance goals.
- Technical expertise.
- Validated methods.
- Strong collaborations.
- Interactions with other researchers in the field have increased the confidence level in the NREL findings.
- Quality lab.
- Good strong team.
- Computational calculations of hydrogen spillover on carbon are generally good; but materials are too heavy and bulky for storage.
- High funding.
- Have responded to many recommendations.
- Very large effort.
- Program has already changed direction away from nanotubes (SWNT).

Weaknesses
- Lots of work going on in this program, but it was barely covered since so much time spent on other required slides (safety, tech barriers and targets, etc.). Need to streamline so more results can be presented.
- Failed material.
- Little or no potential for significant improvement.

- Project presentation is not clear how it will meet targets for wt%.
- Intrinsic material cost may be too high.
- Storage capacity is too low for a commercially viable device.
- Need to show the spill over work actually applies to SWNT.
- No progress on reproducing samples that store meaningful amounts of hydrogen when most of the world no longer believes this is a real effect.
- There seems to be a reluctance to face the fact that at some point it makes sense to pull the plug.
- Will the 4% externally verified go/no-go be enforced?
- Challenges are fundamental in nature, yet goals are very applied.
- Need clear path to reproducible, affordable nanotubes with good adsorption properties.
- The goals for "system weight," "system volume," and "net" energy delivered are too low.
- Little progress for such a long term program.
- Still no correlation between hydrogen uptake and material method or material structure.

Specific recommendations and additions or deletions to the work scope

- The go/no-go decision should be moved to 4Q '04.
- 4 wt% capacity as a target is inadequate - should be revised to at least 8 wt% for any chance of success.
- Try to get industry involvement in collaborations.
- Scope should be refocused beyond carbon nano-materials.
- The program should be stopped as soon as possible.
- Need to list what a system based on carbon materials would contain (including masses and volumes).
- Cost needs to be assessed.
- Focus totally on making a sample others can measure 4% storage in.
- Cryo work is an appropriate addition.
- This would be much better funded by NSF/BES where the horizon is longer and the deliverables need not be so focused. See Special Report of DOE-EERE written by SwRI: Carbon Nanotube Sorption Science - External Review.
- Don't burn up too much of your research base on the Yaghi-type MOFs, they only look interesting on paper (volumetric storage goals will be hard to meet).

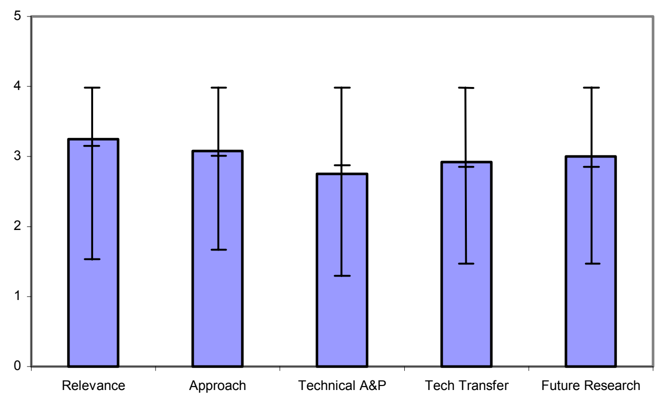
Project # ST-14: Standardized Testing Program for Chemical Hydride & Carbon Storage Technologies

Page, Richard; Southwest Research Institute

Brief Summary of Project

In this project, Southwest Research Institute (SwRI) will develop and operate a standard testing and certification program aimed at assessing the performance, safety, and cycle life of emergent solid state (e.g., metal hydride and carbon) materials and systems. As part of this project, SwRI will work with industry, DOE and other stakeholders to develop an accepted set of performance and safety evaluation standards.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- The relevance of such an activity is quite important to the overall DOE objectives. This project should facilitate quick, unbiased measurements of the sometimes contradictory storage claims. Also, it will enable "materials discovery" labs to concentrate on discovery, without having to build the equipment for measurement capabilities.
- Important project if solid state hydrogen storage is considered to be the ultimate solution.
- Having the ability to independently test materials in the program is essential.
- Establishment of facility serves as a safeguard against catastrophic distractions caused by "false positives."
- Possibly the most critical program in the portfolio. This has to be right and it has to be good enough so that when samples are judged as high or low capacity there is faith in the external community that this is correct. Hard to administer the program without a good testing facility.
- Testing program represents a necessary facility.
- This project will provide the Hydrogen Program with the credibility it needs to prove real progress toward meeting H_2 storage goals and targets. Need to keep duplication of capabilities with the Centers to the minimum without impeding progress at either location.
- Independent verification is important.
- Support role in storage development.
- Some overlap with existing capabilities.
- Test and evaluation only. There is no innovation which would lead to meeting goals.

Question 2: Approach to performing the research and development

This project was rated **3.08** on its approach.

- An excellent set of equipment has been assembled.
- Appears that necessary equipment is or will be installed soon to test solid state storage systems.

- Communication with solid state researchers important to identify standard protocols.
- The project should de-emphasize the opportunity to do science since their charter is to support the program impartially.
- Competent scientists and high quality instrumentation - adequate but "nothing special."
- Approach is on target.
- Good instrumentation has been acquired but the SwRI staff needs to acquire the practical level of personal expertise that's needed for effectively exploiting these capabilities.
- A well planned out program that is structured to set the standard for measurements of reversible H_2 storage capacity and "net" energy. This program will be the adjudicator of all claims that new vistas in hydrogen storage/delivery have been reached.
- Quality instrumentation.
- Good combination of instrumentation.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Many industrial sites have recently brought similar facilities online in much less time.
- Making progress in facilities but no technical contribution made.
- Most equipment is already in place, though not all.
- Seems like progress is good toward establishing the facility.
- Wish the progress was faster.
- Hard to evaluate as major deliverables are at the end of the year.
- Good appropriate instrumentation has been acquired for getting H_2 sorption/desorption data. It is, however, disappointing that almost no thought has been give to getting H_2 adsorption heat data.
- Making good progress, but they should be. They are generously funded by DOE with a mere 20% cost share.
- Still more equipment needed to be installed.
- Good progress has been made on equipment procurement and installation.
- Progress is modest and in the right directions, although somewhat slow and not particularly impressive.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.92** for technology transfer and collaboration.

- Meeting with Centers of Excellence. They should visit many more laboratories.
- Suggest interaction with industry in addition to academia and other government labs to transfer procedures and protocols for use development of solid start storage technologies.
- By the very nature of the project, tech transfer and collaboration have been, and will be, good.
- Efforts are being made to obtain input from all storage groups in the program.
- Highly important program.
- Collaboration with other testing organizations might be improved but adequate.
- The SwRI people have done a good job in visiting the best lab that currently does H_2 adsorption measurements.
- Seem to be working closely with the bigger programs funded by the Hydrogen Program. Have learned from leading experimenters with state-of-the-art facilities.
- Round-robin good.

- More interaction and collaborations would be very helpful to this effort as well as the program in general.
- Once this facility is online, this will be the single most important topic for this facility - collaborations with other laboratories.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Testing to begin this summer. They need to get a lot of testing under their belt to be able to identify appropriate test methods.
- Consider doing some correlation with test facilities at research providers.
- Question the effort to test a full scale system if this work is being done at UTRC too.
- Seeking to establish credibility.
- The SwRI lab operations staff may wish to once again visit and learn from the labs, especially after they have had some hands on experience with their current instrumentation.
- The plan looks good at this time. Assess where they are a year from now to make a more definitive judgment.
- Good plan.
- Well defined program of future work.

Strengths and weaknesses

Strengths
- Facilities - excellent.
- Independence.
- Provides a much needed independent testing source for verification of solid state storage systems.
- SwRI has the expertise and personnel to provide this function to the DOE program.
- Solid state measurement of hydrogen storage.
- Facility seems to be adequate to carry out envisioned function.
- Much experience and diverse talent at site.
- Well equipped to do the work.
- Will do quality measurements.

Weaknesses
- Should lead in developing test protocols.
- Further development of technical expertise.
- The breadth of the effort may require that the focus be limited to capacity measurements. If the program moves to all apparatuses, and does difficult measurements (like TGA and TPD), the throughput will be slow.
- Can't be used for other forms of hydrogen storage measurement.
- Value to program is not yet established.
- New to this branch of testing.
- Achieving the 2 minute H_2 refueling goal requires for an H_2 adsorbing carrier, a very rapid transfer of adsorption heat. It's critical that there be the means to measure this heat of H_2 adsorption.
- From R. Page's talk it seems that the SwRI folk need to put more thought and planning on measuring heats of H_2 adsorption at least for carrier materials.

Specific recommendations and additions or deletions to the work scope

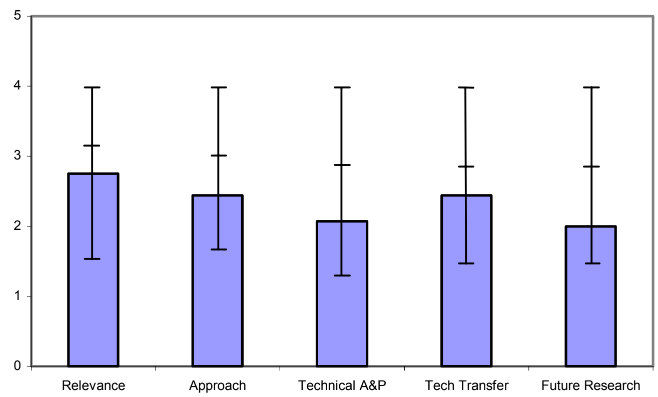
- Must focus on getting highly dependable results every time. Fast start is also critical. Balancing these two items will be important; much attention must be paid to this.
- Once again visit and learn from other labs (including industry), especially after having had some hands on experience with their current instrumentation.
- Communicate test procedures and protocols with industry.
- Need to ensure that the lab will be capable of expanding and adapting as storage technologies advance.
- SwRI should become the testing methods standards.
- Consider expanding this to test for liquids or other type of hydrogen storage materials.
- The project should reduce its desire to do science with the very nice equipment they will have, and focus more on testing.
- This project must not fail.
- The H_2 storage community does indeed need a rapid measurement tool (e.g., a litmus test) that at least roughly characterizes the gravimetric and volumetric storage capacity and the reversibility properties of candidate storage materials to keep up with, e.g., combinatorial synthesis efforts throughout the DOE sponsored enterprise. Ensure that there is a rapid measurement tool.
- Integration with the center needs to be established.
- It is more important for SwRI to concentrate on materials rather than systems at this time.
- Add capability to test chemical storage.
- Add calorimetry. Add plan for measuring heats of H_2 adsorption.
- Define throughput goal - samples/month.

Project # ST-P1: Next Generation Physical Hydrogen Storage
Weisberg, Andrew; Lawrence Livermore National Laboratory

Brief Summary of Project

Lawrence Livermore National Laboratory's (LLNL) project goal is to develop conformable hydrogen tanks that will meet DOE targets. Conformable tanks have the potential to optimally utilize available space in a vehicle and thus greatly improve volumetric efficiency. In this project, LLNL is investigating pressure vessels made of replicants. **This is a new project, started in 2004.**

Overall Project Score: 2.34



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Innovative approach to making lighter/stronger material for vessel.
- Not clear how it would apply to H_2 storage.
- I could not understand why statistical process control was used. The subject is to come up with the next generation hydrogen storage system.
- Information was disorganized in the slides.
- Replicants concept seems to be a good one.
- No evidence it will work, but may be worth trying.
- Work on statistics and overall system (includes synergies with vehicle) quite good. Novel ways to lighten and cheapen tanks also very on target.
- Would benefit from clearer presentation and explanation of project.
- The project is quite relevant in that it may provide the basis of a more conformable hydrogen storage system that could utilize the available space within a vehicle to much better advantage than do cylindrical tanks.
- A chance for innovative ideas.
- Relevant to conformability improvements for compressed gas storage.
- This work is of questionable relevance to DOE's objectives.

Question 2: Approach to performing the research and development

This project was rated **2.44** on its approach.

- Novel approach.
- Too many visual aids without addressing how to resolve the technical barriers.
- Novel approach is to be commended.
- Use of statistics is good and not seen in other programs.
- Need to exhaustively evaluate all space groups is probably not the most efficient.
- Really needs to find a partner to increase the physical data portion of this work so that more grounding of the theory can be accomplished.

- Theoretical approach seems to be giving good insights into potential new storage approaches.
- Novel shapes are being considered. The use of replicant structures should be cost-effective - many similar parts that can achieve volume manufacturing economy of scale. Analysis techniques appear robust and are drawn form numerous fields. A big question is how the skin will be attached to the skeleton. The materials of construction will determine the ultimate cost of the system. Internal structure does compromise the volume density but may be partially offset by the gains in conformability.
- Lots of ideas. Not enough money to pursue many.
- Manufacturability, bonding of materials and cost may kill these innovative ideas.
- No apparent improvement in volume, weight density except for conformability.
- Creative idea, but need to focus more on the utility and applicability or this idea, rather than the theory of it.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.07** based on accomplishments.

- By the presentation material, it wasn't clear what has been achieved beyond theoretical contemplations.
- Concepts need to be proven.
- Fairly good progress on theory, fairly little progress on confirming the theory by tests.
- Harder to gauge with theoretical work than experimental. Some advances over last year, but hard to quantify and understand.
- Budget is so small so great progress is not expected. However, it is time for some prototypes to be built and tested.
- Hasn't started.
- Needs a direct demonstration of fabricating a tank and testing it. Plastic models don't help much.
- The lack of experimental progress in this area is disturbing.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.44** for technology transfer and collaboration.

- Appears to have wide contact.
- Very little active collaboration but potentially very important program.
- Needs to explore possibilities of small devices to verify theoretical concepts. Reduction to practice may eliminate some of the concept's advantages.
- Collaborations with universities are underway to attempt to increase academic research in the topic.
- Some universities.
- PI understands importance of collaborations but hasn't launched an effort yet.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- Needs specific goals to address 2010 H_2 storages.
- Confusing.
- Needs clear and concise "roadmap" to project how work might actually be commercialized.
- Build and test prototypes should be the primary objective of future work.

- Too early.
- The creative new idea is there (and has been for some time); the crucial point is to try and make it work. Is there any benefit to this idea?

Strengths and weaknesses

Strengths
- Great visual aids.
- May result in a neat concept for hydrogen storage.
- Novel approach.
- Strong theory background.
- Novel concept with significant potential for compressed storage. Well grounded in theory.
- Smart, innovative PI.
- Innovative. Very different approach to pressure tank fabrication.

Weaknesses
- Need to address practical (cost, manufacturing …) issues as well.
- The poster slides were hard to follow.
- High risk.
- Budget slide unclear.
- Almost no confirmation work to date.
- Not clear this approach can be implemented in a manufactureable tank, the attachments of thousands of struts to each other and to the tank wall will be a huge challenge.
- Ideas not presented clearly.
- Collaborations appear to be with universities.
- Not focused (but this may be good if you want innovation).
- Many uncertainties in proposed tank fabrication.

Specific recommendations and additions or deletions to the work scope

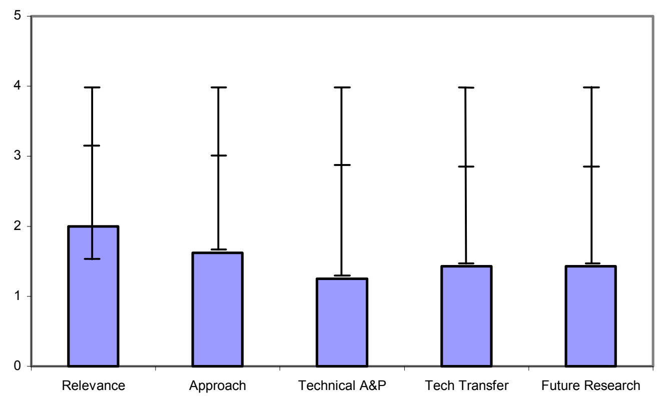
- Cost is the key in these carbon tanks, and they need to stay focused there.
- Tank manufacturers should be encouraged to interact with LLNL to develop plans and concepts for prototyping these structures.
- Would benefit from some early experimental work to confirm concepts and identify practical barriers to implementation.

Project # ST-P3: Fuel Cell and Hydrogen Research
Stefanakos, Lee; University of South Florida

Brief Summary of Project

This multi-faceted University of South Florida project will investigate several hydrogen production techniques: hydrogen storage in the areas of transition metal hydrides; nano-structured materials (nano-composite conducting polymers), and components designed for manufacturability; electrode improvements; water and thermal management; and a testing facility for fuel cells; and a demonstration project using solar power to generate hydrogen for storage and conversion. **This is a new Congressionally-directed project, started in 2004.**

Overall Project Score: 1.55



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- For the hydrogen storage part, it was not clear what they are doing. No answers to the questions given.
- Much of the money in this storage program goes to production and use, which does nothing to further storage.
- Traditional hydrides are highly unlikely to meet anything but the 2005 goals.
- Given the late 2004 start, that is aiming too low. Conductive polymers are dubious but worth diagnostic study – it is not clear this study will really tell if the class has a future.
- Packaging research is relevant.
- Looking at several relevant projects. Many are unrelated to storage. Production projects should be funded in that program - not storage.
- $MgFe_2H_6$ is "well-plowed" ground. What new is the team going to do?
- This project has components that by title alone are relevant to the DOE effort. However there is no coordination evident with any of the DOE projects.
- Collection of about 8 individual projects at various institutions.

Question 2: Approach to performing the research and development

This project was rated **1.62** on its approach.

- Not clear what they are doing and how the barriers are addressed.
- Little information.
- Storage approach appears not to comprehend FreedomCAR goals.
- The material of choice $MgFe_2H_6$ has effectively no chance of meeting the system goal of 2 kWh/kg.

- The methods to improve performance were not well understood by the presenter, and catalysts seem to be essentially a guess based on weight or benefits in the alanate system, which is functionally quite different.
- The polymer work seems only likely to work at low temperatures, but this was not in the plan as stated.
- Project needs focus. Dollars spread among lots of unconnected projects. Work appears to duplicate work going on in other DOE programs. No indication of how these projects differentiate themselves from others.
- The approach is poorly defined and lacks detail. It appears to be all things to all people.
- Management challenge.
- Excellent PI and lead at other university.
- Project way too broad.
- Storage materials approach not likely to lead to improved performance.
- Some of proposed storage materials have been thoroughly studied previously.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **1.25** based on accomplishments.

- Not sure if any work was done.
- Little information.
- Program not yet started.
- New Project. No work done yet.
- No results were presented.
- Not yet started.
- New project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.43** for technology transfer and collaboration.

- Significant partner network planned, the reality is unknown as the work has not started.
- Appears to be little or no plan for collaboration outside this group of universities.
- Collaboration outside of the Florida schools is not evident. They appear to be operating in a vacuum.
- Not yet started.
- Only interactions are within group partners.

Question 5: Approach to and relevance of proposed future research

This project was rated **1.43** for proposed future work.

- The outline plans are unclear.
- Too wide.
- No focus.
- Lack of specificity.
- Planning is complete but not compelling.
- Much too much of the storage money is planned for non storage work.
- System goals unlikely to be met.
- Vague statements about future research that relates to the DOE targets and objectives.

- Not yet started.
- Examining some potentially good material candidates but low probability of success.

Strengths and weaknesses

Strengths
- Partner network is good.
- Some experience from prior NASA H_2 work.

Weaknesses
- Lack coherency and focus.
- Too wide an objective and scope.
- Weak partnership.
- Low chance of meeting goals with systems planned as stated.
- Too many projects. Little focus. Don't know about expertise of PIs in this area. Projects unrelated to storage.
- Scope of overall project huge partners in project likely not large enough to complete even one part and certainly not all parts.
- Poorly defined program.

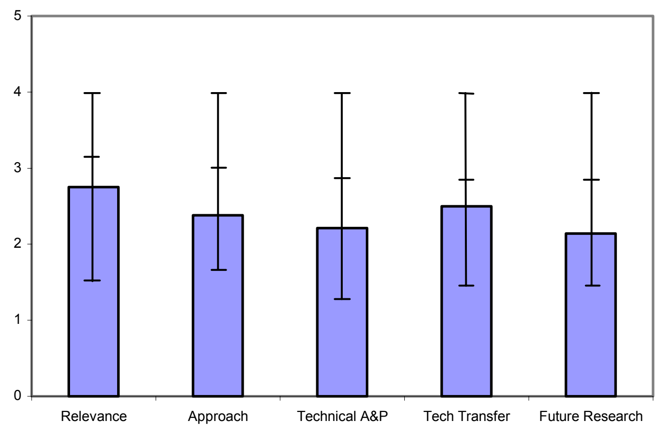
Specific recommendations and additions or deletions to the work scope

- Needs to narrow scope.
- Needs to be rethought and integrated into the overall plan with objectives more aligned with storage and more likely to succeed.
- Focus project. Eliminate the production work and collaborate with experts in storage.
- Allow them to choose balance of projects (DOE wants them to focus mainly on storage - but they have limited experience there compared to your other storage contractors.)
- Choose one strong area and focus on it. Production? Fuel cells? Demonstration? Storage: No!

Project # ST-P4: Development of Complex Hydride Hydrogen Storage Materials and Engineering Systems

Ritter, James; University of South Carolina [Ralph White overall project PI]

Overall Project Score: 2.40



Brief Summary of Project

In the area of engineering systems research, the University of South Carolina will develop 1-D, 2-D and 3-D models for metal and complex hydride hydrogen storage systems, calibrate models using Savannah River National Laboratory's (SRNL) metal hydride hydrogen storage system, and develop a user friendly software package for metal hydride hydrogen storage system design optimization and scale-up. In the area of materials research the group will: study the effect of metal dopants, proprietary additives, and Al powder on dehydrogenation and rehydrogenation of $NaAlH_4$; compare dehydrogenation kinetics of un-doped and Ti-doped $NaAlH_4$, $LiAlH_4$, and $Mg(AlH_4)_2$; and initiate Raman and other spectroscopic and molecular modeling analyses for fundamental understanding of dopant and other additives. **This is part of a new Congressionally-directed project funded in 2004.**

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- How is this project different from others?
- Both improvement of materials and improved engineering are important goals. The work seems to trail others in the field. It will be important for this program to be interlaced with the Sandia based Center so that this work is focused on objectives not covered already (UTRC contract) or concurrently.
- Modeling work looks interesting. Not sure whether experimental work duplicates other DOE work.
- Reversible metal hydride systems do not meet the DOE performance targets. New materials are needed.
- Some good modeling and hydride characterization.
- Focus on complex hydrides is good but other work in this area has better chance of success.

Question 2: Approach to performing the research and development

This project was rated **2.38** on its approach.

- Not sure what's new or innovative. The alternate complex methal hydrides are not very promising.
- The work outlined has been done elsewhere in part, and is planned in a much deeper and broader fashion in the Complex Hydride Center. The work is adequately designed, but is not as ambitious as

other work in the same field. Engineering effort is attacking more of the correct issues (predicting, measuring, using transfer properties) but the geometry is not very ground breaking.
- Interesting results for additive, but need more info. If patent is pending, why isn't composition given. IP should be safe if patent application has been filed. Model for actual devices is good tool. Should be made available to researchers in other groups.
- The approach lacks detail. Much appears similar to the work at Sandia National Labs.
- Some prior experience from DOD project.
- Combined theory- experiment is good. Addresses both material synthesis/performance and engineering properties.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.21** based on accomplishments.

- Comparatively not much progress (as compared to others in the field).
- Progress good for the amount of manpower applied, the challenges have not been especially stiff to date though. Progress reported is not cutting edge any more.
- Good results on additive and model.
- Not a lot of funding. Confusion as to when the project began-slides indicate 06/06. Assume it is 06/04.
- Hasn't started yet.
- Good modeling effort on tank design.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Good contact with National Lab and other fields.
- Suitably connected and aligned with goals.
- Reasonably good collaborations with the notable lack of interaction with Sandia.
- Good list of collaborations. Haven't started yet.
- Good list of collaborators.
- Need to insure that the modeling and other work is integrated into existing projects in this area.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.14** for proposed future work.

- It is not addressing the important issues and practicality of the proposed storage system.
- Again, the work proposed is already underway elsewhere. The plans are suitable, they simply are not new.
- Would like to see results from systems design using model. Info on additive should be made public.
- Vague statements for future plans.
- Too early.
- Proposed research overlaps other efforts. Modeling of Al foam insert not generally relevant.

Strengths and weaknesses

Strengths
- Team seems to understand the problems. Team is doing good work
- Heat and mass transfer model. Needs to be made available to others.
- DOD experience.

Weaknesses
- Work is not adding much to the knowledge base, though it does confirm the results of others, which has some value.
- Not enough information given on additive to make judgment.
- Not chosen by competitive solicitation.
- Hasn't started.
- Overlaps other complex hydride projects.

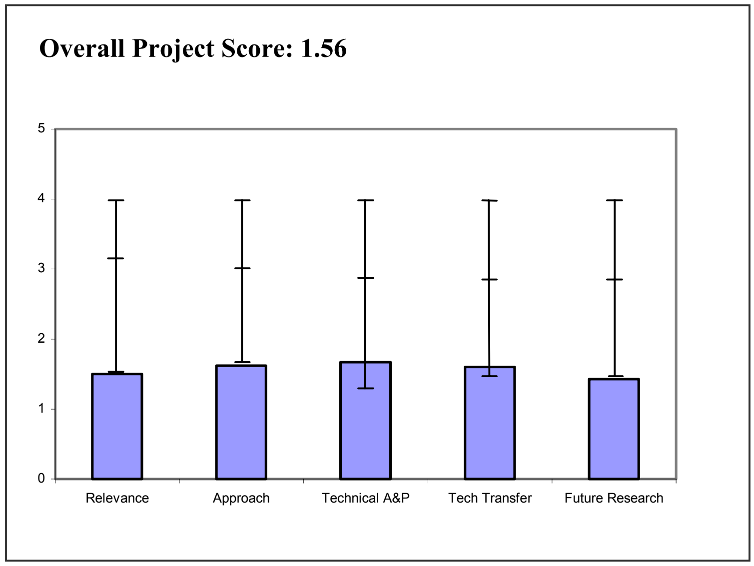
Specific recommendations and additions or deletions to the work scope

- See if some of the effort could fit in the Sandia National Lab center effort.
- Coordinate with hydride center or be part of the center.
- The heat management models are a unique and important contribution to DOE's research. This modeling work should be encouraged, and DOE should insure that these models will be publicly available to other researchers during and after the duration of this project.

Project # ST-P5: Advanced Manufacturing Technologies for Renewable Energy Applications
Ryan, Chuck; National Center for Manufacturing Sciences

Brief Summary of Project

Working with DOE and the private sector, the National Center for Manufacturing Sciences (NCMS) will (1) identify and develop critical manufacturing technology assessments vital to the affordable manufacturing of hydrogen-powered systems and (2) leverage technologies from other industrial sectors and work with our extensive industrial membership base to do feasibility projects on those manufacturing technologies identified as key to reducing the cost of the targeted hydrogen-powered systems**. This is a new Congressionally-directed project, started in 2004.**



Question 1: Relevance to overall DOE objectives

This project earned a score of **1.50** for its relevance to DOE objectives.

- At present the program has essentially no goals other than to find some work that might be worthwhile to do, and then do it. As such it is impossible to say of what value the program will be to anyone.
- The relevancy with H_2 storage is missing.
- As a hydrogen storage program this project will not be economical in that much of the money will be spent on fuel cells and other, non-storage research. This funding should come through fuel cells, not hydrogen storage.
- This process is essentially duplicative of the DOE program and wastes effort in that duplication. It also circumvents the peer review process in funding selection.
- Little relevance to DOE programs. No storage focus.
- Assuming fuel cell developers have manufacturing issues and are willing to share them with NCMS, there may be some relevance to the DOE program. However, there is no guarantee that the developers will interact with NCMS.
- Cost is ultimate issue.
- Redundant to DOE program management.
- Huge amount of funding for a project with no connection to DOE hydrogen storage goals.

Question 2: Approach to performing the research and development

This project was rated **1.62** on its approach.

- Not clear what is considered as barrier with objectives.

- While the technical aspects of the approach can not be appraised since the work is not laid out yet, they are stating that they will seek input on the areas needing research and then do work there, which is at least good.
- Design and feasibility are unknown, and again, no program should be funded that has so little definition beforehand.
- No prior H_2 expertise.
- Likely spending money to train recipient rather than generating useful information.
- The approach is similar to past efforts at NCMS and depends to a large extent on the skill of NCMS to develop projects that will attract investment from the private sector in projects attacking common problems.
- Project has not started.
- Collaborations and components/systems have not been selected.
- Proposed work has already been done.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **1.67** based on accomplishments.

- No accomplishments because they have not started, but in addition at this point they have no programs defined.
- New project.
- The project is due to begin on July 1.
- Project not started.
- No work has been done.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.60** for technology transfer and collaboration.

- Again, there is little clear direction at this time. It appears many teams will work in a coordinated plan, that aspect is good if it is fulfilled
- None yet.
- Yet to be determined.
- Project not started.
- Project is simply one of coordination; not collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **1.43** for proposed future work.

- Hard to judge what the plans are.
- Essentially no plans at present.
- Not obvious that recipient has skills, relationships, or experience needed. Don't see how this fits into storage portfolio.
- Needs to be defined.
- Proposal does some of this.

Strengths and weaknesses

Strengths
- Large group of players, and much industry participation, which could lead to development of a supplier base.
- Good firm - lots of manufacturing experience.
- Turned in safety 1-pager.

Weaknesses
- Difficult to place this program in context of H_2 storage.
- No plan.
- No obvious expertise in the area of hydrogen.
- Hydrogen storage money is apparently planned to be spent only in part on hydrogen storage.
- The project seems a bit premature. The fuel cell industry is still trying to develop technology that can demonstrate the durability required for the intended applications. When they do, the technology may well look considerably different than envisioned today. Manufacturing solutions developed today at NCMS may not apply to the technology that is ultimately fielded.
- This project does not help the hydrogen storage team reach its targets.

Specific recommendations and additions or deletions to the work scope

- Need to narrow the scopes on barriers or develop infrastructure.
- Use existing DOE assessment of the needs, avoid the redundancy of a second appraisal of needs.
- This program should be funded only after it has a clear set of projects that meet DOE goals if they are fruitful.
- Get OEM auto manufacturers involved.
- Delete entire project.

Fuel Cells

Summary of Annual Merit Review Fuel Cells Subprogram

Summary of Reviewer Comments on Hydrogen Fuel Cells Subprogram:

In general, reviewers agreed that the projects covered the appropriate technology areas and were clearly focused on addressing key technical barriers and meeting program targets. Reviewers applauded the program's use of go/no-go decisions in project management and recommended that all projects incorporate these as part of their work plans. They also emphasized the importance of establishing cost and performance targets that are *customer-based*. The reviewers recommended increased emphasis on high-risk, high-payoff R&D to achieve scientific and technical breakthroughs. In particular, they recommended high-risk work on novel new materials and catalysts.

Several reviewers questioned the funding of industry-led projects that appeared to support product development that would provide benefits to only the funded company. There was concern that a significant portion of the results would be proprietary and therefore not benefit the industry as a whole. In this regard, these reviewers recommended increasing funding to universities and National Laboratories for collaborative R&D with industry, and decreasing funding to industry-led projects. Reviewers repeatedly emphasized the critical need for researchers to work in close collaboration with technology developers and manufacturers for identification of requirements and testing.

Reviewers stressed the importance of fuel cell component durability and the need for longer-term (> 1,000 hours) tests for materials. In this regard, reviewers recommended that, wherever possible, projects should incorporate component/material durability tests (with identification of failure mechanisms) under operating conditions defined by OEMs or system developers. More testing of materials and fuel cell systems under "real" conditions is needed to gain a better understanding of the effects of fuel and air impurities and other environmental stressors on fuel cell performance. In related comments, reviewers agreed that demonstrations are extremely important to facilitate technology commercialization and to gain hand-on experience in real-world applications.

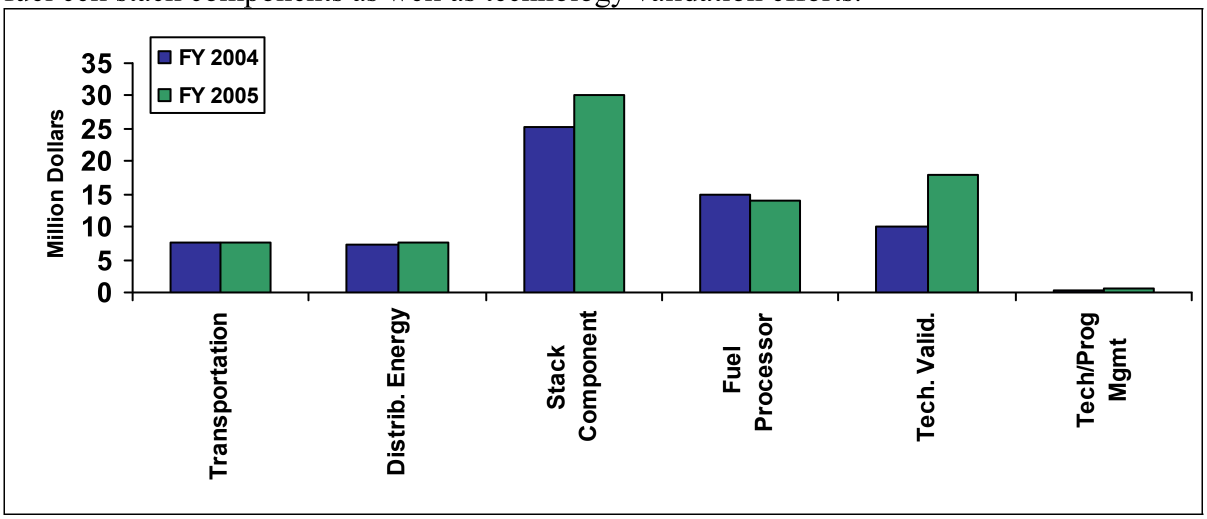
The reviewers were generally critical of continuing further R&D in support of on-board reforming, and were encouraged by DOE's go/no-go review of this research area. In August 2004, DOE announced its decision to discontinue funding of on-board fuel processing R&D based on extensive technical evaluation of the status, progress, and potential of on-board fuel processors.

To evaluate similar projects (especially materials, membrane and catalyst projects), reviewers recommended that the principle investigators present their results using common metrics. Reviewers also suggested a systematic, integrated approach to screening and evaluation of novel materials and catalysts to facilitate the comparison of results.

Reviewers agreed that cost modeling is an absolutely necessary activity to provide an independent assessment of the likely cost of PEM fuel cell technologies. And finally, several reviewers found that the level of funding for portable applications is very low, and suggested that the funding level be improved if DOE intends to support meaningful work in this area.

Fuel Cell Funding by Technology:

The fuel cell program contributes to the President's Hydrogen Fuel Initiative and to the DOE goal for energy security by supporting research, development, and technology validation activities that address stationary, transportation, auxiliary power unit, and portable power applications, including fuel cell stack components, fuel processors, and balance-of-plant components. The President's 2005 Budget Request (subject to Congressional appropriation) addresses the National Academy's Report recommendations and provides greater emphasis on fuel cell stack components as well as technology validation efforts.



Majority of Reviewer Comments and Recommendations:

- **Materials Research:** New materials for improved fuel cell stacks and system components and lower costs are essential. Put more effort into identifying materials that are stable at high temperature rather than optimizing materials that are unlikely to be stable at high temperatures.
- **High-Temperature Membranes, HTM:** Develop common metrics/requirements for HTM and their stability/durability for easy comparison. Understand water transport and water freezing behavior. Look at performance at lower temperature which reflects start and warm-up conditions (60-80C) and at low-humidity testing. Development of high-temperature MEAs is critical and supports RD&D plan objectives.
- **Improved Catalysts:** Continue developing non-platinum or low-platinum catalysts to reduce fuel cell cost. Investigate long-term catalyst durability. Identify approach to develop mass production processes.
- **Low-Cost, High-Durability Membranes, MEAs:** Focus on higher-temperature systems. Address robustness of MEA. Improve understanding of MEA failure mechanisms.
- **Balance of Plant:** Start-up time/energy, durability, and scale-up are important considerations. Fuel processor tolerance to high sulfur/CO/coke is crucial. Balance of plant is dependent on stack design and drive cycle requirements. Sensors—consider mechanical

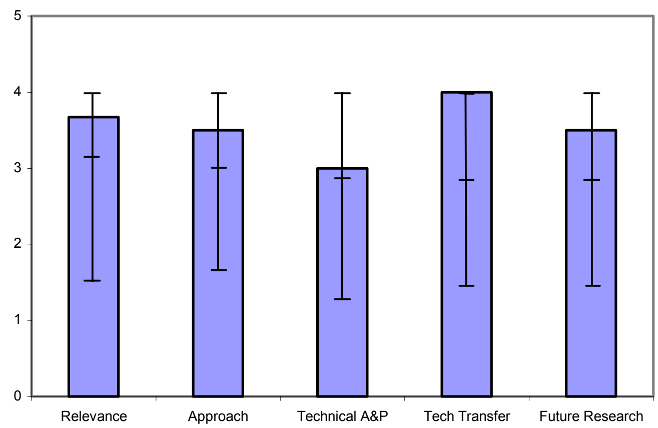
strength, tolerance to occasional exposure to fuel and air impurities, and how to incorporate into fuel cell platform. Low-cost, durable, lightweight, and compact air delivery machines are key to viable fuel cells. Microchannel reactors offer size and cost reductions.

- **Analysis:** Thermal/water management and HTM are critical areas. Models help set development approaches and identify key parameters. Ensure key analysis assumptions are based on industry input. Extend analyses to real-world operation to further guide technical targets and work.

General comments for the fuel cell program included: 1) understanding the requirements of the auto industry for fuel cell system and individual components as well as impact of real world conditions on performance; 2) long-term durability/performance is a critical barrier to commercializing fuel cells; and 3) National Laboratories, universities and other organizations should work with a few non-proprietary systems to enable open publishing of results to benefit the entire fuel cell community.

Project # FC-1: Fuel Cells Sub Program Review
Davis, Patrick, DOE, Team Lead; Nancy Garland, DOE, Presenter

Overall Project Score: 3.53



Brief Summary of Project

The purpose of this Fuel Cells Subprogram overview is to describe subprogram goals/objectives, budgets, barriers/targets, approach to R&D, technical accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and put into context the R&D and analysis projects, which will be presented in this subprogram area during the Annual Merit Review.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.67** for its relevance to DOE objectives.

- Fuel cell research is key to accomplishing the President's Initiative. The fuel cell program is well aligned towards meeting the challenges. The area of on-board reforming is probably a weakness in that it is not a good "bridge" technology until an infrastructure is developed. It is encouraging that the viability of this will be evaluated in June '04 , so further significant expenditures in this area can be avoided.
- Perhaps could have emphasized other go/no-go decisions (not just the on-board fuel processing) a bit more, as such decision points are now becoming normal operating procedure.
- Presentation was delivered along technical difficulties and was a bit hard to follow; otherwise good description of activities.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- This program is definitely focused on addressing the key technical barriers for implementation of fuel cells.
- Cost goals Direct HFC and Reformed HFC system. Systems are same at $45/kW. This is a mistake and distorts decision making. RHFC should allow higher cost since DHFC needs infrastructure.
- Good job of balancing desires of industry with long-term science needed to truly advance technology.
- Challenges adequately identified and discussed. Approach: "focus on high risk R&D" does not happen. Team is very conservative, funding traditional approaches from groups who have been funded by DOE for years. The bulk of funded efforts (>75%) are "same old" work.
- Need more rational approach for screening/directing evaluation of novel materials. Each program has similar goals, but no common figures of merit to compare results.
- This program has demonstrated very high standards on facing challenges and implementing go/no-go decisions.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Progress is generally very, good, but slow progress in certain areas such as cost and durability highlight the significance of how challenging the technical barriers are. It is important that targets are "customer based" if the President's Initiative is to be successful.
- Progress is good but breakthrough required - high-risk, high-payoff research must receive appropriate funding/priority.
- Efforts in portable systems ("consumer electronics") are ridiculously inadequate, almost to the point of being a distraction. Why are there still any efforts in on-board fuel processing? No auto company today is considering this approach!
- It is very well focused and is constantly re-evaluating the challenges, targets -- and addressing them. Managed very well and in a very effective manner.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **4.00** for technology transfer and collaboration.

- Inclusive and extensive R&D network established.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.50** for proposed future work.

- Future research should focus away from on-board reforming, with additional emphasis on stack durability and cost reduction of the entire fuel cell system.
- Very good plans - need to make sure they are living documents. Coordination with SC program important.

Strengths and weaknesses

Strengths
- This program has a strong tech team that has a high level of expertise and a good understanding of the challenges.
- Program has been up and running for several years. Targets and approach have been continually refined based on research findings and policy/market forces.
- Most of the funding to industry supports product development that will primarily (in some cases only) benefit the individual company. These efforts are not R&D, but pure and simple product development. This is grossly unfair, particularly since VERY few new companies are funded. I recommend increasing University and National Lab funding and decreasing or better ending funding to Industry for R&D. The only exception should be specific and defined demonstration projects.
- Would like to express appreciation for the work Valri Lightner has done as project manager -- very efficient, analytical, and responsive.

Weaknesses
- Sound system - well you knew that!

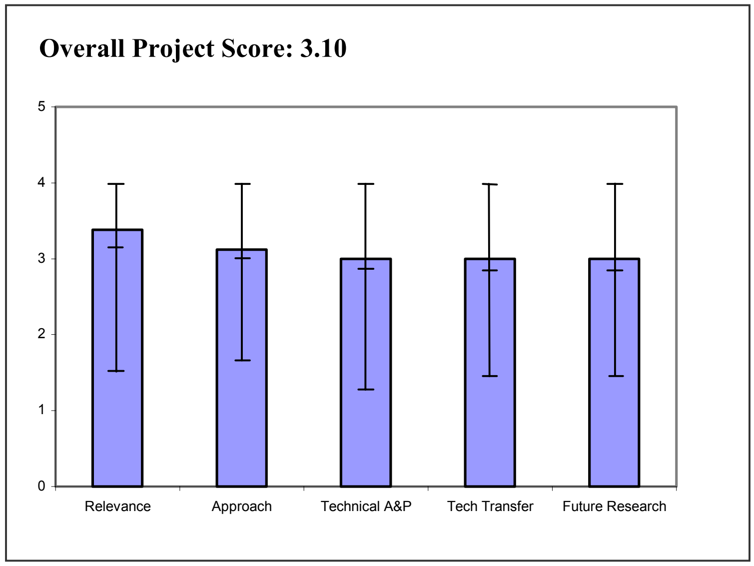
Specific recommendations and additions or deletions to the work scope

- The program should move away from on-board reforming
- In the mix of academia/national labs/industry, I think DOE's FC programs should have a little more emphasis on academia, or academia and National Lab will need long-term commitment to get new people or academic and industry partnership. More academics should be engaged in materials research. More inorganic chemists working on non-precious metals ORR catalysts. More on CU biomimetic. More on MeOH oxidation catalyst. More synthetic organic chemists (academic) engaged on polymer electrolyte. Ideally more funding, but take from industry allocation if necessary.
- Presentation offered good overview. Well managed program.

Project # FC-2: Integrated Manufacturing for Advanced Membrane Electrode Assemblies
DeCastro, Emory; De Nora North America

Brief Summary of Project

De Nora North America and its team are (1) developing new cathode alloys and ELAT structures that allow an overall cell performance of greater or equal to $0.4A/cm^2$ at 0.8V or $0.1A/cm^2$ at 0.85V operating on hydrogen/air with precious metal loadings of $0.3mg/cm^2$ or manufacturing technology; (2) developing a membrane which operates at 120 C and 25% RH; and (3) taking advances from (1) and (2) to integrate into pilot manufacturing, aimed at delivering a 1-5kW stack with performance consistent with the previous objectives.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.38** for its relevance to DOE objectives.

- Although operation of a fuel cell at 120C is the overall goal of the high temperature membrane activity, the fuel cell will need to operate at a range of temperatures throughout the drive cycle. As such performance at 80C, 50C, and 10C should also be reported.
- Project team has a thorough understanding of PEMFC science and the requirements for commercialization.
- The project appropriately addresses electrode and membrane performance and durability which are the keys to commerciality of fuel cells.
- The cathode catalyst and structure work is directly aligned with DOE cost and performance goals.
- Lower Pt loadings will contribute to lower material costs.
- The project is clearly focused on problems of critical importance to the achievement of the cost and performance goals necessary to develop practical fuel cells. The work targets two of the most difficult barriers, namely low cost catalyst electrodes and new membranes capable of high temperature performance.

Question 2: Approach to performing the research and development

This project was rated **3.12** on its approach.

- The approach for high temp membrane development is good. Electrochemical stability should be evaluated. It is not clear that new technology is being developed in the cathode catalyst activity.
- The project and the sub-contractors are well coordinated.
- The approach is well-focused.
- Ink-based approach seems to be promising and unique.
- Approach to catalyst and structures good. Gradient control during materials fabrication should help optimize the system.
- No new catalyst was reported. It is not clear whether IBAD will be useful for catalysts/preparations because the loadings are too high.

- The researcher should try to develop other material than carbon-based GDLs.
- This is a well integrated program containing electrode, membrane and stack development so that feedback can occur from the exploratory or material work to the scale-up. It is a concern that the membrane work is high temperature and the electrode work is low temperature. The connection of the high temperature membrane work to the electrode development appears to be absent and needs to start.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Monomer selection is good.
- Good progress is being made in very complex inter-relationships between performance, durability, and cost.
- Catalyst work appears close to target, but it is unclear if this is superior to other state-of-the-art electrocatalysts. Hi-T membrane work shows promise.
- Some results are at a very early stage and hard to evaluate. The project shows improvements over time.
- Extension of fine gradient approach to electrode an important accomplishment. "Machine fabbed" alloy ELAT is a step forward.
- Good progress in lowering Pt loadings (particularly in the anode). Results provide scientific understanding of material performance. Durability tests are needed.
- It is a little difficult to measure progress in the membrane area with the alphabet soup of classifications, specifically, it is difficult to evaluate if the chemical and structural features of the membranes that lead to successful materials are being fully explored. The low loading catalyst work is making progress but not fast enough.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Good coordination between the various participants is evident.
- Very good multi-disciplinary approach. Good/excellent private industry - university collaboration. A little better explanation of how all the various parties contribute, where the work lies on the critical path etc. would be helpful.
- Work is being published. Patent applications filed on polymer electrolytes.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Add ex-situ catalyst durability testing.
- Would like to see more measured results reported, especially with short-stack testing.
- The project should not focus on broad questions of the structure-function relationships in catalysts.
- Focus part of the effort to improve Pt (or catalyst) utilization.
- Future work looks fine but need to co-ordinate the new high tech membrane work with the electrode work, particularly with respect to understanding how the membranes interact with the electrode's surfaces and particles. The modeling will need some base data and the work needs to show more of the polymer characterization e.g. rheology, dielectric etc. For example, the case shown when the unfilled membrane fails and the filled one does not, can be easily explained by increase of Tg above

the test temperature due to presence of the filler. Basic rheology test would have shown this. Please make sure the polymer people are talking (and listening) to the electrochemists and vice-versa.

Strengths and weaknesses

Strengths
- Excellent overall technical approach.
- Very strong integrated multi-disciplinary team and it is being well coordinated.
- Membrane development activity is good.
- Fine-gradient electrode and GDL work is well done and could be a significant advance.
- Attention to the appropriate fuel cell components is made and effort is expended at reasonable levels for all aspect of the work flow from basic understanding to stack building.

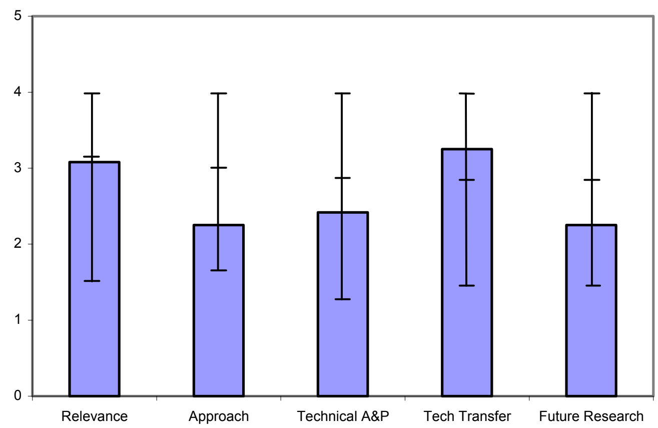
Weaknesses
- Progress could be improved.
- Need more information on catalyst durability/stability.
- Both catalysis and membrane tasks are too diverse.
- No information was reported about the stability of Pt alloys.
- The program might be becoming a little difficult to coordinate. Many players on-board and the review needs to emphasize better how all the participants play in the program.
- Weakness to be addressed is the incorporation of the new membranes into the electrodes. Need to understand mechanical needs as well as thermal and chemical needs. One would think that the chemical instability issues would be at the most severe in the electrodes, so some work with the new membranes in this mode is critical.

Specific recommendations and additions or deletions to the work scope

- CCM and other electrode approaches should be considered to enhance membrane performance.
- 0.4 A/cm^2 is the quarter-power target for the cathode catalyst development activity. Continue to test and report results at higher current densities which will be required to achieve catalyst and membrane cost targets. "GM Format" is an appropriate way to show this.
- Acquire and report data at 80C, 50C, and 10C to reflect automotive conditions. Membrane will likely be saturated at lower temperature conditions.
- New membranes into the MEAs urgently needs to be done.

Project # FC-3: Development of High Temperature Membranes and Improved Cathode Catalysts
Meyers, Jeremy; United Technologies Corp.

Overall Project Score: 2.65



Brief Summary of Project

In the area of high-temp membranes United Technologies Corp. (UTC) Fuel Cells is optimizing candidate membranes for operation at 120C, 50% relative humidity (RH) and characterizing membranes for suitability in high-temperature fuel cells including ex-situ testing (conductivity at various humidity; water uptake; tensile strength) and in-cell tests (performance at 120C and 50% RH, 1.5 kPa; 100 hours stability tests; fuel crossover; elemental analysis of the exhaust water). For improved cathode catalysts, they are selecting the most promising alloy catalysts for evaluation in fuel cells, optimizing fabrication processes, conducting testing to evaluate performance and stability (in liquid cell), and comparing performance of submitted catalysts to that of TEC10E50E (TKK's 46.7% Pt/C).

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.08** for its relevance to DOE objectives.

- All aspects of the project are relevant to DOE goals and objectives.
- High temperature membranes are critical to reducing heat exchanger size and reducing balance of plant needed for water management and CO reduction. Catalyst work important for cost reduction.
- Fuel cell operating condition is unique and different from DOE/FreedomCAR requirement. 120C 25% RH is appropriate.
- Project team understands important issues.

Question 2: Approach to performing the research and development

This project was rated **2.25** on its approach.

- There is insufficient recognition of low-humidity requirements for high temperature membrane testing.
- High temperature membrane and catalyst research areas require fundamental development. UTC's approach of evaluating materials from other organizations leverages their expertise in MEA synthesis and fuel cell testing, but does not necessarily direct sufficient fundamental analysis to each material regarding failure modes.
- High temperature membrane down-selected but target wasn't achieved.
- Not developing new polymers, just testing polymers from others. Appears to be a "bench marking" effort. Alloys for catalysts tested are well known in the literature.
- Catalysis work is realistic and the strong point of this project. More emphasis is needed on utilization issues.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.42** based on accomplishments.

- The catalyst loading of the alternative catalysts is not clear. A direct comparison of the alternative catalysts is present only in table and not on performance curves.
- Results presented relative to industry benchmarks not against DOE goals. Catalyst shows greater activity but Pt/C not plotted on durability or performance plots.
- Need to explain why TKK catalysts shows good performance.
- All the membranes evaluated are well known as are their strengths and limitations.
- Strong, clear presentation.
- Membrane down-select yielded very disappointing results.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Team includes industry and university participation as well as UTRC. There is National Lab involvement although small.
- UTC evaluated materials from a range of research organizations, leveraging the resources of Phil Ross's laboratory.
- Not working with companies that will really commercialize these materials as MEAs, e.g. Gore, Dupont or 3M.
- Well-coordinated multi-party effort.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.25** for proposed future work.

- Membranes have been down-selected for further work.
- Next steps in membrane area appear to represent new starts with introduction of composites and ionic liquids. Catalysis work builds on existing work. Presentation did not show connection between next steps and past work.
- Need to investigate durability of alloy catalyst. Project goal and approach should be reconsidered.
- There is no evidence presented that materials work should continue.
- Continuously benchmark the result so as not to lose focus.

Strengths and weaknesses

Strengths

- Leverages UTC experience in building, testing and evaluating fuel cell stacks. Evaluates advanced materials in near atmospheric pressure stack technology.
- Catalyst analysis activity.
- Stack and system testing and design.
- Strong team and well integrated.

Weaknesses

- Lack of low-humidity membrane testing.
- Causes of failure and lower performance of down selected membranes was not discussed.
- Lack of polymer chemistry and characterization, specifically conductivity testing.
- Half-cell testing is not necessarily reliable.
- Lacks new ideas.

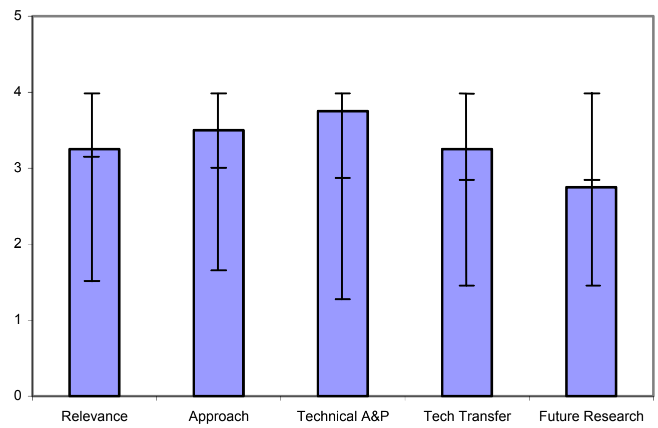
Specific recommendations and additions or deletions to the work scope

- Analysis of materials and sources of performance differences is not included. These activities should be added to advance science.
- It is not recommended to continue this project without meeting target at the technology down-selection phase.
- Scale down and/or end effort soon. We need new materials, not more tests on what is already out there.

Project # FC-4: Advanced MEAs for Enhanced Operating Conditions
Debe, Mark; 3M

Brief Summary of Project

Overall Project Score: 3.30



3M is developing high performance, lower cost membrane electrode assemblies (MEAs) qualified to meet demanding system operating conditions of higher temperature and little to no humidification, with less precious metal catalysts, and higher durability membranes than current state-of-the-art constructions. Objectives include: durable, lower cost MEAs for operation in the range of 85 < T < ~ 120C (develop next generation, thin film, ultra-thin layer catalyst electrodes (NSTE); optimize PFSA based ionomers modified for enhanced durability at low RH; match MEA components for enhanced performance under demanding conditions; utilize roll-good fabrication processes for lower cost) and development of MEAs for operation in the range of 120 < T < 150C (new PEM's that do not rely on standard modes of aqueous proton conduction); understanding relationships between materials, proton conductivity, T and RH; screening materials and fabrication processes.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Although operation of a fuel cell at 120C is the overall goal of the high temperature membrane activity, the fuel cell will need to operate at a range of temperatures throughout the drive cycle. As such performance at 80C, 50C, and 10C should also be reported.
- Misunderstanding of DOE/FreedomCAR requirement, of membranes 120C is high temp requirement and at the same performance as low temperatures should be targeted. Check DOE/FreedomCAR requirement. 120 to 150C development are not necessary.
- Development of high performance, low cost MEAs is critical.
- The project is focusing on two of the critical barriers of the Fuel Cell Program. The combination of basic research with development and manufacturing is excellent and can hardly be improved upon.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- Membrane approach is good. NSTE for catalysts is interesting.
- Task 1 is well thought out. Task 2 is good but does not seem as comprehensive as Task 1.
- In general - well thought, but a bit unfocussed.
- Good integration of the electrode and membrane aspects. Use of combinatorial methods is good for screening and provides progress. Perhaps a little more fundamental work may be needed to understand the direction that is leading. Good mix of academic and National Lab participants.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.75** based on accomplishments.

- Good performance, particularly at mass transport region.
- Good progress demonstrated in development of NSTF catalyst and membranes for 85<T<120C towards meeting project targets.
- Several valuable achievements.
- Progress in both catalyst and membrane development is very significant. Difficult to tell how soundly based is the understanding due to proprietary nature of the activity. Extent of the advances indicates good understanding of the technical problem and the science needed to solve them.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Good team of university/National Lab collaborators with excellent coordination.
- Several technical accomplishments are reported within this one project. Technology transfer and application are evolving.
- Roles the partners are clear and necessary. Management of activities is well organized.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Need to investigate the durability (automotive lifetime) of the catalyst alloy.
- A considerable amount of effort is focused on developing high temperature (>120C) membranes for stationary applications. Not sure all objectives can be accomplished.
- Like to see the polymer work explained more fully next time. It looks to be very interesting. Also this reviewer does not understand the no-ink part of the MEA fabrication. The polymer has to contact the electrode surface. Explain how this is done.

Strengths and weaknesses

Strengths

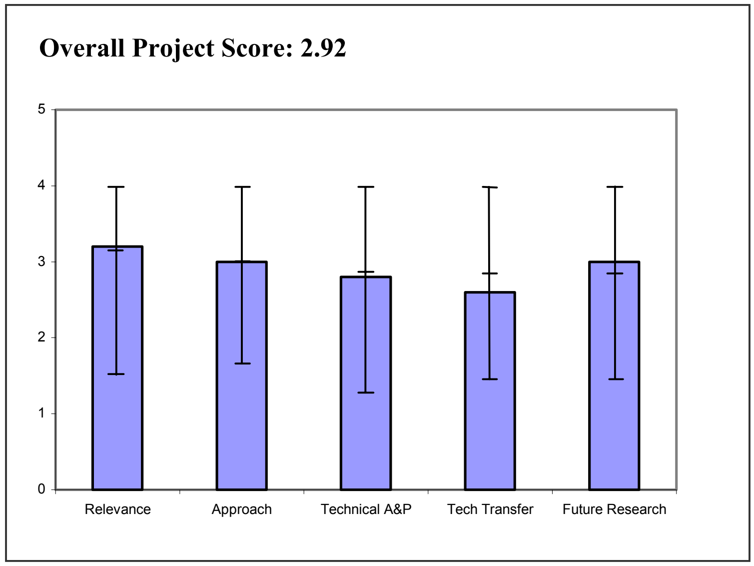
- Continue using LBNL as an independent 3rd party for validation. Verify the gain in specific activity of PtCA and PtCD.

Weaknesses

Specific recommendations and additions or deletions to the work scope

- MEA stability test should be conducted under conditions representative of automotive usage profiles. Longer chemical and thermal stability tests are necessary to verify automotive lifetime requirement.
- Continue making technical innovations available to third party industrial firms.

Project # FC-5: Development of High-Performance, Low-Pt Cathodes Containing New Catalyst & Layer Structures
Atanassova, Paolina; Superior



Brief Summary of Project

This is a four year project led by Cabot Corporation to develop and apply combinatorial powder synthesis platform based on spray pyrolysis for discovery of high performance low-Pt cathode electrocatalysts for PEM automotive fuel cells. This project will use the platform for electrocatalyst composition discovery and microstructure optimization under conditions that can be scaled for commercial powder production, and will deliver high-performance cathode electrocatalysts and MEAs with lower Pt content to meet the DOE target of 0.6 gPt/kW in 2005. Specific objectives include: completing the development of rapid testing equipment – DuPont Fuel Cells; starting high throughput synthesis of ternary alloy compositions in a discovery mode; further optimizing MEA electrode structure; testing long-term stability of new electrocatalysts; and delivering electrocatalysts and test MEAs to stack manufacturers.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Effort aligned with DOE cost, durability and performance targets.
- High volume manufacturing method could reduce catalyst cost.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Test conditions are clearly presented. Novel catalyst composition will be identified by combinatorial screening. MEAs with the novel catalysts will also be screened by combinatorial screening. The task progression is logical.
- GDL surface roughness is an issue. Consider using CCM approach for MEA evaluation.
- The approach needs to be confirmed by long-term tests of the catalysts produced.
- Not truly "combinatorial" method. Still must make "inspired" guesses about what metals to use.
- Rapid-throughout combinatorial screening and "production-capable" spray pyrolysis combine for strong approach.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.80** based on accomplishments.

- Many catalysts samples have been prepared and the equipment has been qualified. There is a clear comparison with Pt catalysts. Most of the samples exhibited better performance than Pt.
- Electrochemical data should be more clearly presented. Catalysts loading are still higher than DOE targets.
- Very limited results shown. Not clear how general spray pyrolysis method is used for catalyst preparation.
- Automatic catalyst/ink/MEA preparation up and running. Process uniformity is very good.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- Team includes GM and DuPont. No National Labs or universities were mentioned.
- Role of Dupont unclear.
- Interactions with mostly unspecified MEA developers, FC developers and OEMs reported.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- CSMP is logically holding to their plan.
- Need to investigate durability of catalyst alloy. Baseline for MEA optimization is too low.
- Development of rapid MEA screening system and combination with rapid-throughput catalyst preparation will be a significant accomplishment.

Strengths and weaknesses

Strengths
- Catalyst and MEA analysis testing.
- A useful tool for combinatorial synthesis has been developed.
- More catalyst optimization than "discovery."
- Approaching "production-capable" catalyst, ink and MEA preparation.

Weaknesses
- A lacks long-term verification of the test results.

Specific recommendations and additions or deletions to the work scope

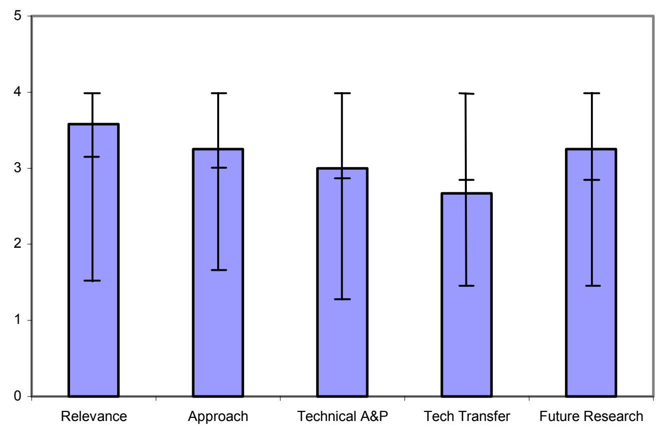
- GDL surface roughness could be an issue. Consider using CCM approach for higher quality MEA evaluation.
- Should focus more on optimizing catalysts known to have some promise using spray pyrolysis method. Increase effort in characterizing what is synthesized.

Project # FC-6: High-Temperature Membranes
Zawodzinski, Tom; Case West Reserve University

Brief Summary of Project

This Case Western Reserve University (CWRU) project is developing membranes for 120ºC minimally hydrated polymers to achieve H^+ conductivity approaching that of well-hydrated PFSAs at 80ºC. CWRU will also focus on new polymers and other scaffolds carrying sulfonic acids or other superacids with 25% RH at operating temperature as suggested by GM, and improve durability. CWRU will also focus on membranes for >150ºC operation which replace water with 'proton mobility facilitators' and non-volatile molecules to effect proton transfer.

Overall Project Score: 3.15



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.58** for its relevance to DOE objectives.

- High-temperature membranes are a key focus of DOE. Consideration of water freezing behavior in the membrane is important and fairly unique in DOE programs.
- This is among one of the most important also most challenging technologies to enable the PEM fuel cells in transportation (Low RH). It is very critical to support this kind of research.
- This program is driving down to the fundamentals of High-Temp membranes rather than just testing out new materials. High-temperature membranes could be game-changing for automotive and stationary products.
- Understanding the water transport mechanism is key!

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Understanding of functional structures is being developed by diagnosis and analysis, physical chemistry, and synthesis trial. The approach should provide basic insights for all HTM researchers. Techniques for augmenting proton/water conduction are being investigated.
- HT membrane development for this group is still at the stage of early exploration and screening. Degree of participation in HTMWG is not clear. The approach to HT membranes is very broad and covers many of the currently known approaches.
- The only team that is taking a molecular scale approach to rationally design the new material.
- Need to identify metrics for membrane and its stability (durability). Technical approaches well covered; present considerable technologies.
- A rational approach to high-temperature membranes. Very good approach to screening. Do not need FC demonstration/MEA optimization at this stage.
- Clearly addressed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Significant results are imminent.
- Excellent characterization techniques for proton transport were used including NMR and thermal analysis. Very limited performance data of fuel cells. No data at 120ºC or higher.
- The sweeping approach this team takes necessitates patience.
- Good work, unlocking limitations.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- With the exception of the High-Temperature Membrane Working Group and VA Tech, no collaborations are mentioned.
- The activities proposed are only limited to academic community. No collaboration with industrial FC developers.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- As far as membrane, MEA, and GDL are concerned, it is a right approach. However, no fuel cell tests were planned. Whether or not the HT membrane or MEAs are good or not relies on the fuel cell performance.
- Need to identify clear path to the goal.
- This is good effort laying the groundwork for future breakthroughs. Need to limit MEA fabrication/testing and stay focused on membrane characterization.

Strengths and weaknesses

Strengths
- The project includes approaches to develop a fundamental understanding of high-temperature membrane (conduction) processes with translation of the understanding to approaches to meet DOE targets. Upcoming work includes input from "new faces from the polymer chemistry community" outside of the fuel cell community.
- HT membrane materials synthesis expertise; some good material characterization techniques. Interesting proton transport studies by NMR.
- Very good grasp of the big picture; excellent job at educating the community about the challenges.
- Membrane and polymer analysis.
- Figures of merit for comparison of emerging technology (ion concentration vs. conductivity) = great way to compare and uncover fundamental limitations of chemistry.

Weaknesses
- No optimization or screening activities of HT membrane development are defined.
- Many results, e.g. conductivity, NMR relaxation were conveyed verbally; this makes the presentation very difficult to be appreciated. Need show more data, not more concepts. Timing/pace of the presentation needs be improved. Latter half has more substantial stuff, but is glossed over casually.

- Project management.
- Prematurely doing FC testing. Need figures of merit for chemical/mechanical stability. Common chart for all HTM projects. Membrane conductivity vs. RH and temperature, water uptake vs. RH and temperature, change in properties after immersion in boiling water.

Specific recommendations and additions or deletions to the work scope

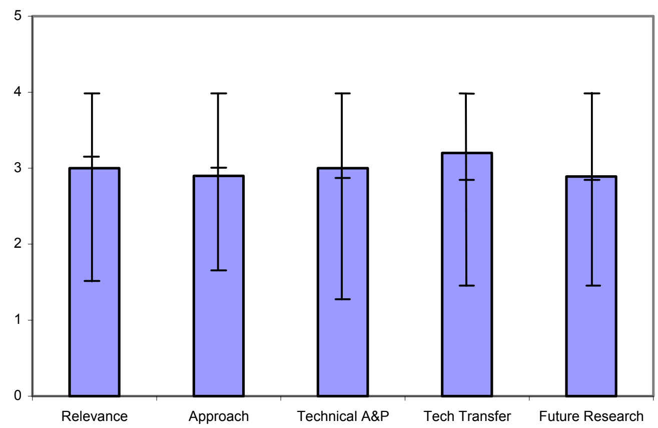
- The fundamental R&D should be continued. More focus on HT membrane developments instead of electrodes, GDL, etc.
- Need to convince people to continue to support this team by really demonstrating one system with tangible, superior results in the next reviews.
- This project is one of the most important projects for automotive FC development. Clear path to the project goal should be identified.
- DOE should demand common figures of merit for all HTM projects for easy reference. Drop MEA/cell testing. Progression should be: basic science, screening of polymers, screen of membranes, MEA fabrication and optimization, cell/stack demonstration.
- The approach to "design membranes" provides an excellent opportunity to overcome some of the obstacles.

Project # FC-7: Electrodes for Hydrogen-Air PEM Fuel Cells
Uribe, Francisco; Los Alamos National Laboratory

Brief Summary of Project

This project contributes to the DOE effort by developing an efficient, durable, direct hydrogen fuel cell power system for transportation. Specific goals of the project include: lower Pt-catalyst content in the MEAs, improved Pt-catalyst utilization, develop low-cost, high surface area support materials that either "replace" precious-metal supports or improve Pt activity for ORR, evaluate catalyst durability, evaluation of the effects of fuel and air impurities on FC performance, additional ways to mitigate negative effects of impurities, and continued collaborations with Industry and other National Laboratories.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- All aspects of the work are relevant. The effects of impurities on cell performance are important.
- Addressing the major issues limiting fuel cell application.
- Development of new materials may not be able to be done on budget effectively. Baseline testing is key capability and contribution -- durability and impurities.
- Objective of this project is unclear. Define clear objective, and it should be to develop "robust" electrodes/catalyst for automotive usage.
- Addressing the impurities issue is important. Validation and testing of new materials made.
- This is a very important program and it is generating very important data regarding PEMFC operation with gas contaminants and impurities.
- This effort on developing electrodes for hydrogen air fuel cells is absolutely critical for the realization of the initiative. It responds to the objective. It is a very thorough discussion involving much collaboration with other National Laboratories and companies such as DuPont, GM and UTC Fuel Cells.
- Determination of the effects of air and fuel contaminants on PEMFC performance is critical to the development of the technology.
- FC developers are already aware of most of these impurity effects.

Question 2: Approach to performing the research and development

This project was rated **2.90** on its approach.

- The results presented seem to be measurements of data taken of components (catalyst) prepared by others, such as Brookhaven National Laboratory. Approaches to making improvements are scarce.
- Systematic conventional approach.

- Life tests. Impurity effects and mitigation important, well done.
- Need to consider more systematic approach, such as design of experiments (DOE).
- Lots of important observations on separate topics. Needs more focus on one topic - migration or impurities and relative importance of each.
- The PIs are demonstrating that a successful PEMFC product must operate in the real-world where clean laboratory conditions do not exist.
- The technical barriers are outlined in terms of stacked materials and manufacturing costs, durability and electrode performance. Each was discussed in a logical manner.
- Excellent approach, overall. Effect of scrubbers for cleaning impurities from fuel or air should either be done thoroughly (i.e. effect on system size and complexity) or eliminated from project scope. Carbide supports will be oxidized at the cathode potential.
- Project objectives are too broad/diverse-need to rationalize.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- The data presented are important but resolution of the issues identified is not described.
- Significant progress in all areas but only obstacles identified.
- Progress on track with original milestones. Efforts on low cost catalyst support materials may not be most effective use of time by this group. Studies of electrode changes with time are excellent.
- Excellent findings on important topics. Round robin testing should produce important information on testing reproducibility.
- Progress seems too slow.
- The accomplishments were very good and showed the negative and irreversible effects of low SO_2 and H_2S levels on performance. Stability up to 1000 hours was demonstrated. Relatively low-cost small particle materials for supported platinum monolayers were demonstrated.
- Good information on impurities. Further measurements required. First-time someone talks about NaCl, great
- Much progress has been made this year, especially in the impurity area and in the collaboration with BNL.
- Results verified known problems - need to explore innovative alternatives to use of filters - undesirable for automotive application.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.20** for technology transfer and collaboration.

- The team includes universities, industry, National Labs, and the US Fuel Cell Council (USFCC).
- Catalysts made at BNL but generally not addressed.
- Some of the interactions listed were only presentations -- not serious interactions.
- Collaboration with BNL provides useful information.
- Many major players including the aforementioned DuPont, GM, UTC as well as several National Laboratories and universities were included in the technology transfer.
- The numerous collaborations and invited presentations attest to the high level of interest in this project.
- Collaboration with USFCC is valuable - industry needs test protocol for establishing/measuring impurity levels of H_2 specification because existing specifications are inappropriate.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.89** for proposed future work.

- Future work logically follows.
- More of the same.
- Most items listed are very specific and important and should be done. Continued formulation of new catalyst supports should be dropped - put resources on other items.
- Need to identify clear path to the goal.
- No slide with future work except the round robin testing - but was included in the printout.
- The PIs must get the message out to the developers that the PEMFC system must operate in the "real world" where gas contaminants and other impurities are present.
- The future work will further quantify the influence of SO_2 poisoning and cleaning and will further evaluate the low Pt content catalyst in long-term tests. Evaluation of Ru migration during long-term operation will be studied and the effort will participate in round robin testing of the new catalysts.
- The causes of ruthenium crossover should be determined (if DOE decides the fuel may contain CO i.e. reformate rather than "pure" hydrogen).
- Focus on establishing "mechanisms" of irreversible effects and degradation in long term tests.

Strengths and weaknesses

Strengths
- Systematic, highly resourced project. Progress made on identifying problems.
- Testing and MEA characterization are strengths that make sense, much more than materials development. Understanding performance decay processes.
- Electrode performance analysis.
- Addressing various aspects of the MEA durability.
- Fundamental sound and broad-based.
- Collaborations, fuel cell fabrication and testing capabilities and experience.
- Low Pt loading results are encouraging but need more long term tests with imposed variable load and temperature (both high and low) profiles (automotive drive cycles).

Weaknesses
- The effect of SO_2 is reported but methods to reverse the effect are not proposed. Using a filter to remove the SO_2 does not address means to deal with filter failure or breakthrough such as air bleed that is used to mitigate CO poisoning.
- Project doesn't seem to be evolving to useable, high performance fuel cells.
- Inadequate staffing or resources to actively pursue new materials development. Rate of progress and ability to relate properties to scale-up processes will be lacking.
- Process.
- Can benefit from more focused systematic study on effects of one factor that is considered to be most important.
- Some conclusions represent too much the scientific side -- e.g. a SO_2 filter means an extra part for the FC system - adds more complexity.
- Need more focus on long term > 1,000 hr impurity effects - not just short term performance.

Specific recommendations and additions or deletions to the work scope

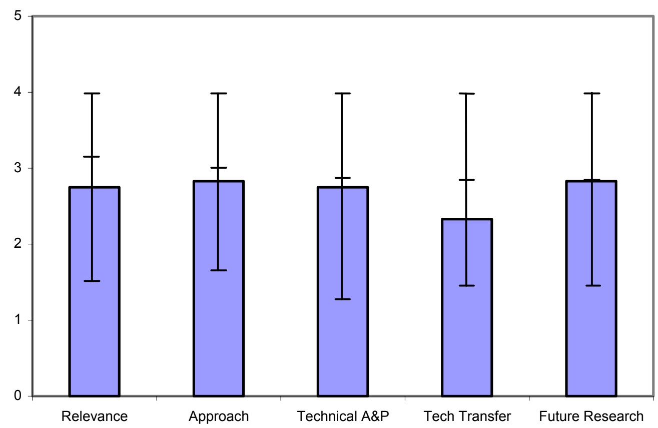
- Given the sulfur problem, I don't think that the problem can be solved by saying "make cleaner fuels".
- More characterization and performance/lifetime testing, done in serious collaboration with manufacturers of materials. Less focus on new materials development, like catalyst supports.
- This project is important for automotive fuel cell development. And this team is capable. It is necessary to take more systematic approach to identify tolerance of each impurity substance.
- Focus on the effect of impurities on FC membranes.
- Though last year's reviewer's comments mentioned addressing a solution for mitigating the sulfur dioxide problem, this project should either focus on the electrochemical issues and not gas clean-up or greatly expand the scope (and funding) to include an extensive study of air and fuel impurity removal.
- Fully exploit use of TEM techniques to derive degradation mechanisms due to time and/or fuel impurities.

Project # FC-8: High-Temperature Polymer Membranes
Myers, Deborah; Argonne National Laboratory

Brief Summary of Project

Argonne National Laboratory (ANL) is working to develop a proton-conducting membrane electrolyte for operation at 120-150 ºC and low humidities to meet DOE's technical targets. The project is investigating dendritic macromolecules attached to polymer backbones, cross-linked dendrimers, and inorganic-organic hybrids. Specific goals include determination of: thermal stabilities and conductivities of samples, preparation and characterization of inorganic-organic hybrids, and fabrication and testing of MEAs with high-temperature membranes.

Overall Project Score: 2.70



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- The objectives of this project are clear to meet the specific DOE's goals.
- Budget too small to have serious impact in required time. Only membrane work, not integrated with other MEA components.
- Well aligned with goals of HT membranes.
- This is a fundamentally oriented project that attempts to assess the architectural aspects of novel membranes, including organic-inorganic hybrids.

Question 2: Approach to performing the research and development

This project was rated **2.83** on its approach.

- It is a good approach to use sulfonated dendrimers blended with colloidal silica gel, although the concept is not new.
- Excellent/brilliant idea to focus on dendrimers.
- Good work, but very narrow focus resulting from limited resources. Not able to study catalysts/PEM ORR issues.
- Why no conductivity data at target 120ºC/25% RH? How stable over the full range of %RH -- is the data only hysteresis?
- Again, highly fundamental studies of branched spherical macromolecules with high surface charged densities with the hope that it may facilitate proton transfer, even at low water concentrations.
- Certainly a sound academic research effort.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- A higher sulfonic group density than Nafion is achieved. A sulfonated organic component blended with silica was made (although it is not clear that the sulfonated organic components are the dendrimers or Nafion.)
- Impressive conductivity result at low RH. Others work years to reach to same level.
- Rate of progress per unit of $ or resources is good - but resource funding too low. Initial samples just being characterized for conductivity at temperatures <100 ºC even though target is >120ºC.
- Benchmark at 120ºC/25% RH. Only two cases "G2 and G3" - a more systematic study in structural modification would be preferred.
- A model dendrimer system has been prepared. Inorganic-organic hybrid membranes have been prepared and initial films were tested by blending these new materials with about 70% Nafion. Some results indicate that the hybrid has higher conductivity than the Nafion control up to 80ºC.
- Chemical/physical properties are far away from DOE goals; e.g. 4 days of testing mentioned as stable.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- The level and degree of collaboration with CWRU and Toyota is suitable.
- Only one serious interaction with CWRU.
- Suggest expanding work at CWRU to include MEA fabrication.
- PIs have applied for a U.S. patent and are establishing collaboration with Toyota.
- Not presented.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.83** for proposed future work.

- The future plan is reasonable. More fuel cell performance tests are needed either internally or through the collaborations
- Use the proposed work to further develop structure/conductivity relationships
- Future work will continue to characterize these dendrimers and to fabricate and test MEAs using the subsequent membranes. It is not apparent that the epi-chlorohydrin polymers will have sufficient stability for the fuel cell operation. However this will be no doubt ascertained.
- The future plan is well based on current accomplishments.

Strengths and weaknesses

Strengths

- The use of sulfonated dendrimers. The concept of sulfonated dendrimers blended with inorganics like silica. The sulfonated dendrimers have higher density of sulfonic groups than Nafion.
- Very exciting program all around.
- High quality technical personnel.
- Interesting approach with great potential based on "kW" equivalent weights (high meq/g).
- Good fundamental study.

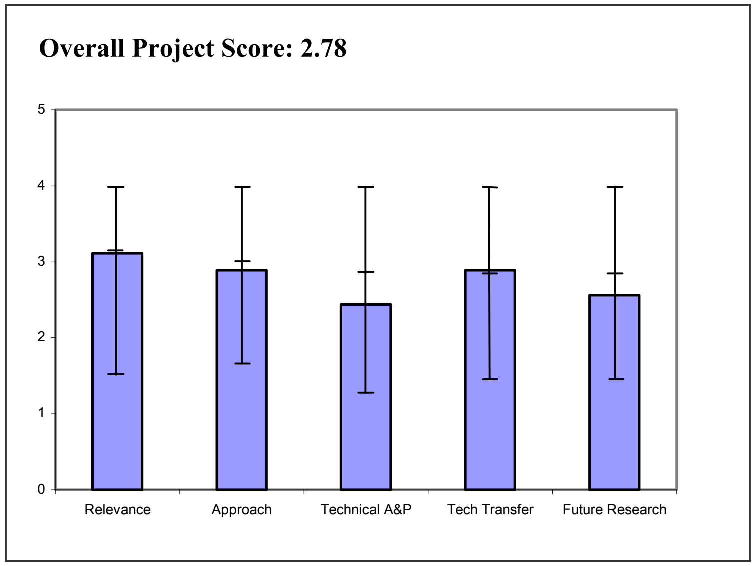
Weaknesses

- The progress is significant, but the pace is slow. Water solubility is a problem for the membrane materials that are being developed. No real membrane based on dendrimers/SiO_2 has been made. No fuel cells tests.
- Is any of this conductivity sustainable with time? Would benefit from complementary work on mechanism, thermal stability, fuel cell electrode interface compatibility.
- Inadequate staffing to make needed rapid progress with these new material sets. Film forming issues may be significant. Lack of plan for overview to anticipate issues with fabricating full MEAs with these new PEM materials.
- Needs better correlation between dendrimer structure and structural modifications and the final "function" of conductivity, stability, and mechanical stability.
- Unlikely exact system will be useful.

Specific recommendations and additions or deletions to the work scope

- Quickly make the membranes based on their future work. Evaluate by fuel cell performance tests and characterized by different electrochemical techniques. Do some durability tests (all tests should be done under high temperature and different RH conditions specifically. Pay attention to the conditions of low RH.)
- Nafion at 20% RH conductivity is about 5 to 7 mS/cm -- the dendrimer G2/G3 (80%) result at 20% RH is about 22 mS/cm, which can be explained by the fact that its ion exchange current (IEC) is 4 x that of Nafion. The question is if and how to further improve conductivity to meet the DOE goal?
- Work with outside membrane company to evaluate film-forming issues. Try to leverage research effort by collaborations on areas of weakness.
- More testing at higher temperatures (conductivity, stability).

Project # FC-9: Development of Polybenzimidazole-based, High-Temperature MEAs
Staudt, Rhonda; Plug Power



Brief Summary of Project

This Plug Power project will identify and demonstrate an MEA based on a high-temperature polybenzimidazole (PBI) membrane that can achieve the performance, durability, and cost targets of both stationary and automotive fuel cell applications. Key objectives include: (1) complete initial screening of potential PBI-based chemistries and structures and downselect top 5 - 10 candidate materials based on chemical and physical properties; (2) initiate rapid screening of candidate PBI materials in 50 cm^2 MEAs,; (3) initiate detailed electrochemical characterization of MEAs made with selected PBI polymers; (4) initiate evaluation of low cost acid-absorbing materials for phosphoric acid management within the system; (5) initiate design and development of bipolar plates with PBI-specific flow fields; and (6) initiate development of a PBI membrane-based MEA with advanced electrode structures providing high catalyst utilization and performance exceeding that of Nafion.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.11** for its relevance to DOE objectives.

- Application to stationary is clear. Not sure how this can be used in automotive, specifically in a freeze and thaw cycle.
- PBI and its doped composites appear to be leading candidates for stationary power activities. However, there are many questions related to the development of a suitable MEA with appropriate electrode structure that will allow performance greater than the state-of-the art materials, e.g., Nafion. The technical targets are outlined with respect to DOE. The team includes Plug Power, Celanese, Rensselaer and Albany Nanotech, a small company.

Question 2: Approach to performing the research and development

This project was rated **2.89** on its approach.

- Screening will result in down selection, ultimately to one membrane for stack testing. Data to date indicate that the PBI system has serious acid retention and mechanical stability issues - presentation lacked discussion of solutions.
- The approach is good. Candidate polymers have been screened and characterized. An attempt to develop low cost membranes has been made.
- The results of this project could lower the cost of PAFC by making stacks easier to assemble. Acid storage is simplified and improved.
- Synthesis of new polymers should not be the focus of this project. The focus should be on catalysis and acid management - the key technical issues.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.44** based on accomplishments.

- Poor acid retention and poor creep under constant load have been identified as significant problems. The PBI system has been projected to 40,000 hours life.
- One of a very few high temperature membrane approaches that shows promise. Improved performance and acid retention have been shown.
- The technical accomplishments include 5 PBI compositions, each with unique chemical structure. Membranes have been made. High molecular weight film-forming systems were developed and all of the phosphoric acid contents for these systems were greater than previously reported.
- Too early to judge if candidate materials will be successful.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.89** for technology transfer and collaboration.

- A good team includes industry and universities but no National Labs.
- Collaboration with RPI, Celanese and Plug appears to be working well and is a key component of the project.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.56** for proposed future work.

- Stated future work does not address resolution of the serious technical issues described.
- The research should focus on the most critical characteristic of this membrane to evaluate its real potential for fuel cell applications.
- High initial creep will need to be addressed.
- Achieved 3.3 gPt/kW (2 atm,0.5v, 1.2A/cm^2, 2mgPt/cm^2) - this is higher that PFSA. Suggest devoting resources to see if g/kW can be further reduced, otherwise, it will be difficult to achieve the cost target.

Strengths and weaknesses

Strengths
- Celanese, PBI manufacturer, is a part of the team.
- Previous work on this area helped to focus project.
- Future work will continue the evaluation of materials and membranes and test selected candidates in single cells.
- Significantly higher temperature demonstrated vs. other PEM approaches. Will deliver thermal system advantages of high temperature.
- Many materials have been screened.
- Solid team.

Weaknesses
- Lacks discussion on polymer structure characterization, (Task 2) and relationship between structure and membrane properties.
- Improve description of contribution from individual collaborators. Is this all new data since 8/03? Saw presentation with Fuel Cell Gordon Conference - June 03 which also showed PBI improvements

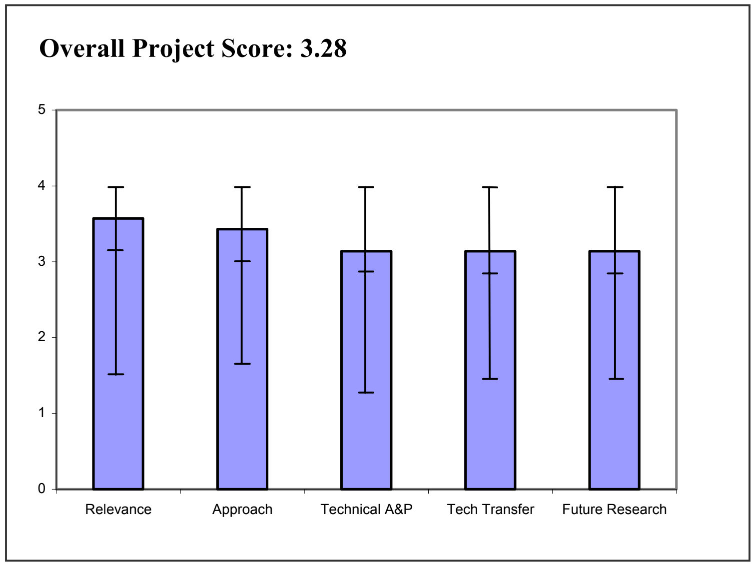
- Show progress (status) compared with the DOE targets.
- More discussion on issues of start-up, electrode performance and electrolyte management.

Specific recommendations and additions or deletions to the work scope

- Recommend speaking/working with PAFC developer who could help with acid management, flow field design and cathode catalyst optimization using Pt ternary alloys.
- Applicability to auto is claimed. Sensitivity of MEA to liquid water is admitted. Begin stack evaluation with auto drive cycles even with a non-optimized version of MEA and to develop water management approaches. Otherwise, this fuel cell will be limited to stationary applications.
- Focus on acid storage and stack assembly issues.
- Continue focus on electrodes electrolyte management and start-up. Reduce effort on flow field development and polymer synthesis.

Project # FC-10: Enabling Commercial PEM Fuel Cells with Breakthrough Lifetime Improvements
Bauman, Jayson; DuPont

Brief Summary of Project



This DuPont project will utilize both experiments and modeling to develop an understanding of potential mechanisms than can lead to membrane failure, including: H_2O_2 formation; radical formation; attack of polymer weak sites; material properties degrade; localized stress which promotes cracks/fissures; and crossover failure occurrences. Mitigation strategies such as peroxide prevention, peroxide decomposition, polymer stabilization, membrane reinforcement, and edge seal design and optimization are being investigated to improve membrane durability. The project will optimize each and incorporate them, in total, into fuel cell products.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.57** for its relevance to DOE objectives.

- Membrane durability is being examined and improved both chemically and physically.
- Peroxy radical mitigation is good objective and relevant to DOE/FreedomCAR objectives.
- Durability is a key barrier to commercializing current PEM Nafion-based fuel cell technology.
- PEM lifetime is critical to the success of DOE's Hydrogen Program.

Question 2: Approach to performing the research and development

This project was rated **3.43** on its approach.

- Physical reinforcement and chemical stabilization approaches are being developed. Accelerated testing is based on extensive and verified UTC Fuel Cell experience.
- Good combination of MEA structure and material development.
- The approach is outstanding, involving materials synthesis, accelerated aging test, analysis, stack testing, materials characterization and cost analyses.
- "Cost not greater than Nafion" target probably not adequate.
- Good comprehensive approach to all important aspects of membrane life.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.14** based on accomplishments.

- 6 months ahead of schedule for stack testing. Eliminated end groups susceptible to chemical attack. Mechanical strength doubled and made isotropic. Some adverse effect on cost and performance observed.

- The accomplishments were not well documented, perhaps because of the relatively recent timing of this project. An accelerated test has been developed, however, it appears to be based on the same peroxide reagent type testing that has been done for some time.
- Early results are showing benefits.
- Progress is encouraging that Nafion can achieve durability goals.
- Significant progress made on resistance to peroxide attack. Would be beneficial to show correlation between OCV and mechanical degradation.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.14** for technology transfer and collaboration.

- Large degree of collaboration with systems integrators. If successful, they will have an easy path for integration into fuel cell manufacturing.
- A good team has been assembled to go from raw materials all the way to full power plants. This allows validation of improvements.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.14** for proposed future work.

- Will examine ways to effect performance and cost.
- Future efforts should include more on cost estimate of membrane.
- Encouraging, broad base of activities.
- Consider how techniques developed can be applied to advanced membranes.
- Future plans look reasonable.

Strengths and weaknesses

Strengths
- Addressing both chemical and physical solutions. The accelerated testing protocols are well-established.
- Team is strong.
- Characterization of MEA. Material development.
- Membrane durability factors well identified and mitigating strategies in hand.
- Multi-attribute, multi-disciplinary approach with testing to quantify improvement of each change.
- Safety appears to be an integral part of the project.

Weaknesses
- Pinpoint discrete progress thus far.
- Degradation factors associated with membrane/electrode/catalyst interface also needs consideration.

Specific recommendations and additions or deletions to the work scope

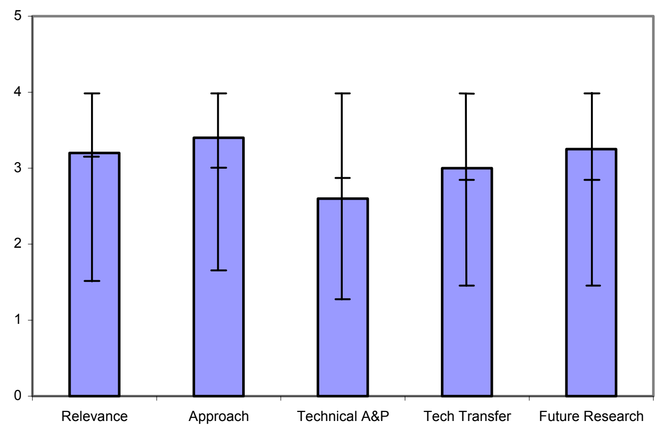
- Establish correlation coefficients for accelerated testing and project to real life expectations.

Project # FC-11: MEA and Stack Durability for PEM Fuel Cells
Hicks, Mike; 3M

Brief Summary of Project

During this project, 3M will determine root causes of MEA failure modes and develop an MEA with enhanced durability and maintained performance, that is manufacturable in a high volume process, meets market required targets for lifetime and cost, and is optimized for field-ready systems. The system demonstration will be for >2000 hrs. Focus will be on MEA component development, MEA characterization and diagnostics, and defining system operating window.

Overall Project Score: 3.09



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Well conceived and well focused.
- Objectives focused more on stationary than transportation application. Stationary fuel cells may plan a role in developing a hydrogen economy, and may prove some learning of value to transportation applications.
- MEA durability is critically important.
- MEA and stacked durability for automobiles, stationary power, as well as even portable systems is clearly a large issue.

Question 2: Approach to performing the research and development

This project was rated **3.40** on its approach.

- Excellent approach.
- Seem to be good, but need more detail explanation of technical approach for polymer materials, electrolyte and lifetime prediction models.
- A reasonable, well defined approach that may not be developing anything new but tests an already developed 3M proprietary polymer.
- Uses 3M's proprietary perfluorinated sulfonic acid ionomer, which is claimed to have improved oxidative stability over the baselined Nafion system. Aging tests developed to correlate single cell data with MEAs.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.60** based on accomplishments.

- Technical progress very good.
- Stack and MEA seem to be too sensitive and limited to narrow operating conditions. It is not an appropriate approach to narrow the operating condition.

- It is claimed that the membrane GDL and cathode catalyst systems show improved oxidative stability. Peroxide measurement is used extensively and believed to be the key to understanding degradation. Membrane, GDL and cathode stability have been evaluated.

<u>Question 4: Technology transfer/collaborations with industry, universities and other laboratories</u>

This project was rated **3.00** for technology transfer and collaboration.

- Excellent collaborations with industry, etc.
- 3M has collaborated with Plug Power, CWRU, and the University of Miami (modeling).

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **3.25** for proposed future work.

- As described work will be valuable. Progress to date is less than anticipated.
- Their proposed future work is to continue the MEA component development, establish decay mechanisms and accelerated lifetime predictor tests, and study the interaction of these parameters to MEA durability.

<u>Strengths and weaknesses</u>

<u>Strengths</u>
- Well presented and managed project. The program should enhance significantly enhance fuel cell reliability. The 3M novel membrane development.
- Characterization of electrolyte material.
- MEA production at high volume. Understanding of factors associated with MEA durability.
- Major player in the field.

<u>Weaknesses</u>
- Robust approach.
- Internally focused project.
- Specifics are a bit difficult to discern.

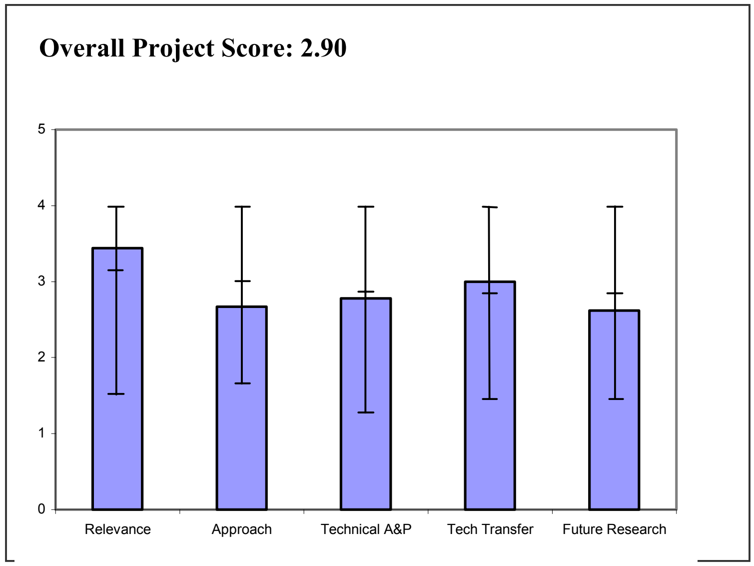
<u>Specific recommendations and additions or deletions to the work scope</u>

- Focus on critical barrier of catalyst support degradation.
- Evaluate according to automotive requirements.

Project # FC-12: Development of a Low-Cost, Durable Membrane and Membrane Electrode Assembly
Gaboury, Scott; Atofina Chemicals

Brief Summary of Project

The objective of this Atofina Chemicals project is to develop low-cost, high-durability membranes by optimizing chemistry and process, validating scale up, developing MEAs based on these membranes, optimizing MEA for new membrane, validating MEA performance, and validating the MEA performance in single cells and in stacks.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.44** for its relevance to DOE objectives.

- Progress in a novel membrane is essential.
- Durability target is relevant to DOE and FreedomCAR targets. Performance target should include operation from high temp (120C) through low temp (10C) for automobile requirements. Low hydration conditions should also be evaluated.
- PVDF membrane has the potential to reduce costs but the total cost will also depend upon the cost of the electrolyte for which no information is given.
- The goal is to develop lower cost, higher durability membranes and to develop MEAs based on these membranes and to validate the performance in single cell and short stack testing.
- Lower cost high-durability membrane development is one of key objectives of the DOE program.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Testing progresses from membrane to MEA to stacks.
- Atofina has an excellent track record in novel materials development.
- The membrane properties that provide superior durability to Nafion are not understood.
- MEA optimization with new membrane material is probably necessary, but starting that before you have a membrane comparable to Nafion may be premature.
- The approach is to blend an electrolyte with Atofina's Kynar PVDF polymer, which by itself is known to be quite stable in the fuel cell environment. In order to produce conductivity, the blended materials must be generated. The chemistry of the blend will be much different from Nafion, so, the approach to forming MEAs is recognized appropriately as being different.
- The electrolyte is not described. Kynar is not fully fluorinated and may actually not be more durable than Nafion. Stability of PVDF membranes in Li-ion batteries is irrelevant.
- Test temperatures are too low.

Question 3: Technical accomplishments and progress toward project and DOE goals
This project was rated **2.78** based on accomplishments.

- Nafion performance is within reach.
- Stable corrosive environment.
- First year progress is slow.
- Need to identify reason for poor performance and failures. Optimization of MEA before membrane is better performance improves may be premature. - need a better membrane first.
- Polarization curves appear competitive with existing materials.
- Performance in cells much lower than Nafion especially at lower humidity.
- Focus on more automotive related testing.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Team includes GA Tech, Johnson-Matthey, and UTC Fuel Cell, although UTCFC's role was not described.
- Good collaboration - high throughput screening should be helpful.
- Atofina has interacted with Johnson-Matthey and Georgia Tech to leverage their new materials. Some of their results look quite interesting.
- Johnson-Matthey is a major supplier of Pt salts and Pt catalysts.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.62** for proposed future work.

- Logical and according to plan.
- In the future they will continue to develop the membrane technology based upon the Kynar chemistry and the blend polyelectrolyte chemistry. They plan to continue long-term testing and scale up the process.
- Fairly flexible approach.
- High temperature operation should be evaluated.

Strengths and weaknesses

Strengths
- Well conceived, well managed program.
- Kynar PVDF is an innovative material for this application.
- Strong polymer group.

Weaknesses
- Need to identify mechanisms/causes of failure in durability tests. No information given on the electrolyte, so it is difficult to assess system. Not clear that root causes of problems are known, so cannot judge whether plans should address those problems.
- Approach may not translate to high temp conditions.

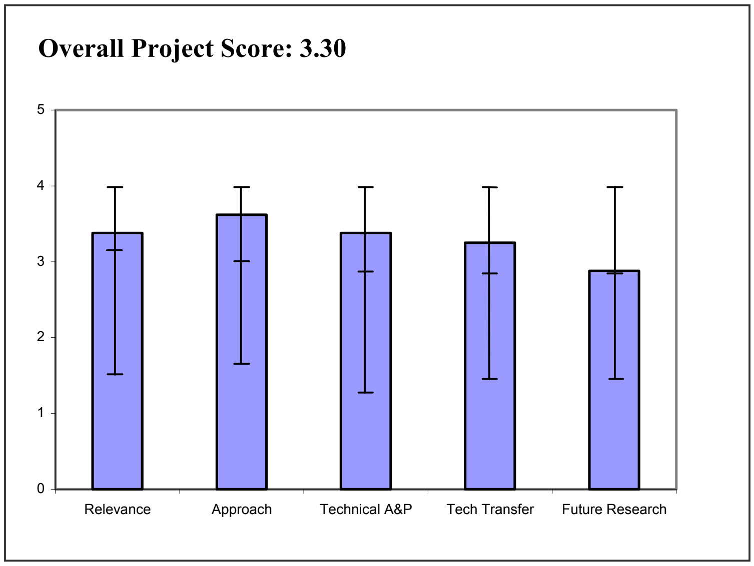
Specific recommendations and additions or deletions to the work scope

- Membrane and MEA robustness should be evaluated as well as durability. Robustness is necessary for automotive application.
- Detailed studies of failure modes and decay mechanism should be included.
- Focus screening based on higher temperature operations.

Project # FC-13: New Electrocatalysts for Fuel Cells

Ross, Phil; Lawrence Berkeley National Laboratory

Brief Summary of Project



For this project, new catalysts for both anodes and cathodes are being developed following a unified concept of PGM-based bimetallic nanoparticles with a "grape" structure (a PGM "skin" with base metal core). The choice of PGM and core metals for the anode and cathode will be based on computational screening of PGM core-shell nanostructures using newly developed (under BES funding) Monte Carlo simulations. Lawrence Berkeley National Laboratory (LBNL) will also: (1) pursue new synthetic chemistry to synthesize nanoparticles with a "grape" structure, (2) continue focus on Re as metal core with Pt and Pd as PGM, (3) optimize AuPd as alternative to Pt in anodes, and (4) conduct fundamental studies of the crystallite size effect for the oxygen reduction reaction in acidic electrolytes on carbon supported Pt and Pt alloy nanoparticles.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.38** for its relevance to DOE objectives.

- Project is highly focused and specific to one of the barriers.
- Great fundamental studies, provide guidance for choice of alloy materials.
- Working to reduce PM loading is crucial to reducing fuel cell costs. This type of work is very important.
- Better catalysts are needed for success of the program.
- Cost target is not mentioned.
- Relevant to better understanding of ORR kinetics.
- The fundamental technology which addresses the limits of current electrochemistry understanding is necessary to move fuel cells/hydrogen use to practical use.

Question 2: Approach to performing the research and development

This project was rated **3.62** on its approach.

- Technical approach is good but I question if this method can reduce the catalyst cost?
- World leading research capabilities and staff. Focus on fundamentals is important and critical for National Labs.
- Focus is sharp and needs to continue.
- Approach is good, but focus on specific key technical barriers should be clearer.
- Approach not well-outlined. Excellent fundamental results need to be incorporated into approach. How do results indicate new approach to prevent leaching? Does leaching of Co, Fe, etc. stop after 1st layer is removed?

- Professor Ross is a well known leader in this field. He demonstrated many fundamental concepts involving sandwich surface structures of Pt-Ni nanoparticles as well as core shell structure. Very fundamental studies of the surface electronic properties were reported. Thin film RDE methods were utilized for kinetic measurements.
- Seems good. It is necessary to identify how to develop mass production process for this electrocatalyst for fuel cells.
- A combination of catalyst characterization techniques, catalyst species, and modeling that has combined resources (BES) is very productive.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.38** based on accomplishments.

- Progress continues to be made on engineered catalyst particle structures.
- The progress this year seems to be most significant - number of important confirmations and findings.
- Project is progressing, but it is not clear that this project will result in overcoming technical barriers.
- Excellent leverage of BES funding with Monte-Carlo simulations. Rejection of Pt in core of Pt-Re alloy is important finding. Only group really characterizing catalyst structure at the atomic scale.
- Thin film RDE methods were optimized for characterizing the 3M nanostructure Pt catalysts. The activity for ORR is close to that obtained on well known polycrystalline Pt.
- Activity is enhanced for Pt skin effect.
- "Grape" structure can significantly reduce the amount of platinum in fuel cells if the catalyst is durable over many hours in fuel cell environment.
- Very good presentation of data and inclusion of description of test conditions. Performance tests certainly appropriate for fuel cell relevance. Incorporation of 3M catalyst is very good decision.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Collaborations are ongoing with GM, UTC and 3M, as well as the Max Planck Institute in Germany and the University of Liverpool in the UK.
- Work with major players in fuel cell commercialization is right approach.
- Great validation studies.
- Project collaboration is good with several industry and university partners. The maturity of this project's technology looks to be enough into the future that technology transfer to an OEM or supplier cannot be evaluated.
- Working with GM and 3M and 2 universities. Good progress in establishing RDE as catalyst characterization tool.
- Significant interactions with leading fuel cell developers. Transferring characterization techniques to developers.
- Very capable collaborators chosen and overlap with industry is good for transfer of knowledge. Interaction with investigators who have different viewpoint or capabilities could be very rewarding.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.88** for proposed future work.

- Fair rating only because future work was not discussed. Suggest more emphasis on fundamental understanding than on how to make materials.

- Continue combination of modeling and fundamental studies on the alloy/Pt morphology and performance.
- Not really covered in the presentation or list of slides. Not clear on how fundamental results are being used to guide new catalyst research.
- The future appears to hold further studies in analogous areas.
- No discussion of future research directions. Assume LBNL will continue to work on characterizing suitable "grape" structured catalysts.
- While the direction of work is clear, what the future plans for taking advantage of information to advance cathode catalyst structure/composition to better materials was not made clear.

Strengths and weaknesses

Strengths
- Capabilities for fundamental understanding of catalysts.
- Project is apparently making progress towards a reduction in PM loading.
- High quality basic science being applied to understanding importance of catalyst structure.
- Material synthesis
- Good interactions with major fuel cell developers - GM and 3M to improve basic understanding of ORR on specific catalysts unique to each. Good return on investment.
- Excellent experimental facilities and techniques. Combination of theory and experimental practice on a range of catalyst candidates provides very good direction and understanding of interacting processes.

Weaknesses
- Size of effort. Should employ more post-docs.
- It is not clear whether the progress will actually lead to overcoming some of the technical issues to implementing these types of catalyst.
- Not clear on direction of work to produce new catalysts with improved activity and endurance. Next steps for improving Pt-Co?
- Seems to be a certain amount of selectivity in choice of experiments and candidate species that support the chosen theory and model. Chooses to extol findings presented 20 years ago.

Specific recommendations and additions or deletions to the work scope

- I would like to see this group get involved with obtaining basic understanding of very low Pt or non-Pt containing catalysts. (e.g., w/Karen Swider-Lyons)
- Keep going. But, it is necessary to consider how electrode can be fabricated in large production basis. Actual cost perspective should be identified.
- What are next steps in reducing "grape" structure concept to practice? How does this catalyst perform in operating fuel cells?
- A concerted effort to carry out a set of experiments, using alloys that are candidates and do not follow theory, to help understand strengths or gaps in the hypothesis. Perhaps working with another theorist or model who has a different viewpoint would provide a little less biased description of catalyst behavior.

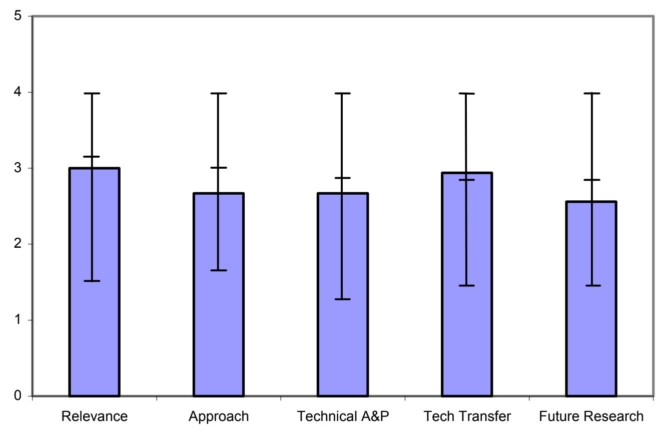
Project # FC-14: Low-Platinum Catalysts for Oxygen Reduction at PEM Fuel Cell Cathodes

Swider-Lyons, Karen; Naval Research Laboratory

Brief Summary of Project

The Naval Research Laboratory (NRL) will target DOE goals to achieve 0.02 g Pt/rated kW before 2010 by focusing on lowering Pt in fuel cell cathode. NRL is using \ oxide-based supports for Pt and other metals to leverage oxygen dissociation by oxides, metal-support interactions with Pt, and ionic mobility of oxide supports. 2004 objectives include: "perfecting" electrochemical methods, rigorously characterizing active and inactive catalysts, devising mechanism(s) to explain catalyst activity, and designing new active and stable catalysts.

Overall Project Score: 2.77



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- It is definitely relevant to reduce the cost of MEA. However, it is not clear if there is any economic benefit of attempting to reduce levels from the point of view of long durability if novel nanotechnology is not used.
- Narrow focus. Addresses one aspect of catalysts needs.
- Very relevant. Needs to stay focused at the fundamental science level.
- The development of low platinum catalysts would be great boon to the fuel cell initiative.
- Supports goals to reduce the cost of fuel cells and to conserve Pt.
- Very well aligned with the goals of the program.
- Cost target is not given.
- Lower Pt loading in line with HFCIT objectives.
- Fills need for work on conducting oxide supports, both to enhance catalytic activity and as a possible alternative to carbon.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Technical approach is good but, I question if this method can reduce the catalyst costs?
- Good approaches for low-Pt ORR catalysts to be characterized by XPS, XANES and electrochemical methods. Would like to see more fuel cell performance testing results. The role of MO_x is not clear.
- Not clear yet how these supports can provide advantages over carbon. Could benefit from modeling, e.g. LBNL embedded atom approach.
- Come a long way! Work is now focused. Approach is good but needs to address broader MEA-electrode elements. Oxide substrates hard to understand how they will work.
- Goal has been to use material selection to choose stable active hydrous oxides/phosphates from selected portions of the period table. Thus this is quite a fundamental study also from the Naval

Research Lab. The approach has been to evaluate the rotating disk electrode systems and to prepare MEAs for fuel cells with traditional anodes. Physical characterization involves spectroscopy, thermal analysis, microscopy and surface analysis.

- Approach is good and some minor issues with data analysis at last year's review appear to have been resolved.
- Good choice of materials.
- Seems good, but need more detailed criteria for down-selection of material for this application. What could be the metric? Also, it is necessary to identify cathode corrosion problem and the solution should be incorporated in the approach.
- Poorly expressed rationale for studying platinized "hydrous oxides".
- Improved focus on materials that are likely to be stable. Combination of performance testing and detailed characterization is just what is needed on such an exploratory topic. Still need improvements in testing - too heavy loading of active materials on disks.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Pt-SnO_x is a promising catalyst. Good results from characterizations by XPS and XANES. Decent understanding of the catalysts mechanistically.
- Progress relative to this project's history is good, but progress relative to overcoming barriers is very low.
- Progress good. Work on mechanisms and fundamentals. Need to see some tie to actual electrode applications so as to get degradation mechanisms understanding as they impact structures.
- Accomplishments include the generation of various hydrous tin oxides with various metals and some enhanced ORR activity for analogous gold or palladium on the tin oxide supports.
- Making good progress with low cost catalytic materials.
- Good progress.
- Chaotic, sloppy presentation. Very few concrete results. Did not look like a year's work at the level of effort stated. No sign in results that this is a promising direction.
- Some improvement in testing and interpretation over last year - still needs further improvement. Data on both Pt - particle and Pt-in-oxide-lattice catalysts provides contrasts that could lead to important insights. Data could still be better presented (e.g. compare activities over a range of potentials, not just one).

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.94** for technology transfer and collaboration.

- Good balance of technology transfer/collaborations among academia and industrial organizations like GM. More collaboration with fuel cell developers are encouraged.
- Big improvement over past years.
- Team is doing better job with externals. Time to get this material into other's hands for feasibility testing.
- Possible mechanisms for the activity were reported.
- Appears to have broad range of collaborations and is working with industry to commercialize technology.
- Well-communicated interactions with good groups.
- What collaboration? GM is trying to correct their sloppy procedures. That's not collaboration.

- Outside interactions are appropriate for an exploratory project. Project takes advantage of outside contacts to grow in productive directions.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.56** for proposed future work.

- Good plan for future work. Develop deeper understanding of the catalysts mechanistically. More fuel cell testing results. Develop ORR kinetic models. More collaborations with fuel cell MEA developers like W. L. Gore, Umicore, Johnson Matthey, DuPont, 3M, etc.
- Not clear that the progress to date justifies an expectation that this approach will ever be able to make improvement in low Pt loading in real fuel cell environment.
- Would like to see more mechanistic work, especially involving OOH mechanism/species. Oxide support optimization and model development.
- Future efforts will continue the study of this important area.
- Going nowhere.
- Planned classes of materials to be studied seem appropriate. Acknowledged need to get ink preparation under control to allow outside labs to reproduce results. Should make sure internal testing procedures give clean kinetic data - don't overload disks.

Strengths and weaknesses

Strengths
- An example of new catalyst design and fabrication through scientific understanding and suitable utilization of catalyst characterization techniques.
- Team has expanded and now has a broader skills set to address more fundamental issues. Team is more focused than years past.
- Electrochemical and physical analysis on electrocatalyst for fuel cells.
- Good choice or research area. Improved methodologies and interpretation of data.

Weaknesses
- More evidence should be provided in order to support the claim of the MO_x's roles in the catalyst mechanistically. No kinetic data. Very little fuel cell testing information.
- Unrealistic assessment of the entitlement performance of this technology approach.
- Selected aspects of talk were too vague. Increase quantitative analyses. Beef up thermodynamics/kinetics elements.
- Can strive further to present data in more standard format to better allow comparison of materials under condition that are both largely under kinetic control and could be analogously tested in a fuel cell. Still need to work on electrode preparation procedures and testing.

Specific recommendations and additions or deletions to the work scope

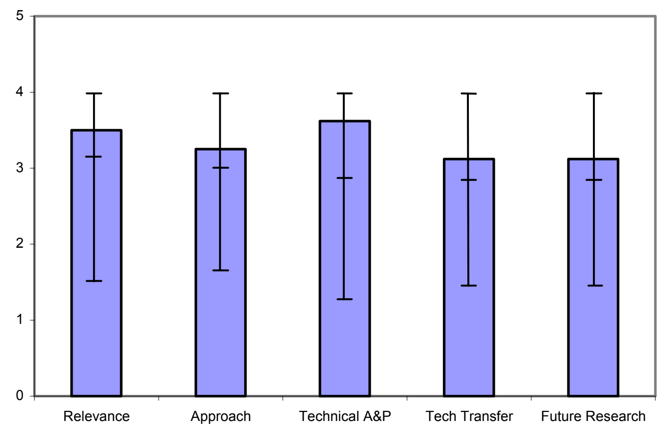
- Should seriously consider if this approach has the viability the P.I. proposes.
- Keep going. But, it is necessary to consider how electrode can be fabricated on a large production basis. Actual cost target should be identified.
- Terminate as soon as possible.

Project # FC-15: Low-Platinum Loading Catalysts
Adzic, Radoslav; Brookhaven National Laboratory

Brief Summary of Project

The purpose of this Brookhaven National Laboratory (BNL) project is to develop low platinum-loading electrocatalysts. The objectives are to demonstrate the possibility of synthesizing novel electrocatalysts for O_2 reduction with monolayer level Pt loadings, further characterize the $PtRu_{20}$ electrocatalysts for H_2/CO oxidation and long term tests, and to gain understanding of the activity of Pt monolayer and the $PtRu_{20}$ electrocatalysts.

Overall Project Score: 3.32



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Very specific focused approach addressing one barrier -- Pt reductions.
- Very relevant for the DOE goals.
- Important area.
- Directly addresses precious metal loading, durability and CO tolerance target for anode and cathode catalysts.
- Work is relevant. Project goals aligned.
- Good, but CO tolerance should be reconsidered to meet hydrogen system as a primary purpose (not reformer system).
- Program continues to make progress toward reducing the Pt content of the fuel cell. May have already exceeded DOE target.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Requirement of Pd or Ru sub-particle dilutes cost advantage of this approach.
- Is this method applicable to other metals/metal oxides as support to Pt? Can this approach be used for making large quantities of catalyst?
- The development of lower platinum loading systems using two different methods for platinum monolayer deposition.
- Excellent combination of fundamental characterization (CV's, XANES microscopy) combine with critical fuel cell-relevant testing at both materials level and in MEAs (with LANL) to provide guidance for further development.
- Approach is methodical and was built upon prior work. Sound fundamental basis. Fundamental yet practical.
- Program has good understanding of fundamentals. Applies fundamentals to successfully develop technology.

Question 3: Technical accomplishments and progress toward project and DOE goals
This project was rated **3.62** based on accomplishments.

- Given the $250K funding. Demonstration of stability very important. Basic understanding of ORR inhibition by unions.
- Validation studies at LBNL very important continued collaboration.
- Stability tests at LANL show no loss of voltage after nearly 900 hours. It is proposed that the durability target of 2000 hours can be reached with this electrocatalyst. With respect to the cathode, the platinum monolayer has been demonstrated to be an active catalyst for oxygen reduction. Further complex mixed-metal electrocatalysts were synthesized and their activities are being examined. Further surface analysis studies have also been carried out.
- Very exciting results for monolayer Pt on Pd and Pt/Pd/C catalysts for ORR. Continued work on PtRu anode catalysts also making good progress in durability and mechanism elucidation.
- Progress is good and practical testing at LANL applauded. Focusing on correct "elements" of potential catalyst.
- High activity observed. What is durability?
- Program continues to show success after success. Movement to cathode catalyst is most exciting.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.12** for technology transfer and collaboration.

- For size of program, interactions with LANL have been productive.
- Collaborations with Los Alamos have been developed, and interactions with Plug Power have been initiated.
- Excellent work with LANL to conduct MEA and durability studies for technology transition. Several other potential collaborations under discussion, including Plug Power.
- Probably could increase a bit.
- No real collaborations listed except for LANL.
- Has key groups from industry and academia.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.12** for proposed future work.

- Studies of PtOH effects on ORR could be critical. More work on CoPd.
- Expand effort on AuNi immerscible alloys -- good approach other materials?
- For the future, hydrogen oxidation will be studied using the platinum sub monolayers. Oxygen reduction will be further studied in conjunction with LANL.
- Pt/AuNi/C work promising and should be pursued. Pt/Pd/C continued effort and LANL tests are a must do.
- Well thought out. Covers all aspects of catalyst/development of electrodes.
- Future work not clearly specified in sufficient detail.
- Well focused objectives and based on past performance, it should be successful.

Strengths and weaknesses

Strengths
- World class investigators.
- Very thorough approach to designing catalysts based on understanding the complex relationship between the catalyst components at the materials level and how that influences reaction mechanisms.
- Solid approach. Good follow-through from theory to application. Very practical yet seems to know what fundamental risks remain.
- Material development.
- Research leader is tops in field.

Weaknesses
- May not have critical mass for adequate rate of progress.
- Should expand a bit further (tech transfer).
- PI tried to put too much information into presentation. Needs to focus presentation on key results that support objectives and goals of program. PI is doing good work on this program but his presentation was so hurried and long that the good work was not obvious.
- Low budget compared to $750K for 1st year projects for non-precious metal catalysts.

Specific recommendations and additions or deletions to the work scope

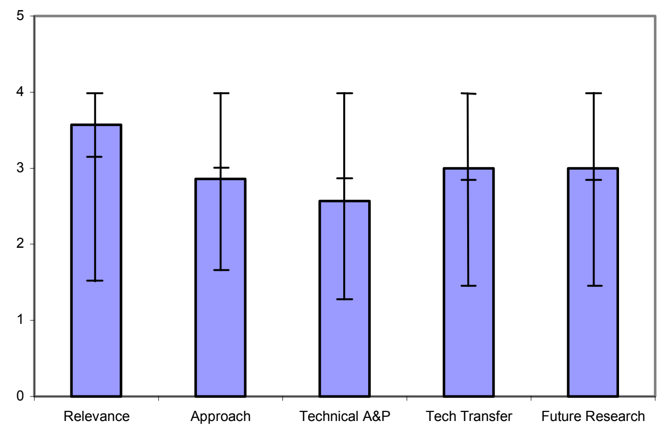
- Work with LBNL to understand commonality of the approach, i.e. "skin" effect. Why not more focus on PdCo system, instead of Au nanoparticle supports for Pt?
- Keep going.
- This program is under-funded. Most successful effort of DOE for reducing catalyst loading but low budget. DOE should consider integrating with industrial counterpart.

Project # FC-16: Development, Characterization and Evaluation of Transition Metal/Chalcogen Based Cathode Catalysts for PEM Fuel Cells
Campbell, Stephen; Ballard Power Systems

Brief Summary of Project

Ballard Power Systems intends to develop a non- precious metal cathode catalyst for PEM fuel cells, which is as active and as durable as current PGM-based catalysts at a significantly reduced cost. Their plan includes development of composition and structure, process development (can be scaled up), and evaluation/ demonstration in fuel cells and stacks.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.57** for its relevance to DOE objectives.

- The non-precious metal cathode catalyst would of course make a major difference to progress in fuel cell development.
- Development of non-Pt cathode catalyst for PEMFC is critical for reducing stack cost (to improve market penetrability) and minimize/reduce U.S. dependency on a non-domestic resource.
- Non-Pt electrocatalysts are critical for commercial implementation of PEM fuel cells.
- Lowering the cost and eliminating the use of precious metals are critical to the commercial realization of PEM fuel cell power systems.

Question 2: Approach to performing the research and development

This project was rated **2.86** on its approach.

- Logical approach culminates in short stack test. Process development is required just to test the materials.
- The approach has been to study optimum catalyst compositions (metal, chalcogen) and the structure using a well-defined thin film material on glassy carbons. Thus, this is also a relatively fundamental study.
- Technical experimental approach is good but lack of a theoretical modeling effort could hamper catalyst development. Not clear that selected metal chalcogens will be better than Ru chalcogens.
- Questionable whether data obtained on thin film "model" catalysts can be easily transferred to "nano-dispersed" catalysts - possibility of missing "magic" formulations. Focus on structural/nano-structural characterization is important.
- Chalcogens have been tested for oxygen reduction in the past (Alonso Vante, 1987-1995). How is this approach different?
- Does not build on previous R&D in this area based on discussion. Technical feasibility not shown.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.57** based on accomplishments.

- Considering the very recent start (4-5 months), progress is reasonable although, so far, the only progress is staffing up and equipment procurement and set-up.
- Too early to evaluate.
- Apparently, the project has only recently started so not too many accomplishments were claimed, except that the research staff is in place and working. The glassy carbon substrates have been machined, and initial baseline data have been obtained and the coating of the thin films is in progress.
- New project (less than 2 months). Very difficult (not fair) to judge effectiveness towards achieving objectives. Appears that research plan for collaborators is in place.
- Too early to assess, in general equipment/apparatus set-up not considered accomplishments.
- Very little progress relative to other DOE-supported cathode catalyst projects initiated at the same time.
- Program just getting started and progress to date is minimal.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Would like to see National Lab involvement for catalyst requirements. University involvement is only for characterization and not for catalysis or materials choice.
- Collaborations with Los Alamos have been developed, and interactions with Plug Power have been initiated.
- Appears that most of R&D effort is being conducted by university collaborators. Role of Ballard in catalyst development effort is not clear.
- Ultimate transfer of technology via demonstration in Ballard stack is excellent approach. Need more collaborations with U.S. universities and National Labs (U.S. $$).
- Several collaborations are in place and the transfer to fuel cell manufacturing will be easy since this is a Ballard Project.
- Appears to have put together good team.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Substantial data were promised "imminently."
- In the future it is planned to do in situ fuel cell optimization using down selected powder catalysts. Obvious variables to be studied will be investigated.
- Technical plan is well structured to allow for rapid screening of catalyst performance. Concerned that they will not be able to make down selection of catalyst by end of 1st year.
- Doesn't appear to have fast track approach to achieve "home run." Need to validate thin-film approach for screening catalysts.
- The research plan is sound.
- No specifics or pathway discussed. Written as a "wish list."

Strengths and weaknesses

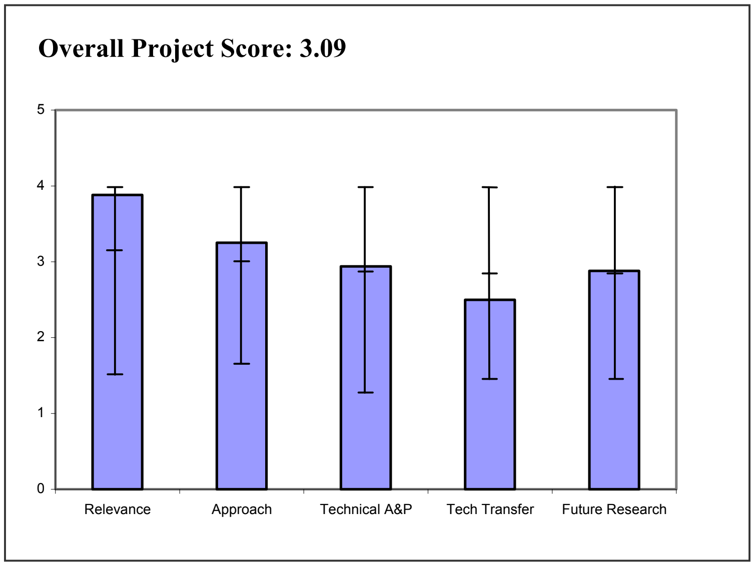
Strengths
- Characterization of catalyst for fuel cell.
- Good approach using well-defined "model" catalysts to gain insight into the catalytically active center.
- Experience and commercial position of Ballard for commercialization and technology validation.
- University collaborations and ease of transfer of technology to fuel cell manufacturing.

Weaknesses
- Doesn't adequately address potential differences between catalysts on glassy carbon and on porous carbon powders. Process development is a major part of this effort rather than catalyst characterization and testing. The project will be a failure if they cannot make the catalysts on the porous carbon. Maybe involvement of an experienced catalyst-maker company would save time and money and reduce risk.
- Need to confirm that the "model" catalyst is truly representative of actual catalyst (not necessarily a weakness). Lack of theoretical modeling effort could hamper catalyst developers. Lack of effort focusing on catalysts durability/stability, especially prior to stack performance and assessment testing.
- Long-term path for feasibility demonstration. Basis for selection of trans-metal chalcogens not clear to this reviewer. Universities apparently in critical path for development (long-term).
- No distinction from past work on this type of electrocatalyst.
- Not apparent the researcher understood topic area.

Specific recommendations and additions or deletions to the work scope

- Keep going.
- Need to determine acceptable volume increase and required catalyst activity relative to "state-of-art" Pt/C catalyst to meet DOE targets. Need to quantify performance criteria for selecting catalyst for stack performance and assessment testing (Phase 3-Task 8).
- Incorporate go/no-go decision into work plan. Need to demonstrate technical viability before proceeding to subsequent phases.
- Restructure program to get better definition of technology, hard (go/no-go) goals. Consider stopping program until restructured.

Project # FC-17: Novel Approach to Non-Precious Metal Catalysts
Atanasoski, Radoslav; 3M



__Brief Summary of Project__

This 3M project will develop and demonstrate non-precious metal NPM cathode catalyst to lower cost (50% less vs. target of 0.2g Pt/peak kW) and to reduce the dependence of PEM fuel cell catalysts on precious metals. Additionally, they will identify opportunities for system cost reduction, through breakthroughs in key areas of the fuel cell, the catalyst and application of cost-effective processes for MEA fabrication, closely associated with the development of the new catalyst. Sample tasks include investigation of Fe-N-C as a model catalytic site, test 1- and 2- step synthesis processes, and fabrication and characterization MEAs.

__Question 1: Relevance to overall DOE objectives__

This project earned a score of **3.88** for its relevance to DOE objectives.

- Supports goals to reduce the cost of fuel cells and to conserve Pt.
- Development of non-Pt cathode catalyst for PEMFC is critical for reducing stack cost (to improve market penetrability) and minimize/reduce U.S. dependency on a non-domestic resource.
- Important to commercialization of PEM fuel cells. 50% cost reduction relative to Pt seems to be a very conservative goal.
- There exists a need for non-precious metals or very low loaded precious metals in fuel cells.
- Lowering the cost and eliminating the use of precious metals are critical to the commercial realization of PEM fuel cell power systems.
- Development of non-platinum or non-precious metal catalysts for fuel cells is critical to cost reduction and poison-resistance of electrodes. This project, if successful will provide a means to overcome a major barrier.

__Question 2: Approach to performing the research and development__

This project was rated **3.25** on its approach.

- Approach seems to have potential to make non-precious metal catalysts.
- Good integration of theoretical and experimental research. Still too early to evaluate effectiveness of approach.
- Developing new vacuum deposited catalysts using 3M technology, including its unique nano-structured thin film substrate. A second approach has also been to develop recent insights based on non-platinum ORR catalysts for PEMFCs.
- Leverages 3M's existing technology base for catalyst/MEA production. Rapid feedback loop with electrochemical testing.

- Not clear this a repeat of previous macrocycle R&D. Presenter did not seem to be aware of catalyst activity limitations.
- Nice combination of experimental and theoretical approaches. I have some reservations that the modification of the edges of graphene sheets to incorporate N and Fe will result in a high enough density of catalytically active sites given that the edge sites constitute a small portion of the total number of sites.
- The project is building upon in-house capabilities and new developments in the literature to attempt to prepare new catalysts using high throughput manufacturing capabilities. The project is integrated with the high surface area nano-structures discussed in FC-4. One would wish to see a little more fundamental work on analysis of the nature of the catalyst. Perhaps some SIMS to see if structures can be identified. Also what would be the difference between these catalyst structures and say, a polyvinylpyridine layer with Fe bound to it? It would be interesting to compare. One is a bit concerned about the catalytic activity and whether it will be sufficient to compete with Pt. If not, how does the nano-structuring of the carbon support affect this?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.94** based on accomplishments.

- Although early in the project, PI seems to have reasonable plans in place to meet objectives of the project.
- Too early to evaluate.
- Very good effort to date in establishing theoretical and experimental program. Progress to date does not suggest technical barriers will be overcome but effort to date is commendable.
- Produced a model iron-nitrogen-carbon system as a model catalytic site. They have demonstrated a one-step synthesis for the proposed target structure and have formed and characterized MEAs for the new catalysts. They have begun to model the incorporation of these systems in the catalyst layers. Various data were produced to support that hypothesis.
- It seems a bit early to expect exciting results, but significant improvement is necessary. Identified alternative processes for producing catalysts with high pyridine nitrogen.
- Showing some results of repeat of literature work from GRI, cited V. Jahlan.
- Excellent progress for the short duration of the project. Next year will be much more critical.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- No discussion of collaboration or interactions.
- Only collaboration identified is Jeff Dahn for fast screening methods. Assume PIs will collaborate informally with industry/academics when appropriate.
- Collaborations with Los Alamos have been developed, and interactions with Plug Power have been initiated.
- Built-in tech transfer. Collaborations with universities. Probably should consider validation at National Labs.
- Presentation did not mention transfer and collaborations. Industry group is strong.
- A subcommittee with Jeff Dahn was mentioned, otherwise there is very little collaboration/technology transfer evident.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.88** for proposed future work.

- R&D to identify active catalyst sites and understand reaction mechanism is critical; theoretical effort is essential.
- In the future they will further study the appropriateness of the nitrogenated carbon precursor as a catalyst system. They will attempt to use surface analytical techniques to identify the nature of the most active site. Modeling will be continued and the limitations of the boundaries of the project will be identified.
- PI seems to have good future plan, increased testing, characterization, broader scope of formulations, etc.
- Average plan. Little discussed on electrochemical aspects.
- Not really clear about future plans and time-frames. No specific milestones given, e.g. how much catalytic activity will constitute success? What surface area will be required? How about stability and durability? When will these tests start.?This aspect of project needs improvement.

Strengths and weaknesses

Strengths

- Characterization of catalyst for fuel cell.
- Good integration of experimental and modeling program.
- Good balance between sample preparation process development, and electrochemical testing. Good technology validation/commercialization path; Fe-C-N catalyst formulations demonstrated to be valid path for non-PM catalysts.
- Unique approach.
- Builds on in-house capabilities and adds to other programs already on-going. Builds on new insights into catalysts.

Weaknesses

- PI spent too much time discussing the time line for future actions which cut short the time available to discuss accomplishments, future plans or collaborations. It is suggested that the PI devote more time to accomplishments and future plans.
- Initial electrochemical activity test results are not encouraging -- need to determine if poor-performance is due to the catalyst or other factors. Need to determine density of active sites - is it achievable?
- Significant performance improvements needed, although this is a new project.
- Researcher did not appear to know history in this area.
- Low density of potentially catalytic sites and poor activity thus far.
- Future plans not well laid out. No specific target provided and effect of high surface areas not developed.

Specific recommendations and additions or deletions to the work scope

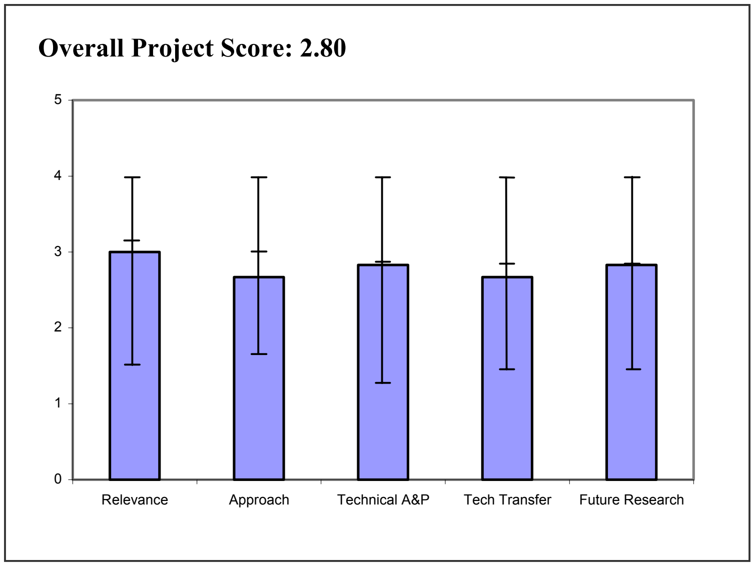
- Keep going. Need to determine acceptable volume increase and catalyst activity required relative to "state-of-art" Pt/C catalyst to meet DOE targets.
- Validate at National Labs (when performance levels warrant).
- Using projected catalytic activity, researchers should calculate the catalyst loadings to achieve performance compatible with Pt catalyst.

- Add better planning for next year. Need specific milestones. Not clear from this presentation.
- The project is co-coordinated with FC4 and FC11 but only contains one specific collaboration with Dalhousie for combinatorial screening. The presenter did not emphasize these aspects and this should be developed in the next year. The fundamentals underlying this work are being kept a little too unclear to justify the large amount of public funds. Clarify this for next year.

Project # FC-18: Novel Non-Precious Metals for PEMFC: Catalyst Selection Through Molecular Modeling and Durability Studies

Popov, Branko; University of South Carolina

Brief Summary of Project



The University of South Carolina (USC) will synthesize novel non-precious metal electrocatalysts with similar activity and stability as Pt for oxygen reduction reaction (ORR). They will focus on high activity for ORR, mass production methods, corrosion resistance, low cost, and improving understanding of reaction mechanism of oxygen reduction on non-precious catalysts. Supporting tasks include theoretical molecular modeling, electrochemical characterization, structural studies (XPS, EXAFS, XANES), identifying the correlation among the catalyst composition, heat treatment and catalytic sites for oxygen reduction, and demonstrating the potential of the novel non-precious electrocatalysts as a substitute for Pt currently used in MEAs.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Very focused on one critical barrier.
- Work is relevant.
- Addresses cost, durability and performance issue for cathode materials.
- Interesting approach based on combination of fundamental studies and synthetic methods.
- Program addresses methods for NPM catalyst and is important.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Approach is a "wish-list." Tasks listed are very large and difficult. For size of budget, doubtful critical gains can be met in allowable time.
- Technical feasibility needs include stability of catalyst and impact of poisoning of membrane.
- Combination of modeling and experiment may accelerate catalyst development. Cost comparisons probably not entirely accurate since some of the organometallics could come down in price if mass produced. Needs to incorporate some additional analytical techniques to really understand what they actually have.
- Approach is logical and consistent.
- Well structured approach that should answer key questions regarding performance capability of catalyst.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.83** based on accomplishments.

- Large amount of data acquired for short time of project. Good sign. Good quality data.
- Good progress. Prior graphic suggests much understanding still in front of team.
- Many others have demonstrated issues with use of Fe; why are they using it? Results are very preliminary -- a lot of work still to be done. Need to move beyond only echem characterization to see if these systems are truly feasible.
- Good progress, benchmarking and comparative studies.
- Claims performance equivalent to Pt on RRDE. This should be quantified in "real" fuel cell.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- For basic R&D like this, the academic interaction is good.
- Collaborative effort with CWRU and Northeastern, but they don't seem actively engaged in the effort at this point. Other interest (industry) not likely until proof of concept demonstrated.
- Collaborators are all excellent researchers and the interaction should provide good path/results from the studied materials.
- Good academic collaboration but needs industry group.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.83** for proposed future work.

- Proposed work on target to meet goals of program. Ambitious plan for next 12 months.
- Too broad. Proposed future work doesn't indicate exactly what they plan to do based on current results. What will the initial modeling studies focus on (current MX/C materials, planned N-containing precursor material, etc.?).
- Good plan for future work.
- Addressing immediate issues.

Strengths and weaknesses

Strengths
- Broad spectrum of technical issues are being addressed by a solid team.

Weaknesses
- Past experience of fuel cell catalyst development might cause one to question whether just transition metals on carbon can achieve the targets.
- Difficult to understand sometimes. Should include a "take-home message" bullet on each slide in addition to the data plots. Approach seems primarily empirical - don't see how all the pieces (catalyst synthesis and testing, modeling, characterization) are going to be pulled together.

Specific recommendations and additions or deletions to the work scope

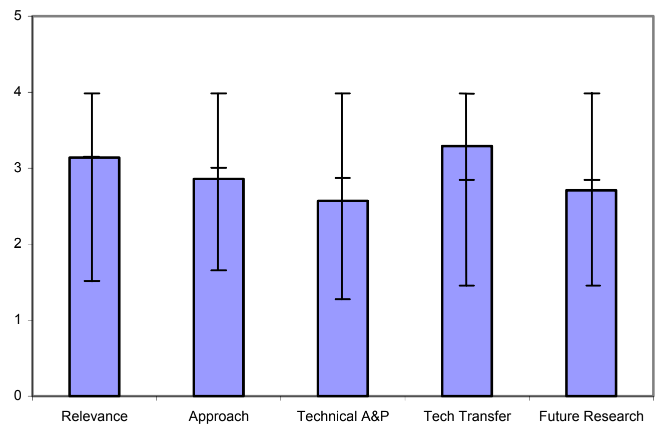
- Pick a class of materials and understand it before beginning a new area (MX/C vs. N-containing) or provide intermediate milestones to determine how long the effort in one class will go before a go/no-go target is either met or not.
- Surprised by claim non-precious metal catalyst with performance equivalent to Pt under RRDE conditions. Key question is whether the RRDE are relevant to fuel cells.
- Suggest prioritizing and focusing on fewer more critical tasks.

Project # FC-19: Scale-Up of Carbon/Carbon Bipolar Plates
Haack, David; Porvair Fuel Cell Technology

Brief Summary of Project

Porvair Fuel Cell Technology intends to develop material and manufacturing methods leading to a low-cost carbon/carbon bipolar plate. Objectives are to: evaluate and demonstrate performance within a fuel cell stack; evaluate potential cost of manufacture; develop low volume production capabilities; develop incremental, near-term cost reduction technologies; manufacture 10 kW fuel cell sealed plate demonstration stack; develop and implement comprehensive quality assurance plan; and develop a comprehensive cost model for high volume production.

Overall Project Score: 2.91



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.14** for its relevance to DOE objectives.

- As FC market fails to develop as rapidly as projected, component scale-up projects become less relevant. More emphasis should be placed on component improvement.
- If $10/kW goal is achievable as stated in the presentation, with volume, this will be a significant cost reduction. 95% of current cost is labor; estimated assembly techniques should cut cost to acceptable levels.
- 10kW stack size is not appropriate for future demands, neither is automotive nor is stationary applications. Need to become larger.
- Project focused on developing cost-effective manufacturing method for bipolar plate, a key component of PEMFC system. Scale-up of promising technology developed at National Lab.
- Bipolar plates are an important topic.
- Novel preparation of a key fuel cell component, offering some unusual possible benefits.

Question 2: Approach to performing the research and development

This project was rated **2.86** on its approach.

- Approach has not been clearly communicated. What is definition of success?
- Initial plan to scale-up may have been able to demonstrate low-cost production of bipolar plates - with change in direction. It is not clear how the approach will meet targets.
- Logical move to get out of pilot plant goal of 300 plates/hr. Instead focusing more on effort of cost reduction R&D. However, automation of assembly might not be as straight forward for ensuring repeatability and quality on plates. Effort must be spent here.
- May be the right way to establish the process first, than having a look to adjust to the right size. But maybe it's too late after establishment of process.

- Current focus on cost reductions through near net shape forming and low cost machining options. Addressing important product quality issues including dimensional tolerance, electrical conductivity, hydrogen permeability. Pursuing development of components for sealed plate stack.
- Not clear that ongoing directions of project area is well-defined following abandonment of scale-up. Incremental improvement is not the best subject for government-sponsored research, but large cost-share is acknowledged.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.57** based on accomplishments.

- The project has shown some improvements in production and improved product to leverage but it is not clear if the improvements are good enough to reduce costs and increase durability - need to do some testing showing correlations of better dimensional tolerance with costs -- other factors with durability. Stated that major costs are related to labor and low volume processing, but have not made progress in goals to high-volume processing as was the original goal.
- If data reported is factual, it appears the targets should be met. Dimensional tolerance important significant and impressive.
- Good progress made in achieving desired dimensional tolerance in pilot scale facility. Promising sealing technology demonstrated. Project manufacturing costs consistent with long term cost targets. Operating a pilot production line at up to 10 plates/hr; sold nearly 40K plates last year; original plan to develop 300/h facility would not be supported by current market.
- The tolerance is far too broad for a real application (slide 12).
- After good start in previous years, project seems to be drifting a bit. Start made on getting sealed plates evaluated, but no data shown yet.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.29** for technology transfer and collaboration.

- Collaboration with best-in-class. UTC validates efforts in this program.
- Interaction with UTC Fuel Cells or ORNL will probably get improvement into a fuel cell, although probably only a fuel cell from one manufacturer.
- Extensive collaboration with UTC. Over 40,000 plates purchased last year and used in various product lines. Sealed plates lacking a customer but plans to assemble stack for testing.
- Minimum number of partnerships shown in this review presentation.
- Authors working closely with UTC in PEMFC demonstrations. Scale up of ORNL carbon technology.
- There is apparently already transfer to customers. Why is this funded through DOE?
- Good transfer of ORNL technology to primary customer. Good efforts to transfer to other customers assuming can be brought to fruition.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.71** for proposed future work.

- How will cost reduction be realized?
- Details of future work lacking. Not working on scale-up, not sure what near term cost cutting technologies they are planning to pursue. Appear to be trying to optimize their current production conditions which can not meet DOE targets rather than a system which can meet the targets.

- Continuing cost reduction R&D. More studies into sealed plates is a must, and is addressed in the 10kW fuel cell deliverable. More study into scale up for volume would be nice to see.
- Clear, but small selection of future plans.
- Project appropriately focused on developing new manufacturing strategies that could incrementally lower costs. Authors have identified important development issues needed for viability of technology.
- Plan is good as long as momentum is regained.

Strengths and weaknesses

Strengths
- Showed great technical progress this year. Choice of subcontractors is excellent.
- Appears to be on target for DOE barriers for cost, durability and performance. Close collaboration with UTC/ORNL continuously keeps plates in testing for reliable use data. Dimensional tolerance improvement is impressive.
- Outstanding example of technology transfer from National Lab (ORNL) to industry. Working closely with fuel cell industry (UTC) to identify and meet technical requirements. Making product on scale consistent with needs; plates being sold to developers.
- Tech transfer; material has some unique properties.
- Project is appropriately focused.

Weaknesses
- Market not ready for 10,000,000 units, so scale-up not practical. Approach not well-defined.
- Program goals appear to have changed drastically from scaling up production to reduce costs from labor and low volume manufacturing (the main cost factors) to addressing smaller cost factors. The scale of the program does not appear to be scaled down with the goal.
- By removing the pilot plant deliverable it is possible problems could arise in scale up for volume.
- Meeting cost targets will be a challenge.
- We do not need sales and marketing presentations during the review.
- With abandonment of pilot-facility, won't really develop knowledge of whether cost could be made competitive.

Specific recommendations and additions or deletions to the work scope

- Quality assurance program is pre-mature. Focus on product improvement (performance).
- Project focus seems to have changed from a major scaling-up effort to improving on an already developed technology at a small scale. Technology appears to be already fairly advanced. Stated they didn't scale-up because they couldn't see the volume to support the work at current costs. Suggest funding be delayed until the market is there for them.
- More study towards scale up of manufacturing volume.
- Push to see just how thin a sealed plate could be made.
- Nice progress with dimensional tolerance improvement. Please relate physical property data back to specific goals and/or project requirements.

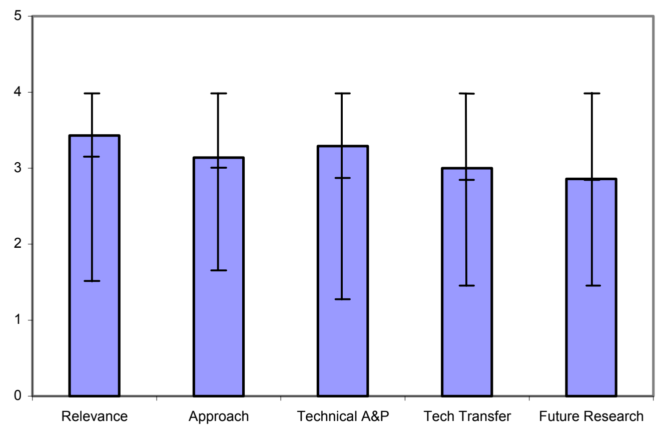
Project # FC-20: Cost-Effective Surface Modification for Metallic Bipolar Plates

Tortorelli, Peter; Oak Ridge National Laboratory

Brief Summary of Project

Oak Ridge National Laboratory (ORNL), and National Renewable Energy Laboratory (NREL) are developing a surface treatment to protect metallic bipolar plates by thermal (gas) nitridation of Cr-containing alloys to form a pin-hole free Cr-nitride surface. Nitrided Ni-50Cr plates will be provided to collaborators for fuel cell testing that is more aggressive than the initial 0.7 V/1000 h. ORNL intends to form protective nitrides on cheaper alloys, such as commercial Ni-Cr base alloys and Fe-based stainless steels. They will scale up efforts and broaden industrial collaborations.

Overall Project Score: 3.14



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.43** for its relevance to DOE objectives.

- Develop a low-cost bipolar plate critical to total FC cost. Metal offers durability in terms of shock/vibration. Identified lower cost alloy options.
- Helps to address cost reduction and durability goals of the program.
- Addresses cost and durability of bipolar plate technology.
- Very little progress shown in the past year.
- Project could improve reliability and durability of this metallic plates made from cost effective materials.

Question 2: Approach to performing the research and development

This project was rated **3.14** on its approach.

- Need to expand matrix of alloys investigated. Do more screening of a low (commercial and non-commercial) using lab methods. More basic work to develop "optimized alloy composition."
- Approach uses low-cost metal alloy plates and a surface nitriding process that should intrinsically cover the entire exposed surface. Industrially established procedure and inexpensive.
- Program must use thin sheet metal (0.003 or 0.004") for nitriding. Thin sheets will warp and look like a potato chip.
- Not clear it was wise spending time to "scale-up" the cost-impossible Ni-50 Cr material, though that may have been necessary to draw the interest of potential collaborators. Need to keep pushing hard on nitriding cheap stainless steels, even through any frustrations. Work towards uniform corrosion testing for the different materials - e.g., get polarization curves for modified passive layer -- not just acid analysis for metals.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.29** based on accomplishments.

- Very good progress in terms of starting to look at new alloys. Promising results for success. Identified needs, but may not have resources to pursue.
- Initial results are promising.
- Excellent progress in overcoming changes of scale-up of nitride manufacturing process. Good progress in understanding influence of nitriding conditions on layer formations and optimization to reduce gaps. Promising results from ORNL/NREL collaboration on N-modified surfaces.
- In two years they have not tested plates in real fuel cell tests.
- Better attention to DOE targets than most others.
- Outstanding, especially in relation to the small budget.
- No new data (at least since Aug 03) shown for nitrided stainless steel - have the initial encouraging results not been repeated?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Participation of industry and other labs excellent. Working with FC manufacturing alloy sources.
- Seems to have reasonable mix of collaborations with industry, potential end users, and research activities.
- Findings by NREL on N_2 modification will be evaluated for transition. Samples will be sent to GM, LANL, DANA Corp, and FCE for fuel cell testing. Working with Gen fuel cell for plate stamping.
- Continue to address real-world test conditions. Company collaborations good. Not really responsive to real world testing -- comment from last year. Need to know test conditions, not just who doing it.
- Seem to be working well with a good range of people. Publishing in a timely manner.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.86** for proposed future work.

- Expand matrix of alloys beyond those proposed. Consider other nitriding methods.
- Look forward to results with lower cost substrates.
- Plan will lead to validation of plates in fuel cell environment and for durability. Advances manufacturability with collaboration. Further optimization of nitriding procedures (theirs and NREL's).
- Should be continued.
- Longer-range tests (2005 analyses of plates from GM and LANL stacks) should be done on cheaper materials, not Ni-50Cr.

Strengths and weaknesses

Strengths
- Potentially good approach to low cost plates. Excellent work with array of partners. Start to expand alloy matrix.
- Mildly encouraging results on economically viable materials.

Weaknesses

- Need more basic work to understand process and then develop optimized alloy and nitriding procedures. Perhaps jumping to scale up too rapidly…although need samples for testing…catch 22.
- This is a high-cost and the process in not simple. Scale-up is a problem since parts will warp if not held down in place.
- Program still isn't adequately weaned from Ni-50Cr model material.

Specific recommendations and additions or deletions to the work scope

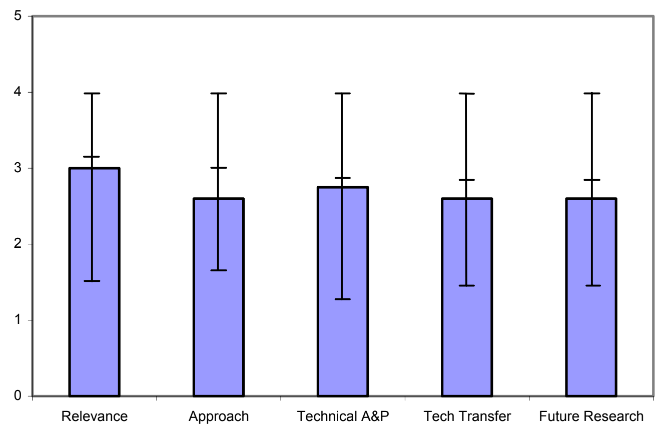
- Expand effort to more understanding and broader alloy matrix. Develop lab methods to screen samples more rapidly.

Project # FC-21: Platinum Recycling Technology Development
Grot, Stephen; Ion Power, Inc.

Brief Summary of Project

This Ion Power Inc. project will assist the DOE in demonstrating a cost effective and environmentally friendly recovery and re-use technology for PGM-containing materials used in fuel cell systems. The initial objectives include development of lab scale processes for the solubilizing catalyst coated membranes, development of lab scale processes for catalyst and ionomer materials, development of test methods to determine vitality of the recovered materials, and partnering with the key stakeholders in this technology area.

Overall Project Score: 2.71



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Although Pt recycling is not one of the specific FreedomCAR goals, it will be an enabler if the vision of high volume fuel cell transportation is achieved.
- There is a clear need to develop the technology to recover platinum group metals from PEM MEAs. The need to recycle Nafion or similar ionomer is much less obvious.
- I do not see a link between recycling and stack durability.
- Necessary activity to understand entire lifecycle of fuel cell hydrogen technology.
- Platinum recycling is critical for life-cycle cost improvements for PEM.

Question 2: Approach to performing the research and development

This project was rated **2.60** on its approach.

- Novel approach.
- Relatively little specific information was provided on how the PGMs would be recovered, so it is difficult to judge the likely efficacy of the approach. Developing a recycle method that doesn't involve pyrolysis certainly a plus. Recycle of Nafion and building MEAs from completely recycled products is questionable. Contaminants are likely to collect in the membrane during FC operation, leading to an inferior recycled product.
- Approach lacks details - there was no mention of how they plan to recover materials.
- Methodology includes the collection of data and information that is valuable beyond recycle, and can provide valuable information about polymer degradation.
- Approach to "remanufacturing" vs. "recycling" seems to be a good way to keep costs down.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Too early to evaluate accurately.
- The project is fairly new, so results are not extensive.
- Process appears more expensive than materials recovered.
- Aging process needs verification.
- Anxious to see FC test results (polarization curves) of remanufactured and recycled catalysts and membranes.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- Limited number of collaborations
- The authors are collaborating with DuPont to obtain new and aged materials for recycle studies, and with a faculty member from Delaware State Univ. External collaborations are not extensive, but probably not unusual for an industry-led project.
- Team needs fuel cell expert to guide testing, aging and analysis.
- Adequate for this task.
- Good industry collaboration w/DuPont as a partner.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- Continued work to understand the issues surrounding PGM recovery from MEAs is considered "good." A key question is whether recovery of ionomer material makes sense, from both cost and performance standpoint. No information was provided on the expected cost of ionomer recovery relative to that of new material produced in large volume.
- Needs to be more well defined.
- Planning on demo of recycled material in fuel cell may be too ambitious for group size and funding.
- The remanufacture and test of these materials is critical to detecting success.

Strengths and weaknesses

Strengths

- Seem to have good understanding of economic and environmental issues relevant to PGM recovery.
- Good plan. Good expertise.
- Excellent relevance to DOE goals. This project is on the critical path and needs to be successful.

Weaknesses

- Processing costs associated with ionomer recovery relative to new material cost not articulated. Because this is a relatively new project, progress is somewhat difficult to judge. Relatively little specific information on flow sheets etc. was provided, due to the proprietary nature of the work.
- Process economics look out of line with respect to materials recovered. Understanding of PEMFC weak. You cannot expect to recover Pt and reuse without reprocessing. Aging under load will change size of catalyst.

Specific recommendations and additions or deletions to the work scope

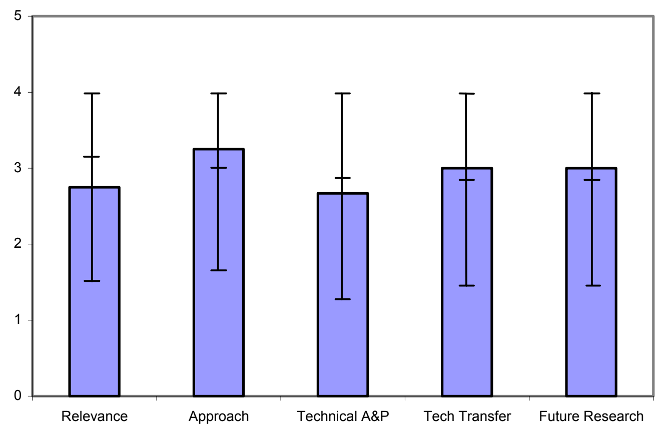
- Recycle of ionomer needs better justification than provided so far -- cost vs. benefits.
- May need to rescope due to dollar limit. May want to incorporate other MEA manufacturers at some point to illustrate range of applicability of process.
- (Milestone chart was too small to read, so comment below may be moot point.) Should add a go/no-go decision based on remanufactured materials achieving X% of original manufactured product, for example, ~ 80%.

Project # FC-22: Platinum Group Metal Technology Development
Shore, Larry; Engelhard Corp.

Brief Summary of Project

This Engelhard Corp. project will examine methods to recycle all precious metal-containing catalysts in a fuel cell "system." A primary objective is to develop a commercially-acceptable, environmentally-friendly process for recovering and recycling Pt and Ru from membrane electrode assemblies (MEAs) – by developing a process that does not emit pollutants (especially HF) and evaluating Ru recovery from MEAs. They will also develop a process for PM recovery from metal monoliths, and maximize precious metal (PM) yield from ceramic catalysts.

Overall Project Score: 2.93



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Reclaiming precious metals is important, but this can be accomplished simply by burning MEAs; recycling involves more effort.
- Although Pt recycling is not one of the specific FreedomCAR goals, it will be an enabler if the vision of high volume fuel cell transportation is achieved.
- Future relevance to President's plan shown through TIAX study. However, how effective and environmentally friendly recycling methods are remains to be seen.
- Recycling is very important to the fuel cell mass production.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Perhaps too many potential ideas. Better scouting is needed before commencement of work.
- Although Engelhard has extensive experience with recycling Pt from automotive catalysts, the approach seems rather complex. Also question the need for the deliverable of a pilot plant – may be premature to plan to build a plant given the current state of technology and timing for fuel cell programs and a H_2 transportation system.
- Working on multiple approaches, and then a down-select is an appropriate approach for creating new technologies. Raises chances for success with multiple concurrent approaches.
- Creative approach. Should consider environmental effects in addition to economic constraints.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Didn't see too much evidence of progress to date. Is Virginia Tech microwave destruction any different from burning?
- Too early to evaluate.
- Tough to say, very young project. Success has yet to be shown in detail. However, VT has achieved interesting preliminary results w/microwave approach.
- Coming along at a good rate.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Nice selection of development partners.
- No tech transfer/Engelhard looking for proprietary information. Multiple instances of collaboration with industry and universities, collaboration vital to their approach.
- Need to collaborate with fuel cell manufacturers to make sure recycling process can be implemented into front end engineering.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- What is contingency plan if no suitable reclamation technologies are found?
- Future research appears sound with appropriate approach. They should look to recycling Nafion as well as PM.
- Sounds reasonable so far.

Strengths and weaknesses

Strengths
- Recycling precious metals is very important, so success in this area is critical to enable fuel cell commercialization.
- Multiple approaches studied raises the opportunities for success. Already demonstrated platinum recycling >90% at low cost, however environmental concerns push for new approach.
- Innovative approach.

Weaknesses
- "Shotgun approach."
- What about impurities accumulating in the fuel cell stack?

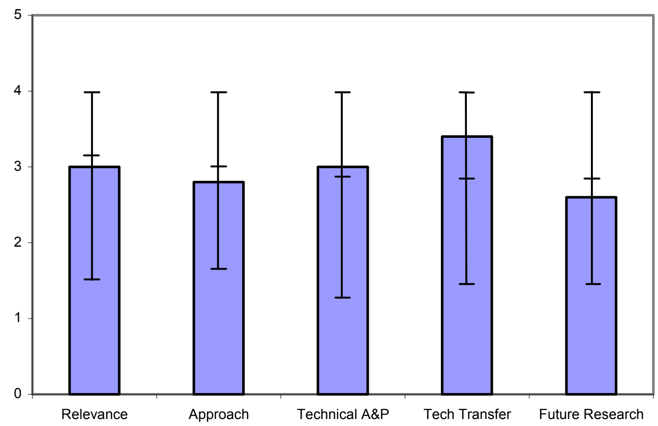
Specific recommendations and additions or deletions to the work scope

- Recycling strategies need to be better evaluated before starting work; this can save time and give program better chance of success.
- Recommend adding Nafion recovery to scope.
- Approach is creative, keep it up but keep in mind environmental effects also.

Project # FC-23: Advanced High Efficiency, Quick Start Fuel Processors for Transportation Application

Chintawar, Prashant; Nuvera Fuel Cells

Overall Project Score: 2.96



<u>Brief Summary of Project</u>

Nuvera Fuel Cells' goal is to develop an automotive fuel processor for PEM fuel cells that is small and powerful enough for vehicle integration. Nuvera developed a new compact fuel processor technology called Substrate-based Transportation Autothermal Reformer (STAR). Its characteristics include substrate-based catalysts researched to reduce volume; developed new technology with leading catalyst companies; FP designed with substrate catalysts / custom heat exchangers; automotive volume achieved (75 liters), under-vehicle; "flat" aspect ratio (height < 9 in); automotive power achieved; and 200 kWth gasoline.

<u>Question 1: Relevance to overall DOE objectives</u>

This project earned a score of **3.00** for its relevance to DOE objectives.

- Funding level omitted.
- Highly focused on application and DOE goals.
- Fuel for fuel cells is the critical issue. This hydrogen generator gives unprecedented ability to move between fuel and hydrogen.
- Efficiency of gasoline fuel processing and fuel cell is too low for commercial applications.

<u>Question 2: Approach to performing the research and development</u>

This project was rated **2.80** on its approach.

- Would like to see durability become a top priority.
- Startup time not met. Weight and energy requirements put additional burden on the fuel cell system.
- This presentation represents the culmination of years of detailed, quality engineering.
- Addressing key issues, such as durability.

<u>Question 3: Technical accomplishments and progress toward project and DOE goals</u>

This project was rated **3.00** based on accomplishments.

- Looks like durability limited to ~1000 hrs (ATR, WGS + PrOx) and needs are 5,000 hours. If durability of one component is improved, durability is still limited by others and could be a maintenance issue.
- Outstanding progress on volume.

- Outstanding progress on cost w/cost estimate at $15-20/kW.
- Collaboration good with government, academic and OEM, but FreedomCAR OEMs not interested.
- Information shared was plentiful. Impact of high sulfur fuel to design and performance was not discussed.
- The packaging is an important design advance.
- Start-up approach is reasonable.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.40** for technology transfer and collaboration.

- U.S. automotive company partner would strengthen effort. Good partner list, could improve technical publications.
- Good interactions at industrial/National Laboratory levels.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- Durability is major issue. Need a plan for catalyst maintenance.
- Not clear what is proposed plan for future research and technical path (durability, start-up time, start-up energy) is not clear.
- This project moves into commercialization, the desired result to meet National goals.

Strengths and weaknesses

Strengths
- Looks like best integrated fuel processor system to date. Cost projections look promising.
- Size reduced to useful level.
- Ability to build on their experience base. Ability to work well together as a team.

Weaknesses
- Issues remain for commercialization, i.e., durability, start-up.
- PROX start-up still slow. CO concentration with PROX at optimal performance is still high using low sulfur fuel.

Specific recommendations and additions or deletions to the work scope

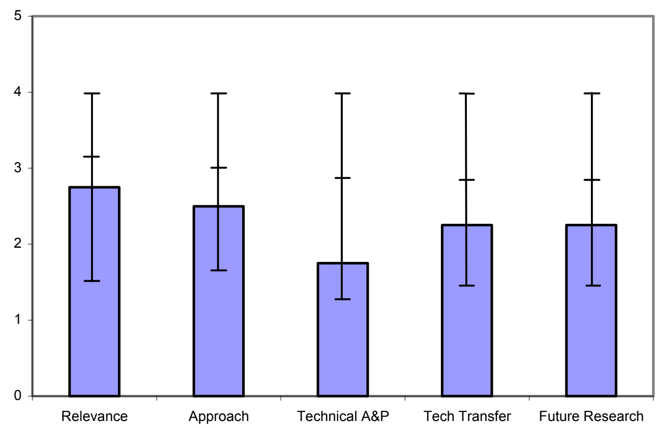
- Improve durability, without increasing catalyst volume and mass.
- Lack of time on test.
- LANL can provide technical approaches for rapid PROX start-up. This technology is within the DOE community. Don't count on higher CO tolerance. Exciting to have DOE-developed technology to enter EC market.
- Complete work in 2004.

Project # FC-24: Fuel Processors for PEM Fuel Cells
Thompson, Levi; University of Michigan

Brief Summary of Project

The University of Michigan project is to develop high-performance, low-cost materials including high capacity sulfur adsorbents for liquid fuels and high activity and durable Autothermal Reforming (ATR), Water Gas Shift (WGS) and Preferential Oxidation (PrOx) catalysts. Objectives are to design and demonstrate microreactors employing high performance catalysts, design and demonstrate microvaporizer/combustor, design and demonstrate thermally integrated microsystem-based fuel processors, and evaluate system cost.

Overall Project Score: 2.30



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Project objective of low cost materials not demonstrated.
- Good goals. Need to get to the state of the art, and succeed there.
- This type of work is very important in order to understand how to efficiently produce hydrogen.

Question 2: Approach to performing the research and development

This project was rated **2.50** on its approach.

- Investigate the unit operations separately rather than bread boarding a small system (100 W). Advantage of micro-reactors (micro channel) is heat transfer, but system uses catalyst coated foams, negating advantage. Unclear how this scales -- size, volume, cost. Start-up time and energy are not addressed.
- Sound approach, but will need to address and demonstrate viable durability and weight, i.e. gravimetric power density. Viability of in-vehicle sulfur absorber needs to be confirmed by OEMs.
- Catalyst and sulfur removal seem commercial. Thiophenome is not removed with adsorbents.
- Poor quality testing with use of local gas.
- This project involves too many different aspects done by several different people/groups, making it difficult to focus on achieving the strongest results.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **1.75** based on accomplishments.

- Sulfur outlet concentration too high at 300 ppb needs to be ~ 20 ppb.
- Little evidence that system integration is being achieved. No evidence of coking in ATR needs to be verified under repeated start-up/shut-down cycles.

- Data shown not encouraging (low conversion, etc.).
- The sulfur absorber prototype is not impressive when compared to system size and other work which has been done.
- Few details are provided on the microchannel work by which to gauge progress.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.25** for technology transfer and collaboration.

- Partner list could be improved by interacting with a system integrator.
- Collaborations appear not to have yet been too beneficial.
- The overall project technology and goals are aligned, but the degree of novelty and size of demonstration limit the value.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.25** for proposed future work.

- Future plans slide was for 2003. Start-up evaluation in a bread board system not relevant. 100W system so far from automotive cost estimates will be questionable. Suggest putting effort into the materials development.
- Need to progress to integrated system, measure start-up time, and project cost, size and weight.
- Completion of planned 1 kW bread board unit and complete evaluation would be acceptable.

Strengths and weaknesses

Strengths
- Key issues of fuel processing are addressed.

Weaknesses
- Do not see this as an integrated system. Behind other fuel processor developers.
- Computer modeling might be helpful.
- Too many varied activities are underway and the focus for specific advances that could add to the technical field are not apparent.

Specific recommendations and additions or deletions to the work scope

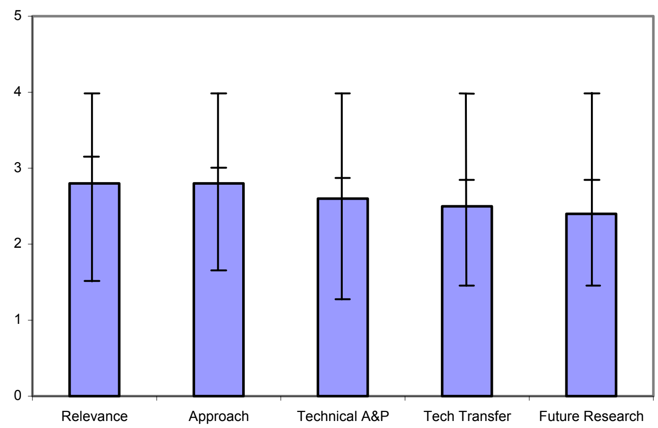
- Concentrate on new materials and material development.
- If durability is not going to be directly assessed, then ensure any projections are based on credible data, i.e., performance loss rate and/or material degradation measurements/mechanisms.
- There is no need to make larger hardware -- the 1kW would be just like the 100W, but bigger. Makes sense to redirect to address specific questions like durability, materials, etc. Needs better diagnostics and verification of data to models.
- Eliminate sulfur absorber work.
- Demonstrate unique technical contributions this finding has provided.

Project # FC-25: Plate Based Fuel Processing System
Yee, David; Catalytica Energy Systems, Inc.

Brief Summary of Project

Catalytica Energy Systems, Inc. is conducting this project to develop new catalytic reactor designs and reactor technology for processing gasoline to PEM quality H_2; developing improved catalyst materials compatible with these reactor systems; designing and fabricating prototype units for each reactor at the 2 to 10kW(e) scale; demonstrating steady state and transient performance; and evaluating rapid start up performance.

Overall Project Score: 2.62



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- Question about automotive dedication to using on-board reforming. This system might be more suited to stationary hydrogen generation as start-up issues seem prohibitive.
- If go/no-go decision for on board reforming is no-go, then this work is slightly less relevant.
- This project is well-focused on meeting the performance criteria established by the Hydrogen Program for on-board reformation. Whether DOE will continue to support research on on-board reformation technologies is in question, of course.
- Not directly applicable to primary route to transportation fuel cells--direct hydrogen. But, as a steam reforming process that could be carried out above 5 bar pressure, could be coupled to a hydrogen purification unit for hydrogen production at fueling station.

Question 2: Approach to performing the research and development

This project was rated **2.80** on its approach.

- This approach does not appear it will make start-up time and energy. Don't see how 80 sec combustor heat-up of SR can also heat up WGS at same time.
- Use of available heat exchanger plates may have reduced costs, but probably reduced efficiency and added mass to reformer. If testing for fast-start, should design for fast start and limit any excess thermal mass and should test an integrated system.
- This project is developing a combination of steam reformation, water gas shift, preferential oxidation, and sulfur trapping to achieve efficient reformation of gasoline. The steam reformer prototype design appears to be one of convenience (use existing heat exchanger plate section) rather than function. Experimental details are a bit scant. For example, form of reformation and combustion catalyst not obvious.
- The steam reformer prototype design appears to be one of convenience (use existing heat exchanger plate section) rather than function.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.60** based on accomplishments.

- Precious metals cost is high. Relatively far away from most targets-efficiency, power density, specific power. Low on presented data, is there durability data other than on PROX? WGS reduction good.
- Have demonstrated durability to 800 hrs for PROX. Still a ways to go, but a good accomplishment. Close to 2005 targets. However, WGS due to larger size, should take longer to bring up to temp than steam reformer-temperature control; also more important in WGS and PROX.
- Steam reformer results look quite impressive. Very substantial progress has been made in lowering start-up time to about 80 seconds. Good progress made in reducing the size of the WGS unit, to under 20 L. Significant progress from last year. No PROX reactor developed yet; results limited to catalyst performance data.
- Good progress made in reducing the size of the WGS unit, to under 20 L. Significant progress from last year.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- No publications/presentations. Lack volume manufacturing system integrator as partner.
- Reasonable number of collaborations with National Laboratories, universities, and private industry.
- In collaborations, Catalytica seems to always be on the receiving end.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.40** for proposed future work.

- Vague on start-up approaches to be pursued.
- Should include test of fully integrated system at end of phase II.
- Future research aimed appropriately at technical targets established by the Hydrogen Program. Startup, transient response analyses needed, including energy costs of startup. Energy costs of startup should be broken down by component (SR, WGS, PROX, HXs, others). Future testing should include repeated start/stop cycles.
- Startup, transient response analyses needed, including energy costs of startup. Energy costs of startup should be broken down by component (SR, WGS, PROX, HXs, others).

Strengths and weaknesses

Strengths
- Start-up of SR in 80 seconds is a significant accomplishment.
- Project has made good progress towards achieving interim startup times to full reformate flow.
- Substantial progress has been made in lowering the required size of the WGS reactor.
- Early work assessing thermal mechanical stress effects. Presumably, generation of kinetic equations for catalysts-this could be fully credited only if the parameters for the equations (at least for same of the catalysts) are shared.

Weaknesses

- PROX still has not made 10 ppm target --most all other developers can do this, at least at one set of operating points.
- Design as fabricated less than ideal flow manifolding for reactants and products is probably not uniform over the plate. Design should be optimized to utilize combustion heat most effectively. H_2S removal is not as easy as authors imply--still a problem if significant sulfur is in the fuel.
- Startup energy costs not yet addressed. Transient response characteristics not yet addressed. Estimations of power density seems to be overly optimistic, given the size of the WGS. Volumes of other subsystems not reported. Fuel processor not tested as an integrated system yet. Components (e.g. PROX) not yet developed.
- Transient response characteristics not yet addressed.

Specific recommendations and additions or deletions to the work scope

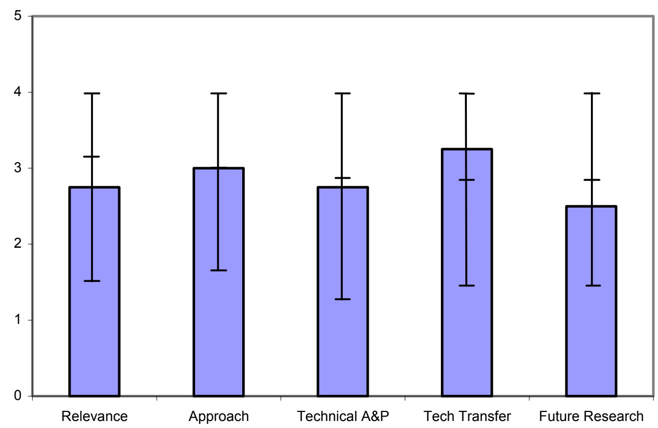
- Test design made for this application. Test complete fuel processor system (SR, WGS, PROX).
- Consider repeated startup/shutdown cycles as part of durability testing. Integrated fuel processor testing needed.
- Address energy costs associated with startup; assess transient response characteristics. Integrated fuel processor testing needed.

Project # FC-26: Quick Starting Fuel Processors - A Feasibility Study
Ahmed, Shabbir; Argonne National Laboratory

Brief Summary of Project

This Argonne National Laboratory (ANL) project will study the feasibility of fast-starting a fuel processor (FASTER) to meet DOE targets for on-board fuel processing (FP). Objectives are to estimate energy consumed (by FP) during start-up; design, fabricate, and demonstrate the fast-starting capability of a laboratory-scale fuel processor; conduct a collaborative effort with DOE labs and private industry (LANL, ORNL, PNNL, PCI, AM, QG, academia); and model fuel cell system designs to estimate the lifetime (start-up and drive cycle) fuel usage.

Overall Project Score: 2.85



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- The project has potential to meet DOE targets for fuel processor, but many hurdles remain.
- Approach is systematic and pedestrian--very straight-forward with standard approach (where is the uniqueness? The innovation?).
- Provides public domain analysis, and should have provided experimental data of relevance to the go/no-go onboard fuel processing decision.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- While this project is closer to DOE targets than other reformers, it does not seem practical for meeting the President's Hydrogen Initiative.
- If continued at present pace, the delivered system will not reach start-up time targets.
- Provides additional efficiency challenges over a fuel cell system with on-board storage systems.
- Using vendor parts, ANL has many opportunities to increase system efficiency and decrease integrated component weight. Have outlined current start-up energy sinks and are ready to optimize. Found new heating strategy for catalyst that should significantly speed heating.
- Standard--no clear innovation; but the work/model is solid. Addressed previous reviewers' comments but number of components not really reduced (?).
- Good planning got many National Labs' and suppliers' technology to come together. A bit more analysis prior to commitment to design for experimental work would have helped (20-20 hindsight).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Start-up time is still not close to requirements.
- Progressive designs have lowered energy consumption, while suffering efficiency.
- Major challenges have been laid out (catalyst heating, start up energy, component weight) and strategies to over come them are in place.
- No PROx reactor developed yet; results limited to catalyst performance data. Power densities/specific power appears to be too high to be consistent with volume of WGS (19L). The SR, PROx, HXs, etc. collectively could not be larger than 11 liters. Did not provide estimates of startup energy, transient response
- Though start-up time has been reduced, it is still not close to meeting requirements. The systems provide additional weight and energy consumption penalties.
- Did not provide estimates of startup energy, transient response.
- Need more information on Δ pressures, flow issues, why the design as configured. Would further design innovations affect results? Multiple air injections -- reasonable for scale-up to practice?
- Very good analysis. Experiments have come along slowly, in part because extreme dedication to efficiency led to a complex, cumbersome design. Heating of downstream components by local air injection and partial oxidation still untested. Good, accurate, honest description of what has actually been accomplished experimentally.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- There appears to be collaboration between academia and the government but not with OEMs.
- Great collaboration w/National Labs and industry. Project combines components from multiple independent sources into a novel design.
- Very solid group of collaborations in terms of components. But system integration-could it be better optimized (to reduce discrete components?).
- Excellent job of coordinating components and concepts from many sources, albeit a bit of a camel (i.e., a horse designed by a committee).

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Future testing should include repeated start/stop cycles.
- Without OEM interest in this technology, the program should reconsider whether or not future research in this area is valuable.
- With future work proposed, ANL seems on target to meet DOE goals with next generations of FPs. Current FP will be used to validate models for future design work.
- Need more specifics: On nozzle (current versus improvement); what else beyond simple reduction in thermal mass; why the current choice of stages?
- Too much hope placed on electrically-heated catalyst support. Alternative means of heating downstream components should be considered.

Strengths and weaknesses

Strengths

- Novel FP design with a high chance for project success. By using components from multiple National Labs and industry, ANL can focus on optimizing FP design while not getting bogged down with component research. Integration is vital.

- Work is solid (but pedestrian); data set very useful. Excellent set of collaborators; strong model to be built upon. Good understanding of feed variations which could affect subsequent operations.
- Thoughtful design and analysis, good application of data on catalysts for FP1. Design would likely give unusually good efficiency, if it can be repeatedly started without damage. A valiant effort.

Weaknesses

- Estimations of power density seem to be overly optimistic, given the size of the WGS. Volumes of other subsystems not reported.
- More creativity in control points (i.e., broader model) with broader range of catalysts.
- Project had very little time and therefore only one shot to get full system database on quick starts prior to go/no-go decision; didn't make it. Had to learn the hard way some things that might have been realized from industrial contractor's efforts-minimize total number of unit operations and don't try coaxial annular reactors until the system has been proven out as a train of linear reactors.

Specific recommendations and additions or deletions to the work scope

- Address energy costs associated with start-up; assess transient response characteristics.
- Beautiful design, continue this work.
- Change of catalysts (or catalytic rates) could alter optional feed conditions-how do you integrate feedback controls? System architecture defines operational controls; need to develop model for feedback controls. Need more $ support to expand program (good solid start).
- If the project continues, replace ATR with a steam reformer, operate at 5-6 bar, and after the shift go to a PSA unit as a forecourt H_2 production unit.

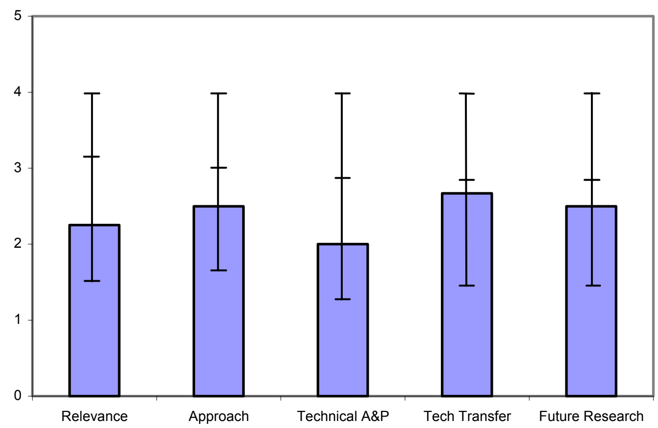
Project # FC-27: Development Status of a Rapid-Cold-Start, On-Board, Microchannel Steam Reformer

Whyatt, Greg; Pacific Northwest National Laboratory

Brief Summary of Project

Pacific Northwest National Laboratory (PNNL) will utilize microchannel steam reformers and vaporizers to demonstrate rapid cold-start of the steam reforming sub-system. Tasks are to develop a prototype microchannel-steam-reforming fuel processor at ~2 kW_e scale that will meet DOE performance targets when scaled up to 50 kW_e; develop reactors, vaporizers, recuperative heat exchangers, and condensers broadly applicable to other fuel processing options; and engage industrial partner(s) to facilitate application of technology to full-scale fuel processing systems.

Overall Project Score: 2.38



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.25** for its relevance to DOE objectives.

- Overall viability of onboard steam reforming of gasoline still questionable.
- This work should be moved to stationary because it is too heavy for automotive needs.
- It is true this work could impart the vision, if successful. However, there is some need to also be contributing novel concepts to reach that goal.

Question 2: Approach to performing the research and development

This project was rated **2.50** on its approach.

- Microchannel processors promise plenty, but fully integrated systems still awaited.
- Interesting approach but needs to scientifically relate back to the DOE targets.
- Data is qualitative with key data sets missing. Gas composition of featured hardware not given. New data (or improved hardware) not available. This makes things impossible to evaluate.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.00** based on accomplishments.

- Fast start reformate flow at 12 seconds encouraging. However, cost and durability not yet addressed effectively. Sulfur remains a problem.
- The start-up energy in the microchannel design shows no advantage compared to ANL, for example.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Valuable partnering has been achieved.
- Supplying hardware is ok, but engineering design, catalytic design etc. should also be done as part of the tech transfer process.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Next steps well identified. Be careful about higher temperature operation vs. Inconel cost trade-off.
- Need to address the issue of density and how can it contribute to the DOE goals.

Strengths and weaknesses

Strengths
- Prospects for achieving <60 s start-up time are good.

Weaknesses
- Computer modeling could usefully complement empirical approach to systems integration.
- The careful combination of good modeling with carefully conducted experiments is sorely missing.

Specific recommendations and additions or deletions to the work scope

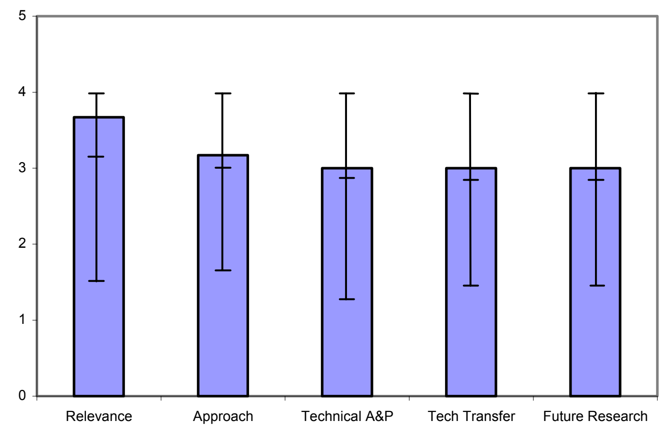
- Durability testing under repeated start-up/shutdown cycling would be very valuable.
- Future work needs to compare dynamic models (reactive CFD) with well-done, quality test data. PNNL can do much more to advance microchannel technology.

Project # FC-28: Catalysts for Autothermal Reforming
Krause, Theodore; Argonne National Laboratory

Brief Summary of Project

Argonne National Laboratory (ANL) plans to develop advanced fuel processing catalysts which will, when compared to Ni-based steam reforming catalysts, be able to process complex fuel mixtures such as gasoline; process these fuels at higher rates; be more resistant to coking and sulfur poisoning; improve our understanding of reforming reaction mechanisms, catalyst deactivation, and sulfur poisoning; and define operating parameters (e.g., air:fuel and steam:fuel ratios, temperature, gas hourly space velocities (GHSV), catalyst geometry) to optimize catalyst performance and lifetime.

Overall Project Score: 3.17



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.67** for its relevance to DOE objectives.

- Development of new reforming catalysts critical to H_2 production.
- Sulfur tolerance promising. Fairly high Rh loadings/difficult to adhere cost targets. Why perovskites?
- An advanced understanding and development of catalyst for more compact efficient reformers to produce H_2 is necessary.

Question 2: Approach to performing the research and development

This project was rated **3.17** on its approach.

- Approach is excellent. Key is to eliminate or reduce PM content without sacrificing activity. On good path to doing this using mechanistic studies and catalyst characterization.
- Selection of CeO_x supports follows previous work/now moving back to aluminas (modified?). Question need for some characterization (e.g., use of neutron spectroscopy vs. XRD). Well integrated with other research on Ce oxide supported SR catalysts.
- Although the project is building on past experience in catalysts, it does not appear that this is actually being practiced. Why perovskites? Why do 600, 900, 1200 cpi honeycomb monoliths need to be investigated again and how can one set of conditions be used for aging process?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Excellent progress on developing new WGS catalysts. Pt-Re & $PtCeO_2$-Re & Pd-Base metal.

- Started in '95; seems have achieved good progress but over long time. Should compare to other catalysts that are being developed (not just those available from commercial partner).
- Because sulfur content of fuels is dropping and sulfur can be removed from liquids, why continue to emphasize sulfur tolerant catalysts?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Not real clear on how much is really being done. Results of Toyota, Nissan and Süd-Chemie evaluations? Papers/patents as a result of work?
- Patent in 2000. Tech transfer to Süd-Chemie. Mentioned problem with patented catalyst.
- Fundamental catalyst research and a demonstration project w/GE and U of MN don't correlate well. More interaction with industry would be good.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Keep up high level of catalyst characterization to understand deactivation mechanisms.
- Will use characterization studies to improve durability/need to improve activity. Seems heavy on fundamental vs. applied research/consider partnering.
- Understanding fundamental catalyst mechanisms, and hearing this information openly will be the greatest progress in achieving commercially viable catalysts.

Strengths and weaknesses

Strengths

- Excellent approach. Combination of mechanistic studies and modeling with catalyst characterization proving excellent insight on how to proceed with WGS development. Monolith vs. foam comparisons used w/all catalysts.
- Demonstrated a good formulation. Not clear that it meets DOE target.
- Test capabilities.

Weaknesses

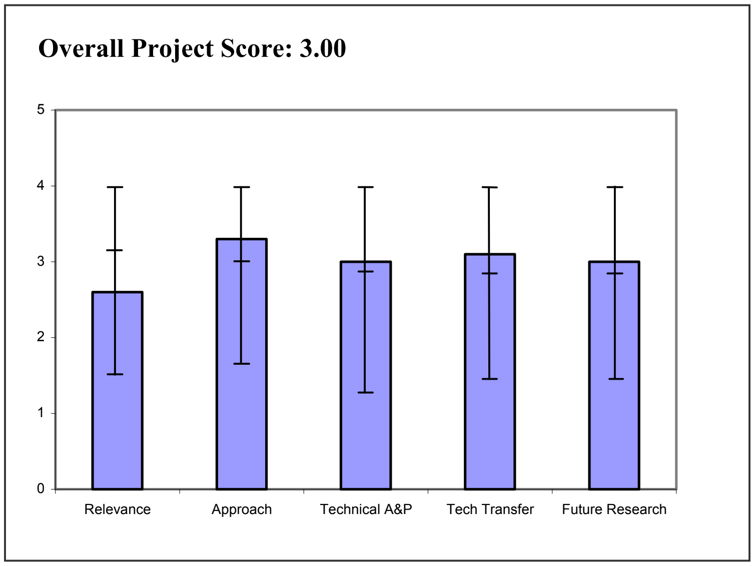
- Durability and ability to reduce methanization and keep CO levels <1% still critical drivers. More of these aspects in next review.
- Heavy on characterization; should more closely tie this part of effort to improvements in performance.
- Test protocol does not seem to adequately address advancing the catalyst mechanism. Past experience should have predetermined a higher temperature at exit of 1st monolith, etc.

Specific recommendations and additions or deletions to the work scope

- Keep up high level of catalyst characterization to understand deactivation mechanisms.
- Seems a bit heavy on characterization and some question about use of methods.
- Examine catalyst properties required for different reaction zones in reactor. Work with other catalyst suppliers/manufacturers to broaden experience.

Project # FC-29: Water Gas Shift Catalysis
Krause, Theodore; Argonne National Laboratory

Brief Summary of Project



This Argonne National Laboratory (ANL) project will develop water-gas shift (WGS) catalysts which, when compared to Cu-Zn and Fe-Cr WGS catalysts, will be more active (higher turnover rates); less prone to deactivation due to temperature excursions; more structurally stable (able to withstand frequent cycles of vaporizing and condensing water); and more resistant to sulfur poisoning. This project is intended to improve the understanding of reaction mechanisms, catalyst deactivation, and sulfur poisoning, as well as define operating parameters (e.g. steam:carbon ratios, temperature, gas hourly space velocities (GHSV), catalyst geometry) to optimize catalyst performance and lifetime.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.60** for its relevance to DOE objectives.

- Enhancing WGS catalytical activity (decreasing the volume of catalyst). Reducing cost of catalyst and having long durability of catalyst (>5000 hours) is critical for commercialization of on-board fuel processors.
- Water-gas-shift will be required for decades to make H_2.
- ANL is doing vital research into chemistry and characteristics of WGS catalysts. Testing lower cost materials that can approach DOE targets for performance/durability.
- Catalyst cost & durability still remain as major drawbacks to onboard fuel processing. This project verifies that!

Question 2: Approach to performing the research and development

This project was rated **3.30** on its approach.

- Good mix of catalyst formulation optimization and catalyst characterization by TPR, EXAFS & sulfur effect. Kinetic rate equations are useful for reactor designs.
- Uses advanced techniques appropriately and effectively.
- Excellent approach combining modeling and experimentation to determine best performing catalysts. Combined with ANL FP catalyst research, knowledge can be leveraged from lessons learned.
- All objectives were appropriate to task--particularly need for structural stability--key to durability.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Gradual progress has been made chronologically from 10/97 to present. Good effort towards improved catalyst activity by changing catalyst formulation. Very good approaches to characterize the catalysts.
- This is a long-term program--could not really evaluate what are current results vs. those done previously.
- Has met all DOE performance/durability targets. Only cost remains to be met. 30,000 h^{-1} space velocity @ 1% Cu with Pt-Re catalysts.
- Progress made in understanding challenges to developing base metal catalysts, but still a long way to go to show viability.
- Coming along at a good rate.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.10** for technology transfer and collaboration.

- Very good interactions with academia (University of Alabama) and industrial partners including Catalytica Energy Systems, Toyota, Nissan & Süd-Chemie Inc.
- A few samples to a couple companies is sufficient.
- Testing and catalyst characterization at university. NDA with Catalytica to evaluate new catalysts. Work given out to Toyota, Nissan, Süd-Chemie.
- Limited interaction with North American industry--why?
- Good collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- It is appropriate to continue the effect of optimizations for both bimetallic PM-BM & BM catalysts. Once the optimization is finished the next effect should be focused on long-term durability testing. Catalyst deactivation mechanism studies are also very important. Address the "quick start" of the developed catalyst.
- Appropriate but should be tied to and funded by industrial partner to help focus efforts.
- Future work focus on lowering cost. Base metal work shows some promise but significant barriers still remain. Work in understanding deactivation methods of WGS catalysts essential to meeting targets.
- Proposed work is appropriate but cost challenge is formidable.
- Sounds reasonable so far.

Strengths and weaknesses

Strengths
- Reasonable progress toward better catalyst activity. Catalyst characterization & kinetic equations.
- Applying knowledge from one field (SOFC) to catalysis issues in another (WGS). Knowledge of appropriate ceramics & metals & their catalytic activities. Ability to easily leverage unique ANL facilities (e.g., synchrotron source) to technical issues of problems at hand.
- ANL is the appropriate location for WGS catalyst work. Can leverage other PM catalyst knowledge to streamline approach/reduce redundant tests.
- Project is well-focused on the right objectives, but could be facing a "Mission Impossible."

Weaknesses
- No durability data; cost issue.
- Tech transfer collaboration with industry. PI should team with someone to get materials out into the world.
- Demonstrating achievement of DOE durability targets--do sufficient candidate catalysts, project resources and time remain?

Specific recommendations and additions or deletions to the work scope

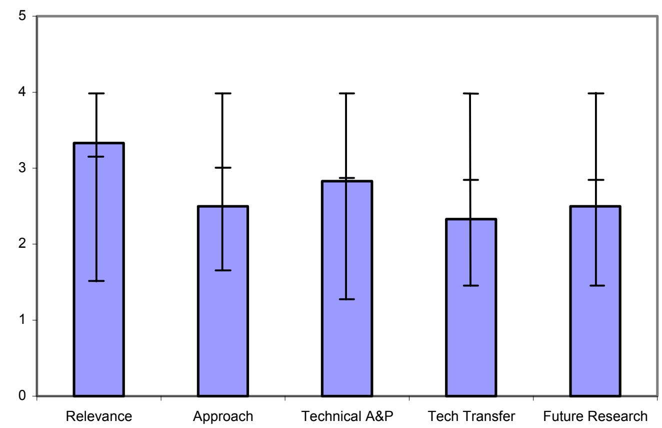
- Once the catalyst formulation is optimized, long-term durability tests should be started ASAP. At the same time, the catalyst deactivation mechanism studies should be carried out. Quick "start-up" strategies should be set up for the optimized catalyst.
- PI is a good scientist doing good work. It's time to move some of these materials out of the lab into practice, if possible to Engelhard, JM and others to transfer technology if it is really worth it. It's time for support of this work to move from DOE gov't to industry.
- Emphasize effort on base metal catalysts, for a finite duration (~ 6 months). Then Review for go/no-go decision.
- What will happen to this project after the go/no-go decision?

Project # FC-30: Selective Catalytic Oxidation of Hydrogen Sulfide
Schwartz, Viviane; Oak Ridge National Laboratory

Brief Summary of Project

The goal of this project is to develop and optimize an oxidative process to reduce sulfur levels to the parts per billion level in reformate using low-cost, carbon-based catalysts. In FY04 Oak Ridge National Laboratory (ORNL) will develop different activation protocols to tailor the carbon-based catalysts, define reactivity tests to determine operational parameters for the selective oxidation reaction, demonstrate continuous removal of sulfur to 'ppbv' levels, and carry out preliminary thermodynamic analysis to verify reaction constraints.

Overall Project Score: 2.70



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Project is aimed at one of the principal barriers to hydrocarbon fuel reformation for fuel cells-sulfur management. This is an interesting alternative to high temperature traps. Similar approach being followed by Berry et al. (NETL), with whom authors are collaborating.
- Performance of downstream components depends on removal of sulfur. H_2S concentrations seem high (explained).
- Removing H_2S is an important goal. 200 ppb may not be good enough. Question -- does this activity contribute to this goal?

Question 2: Approach to performing the research and development

This project was rated **2.50** on its approach.

- Selective oxidation of sulfur may be an attractive alternative to high temperature trapping by metal oxides, which have high bleed rates especially in the presence of steam. Project appropriately evaluated commercial carbon materials first. Also modeled system thermodynamics. Measure of sulfur compounds in very low concentrations can be challenging. The authors should utilize GC-based analytical techniques shown to be very sensitive to sulfur, including chemiluminescence and/or pulsed flame photometric detection. The fact that sulfur compounds were not detected may relate to insensitive analytical methods.
- Good progress w/ORNL catalysts. Should be careful stating that if performance is good that high P (H_2S) it will be good at low P (H_2S) (rate low?).
- Most likely adsorption would be a better approach. No need to oxidize sulfur. Will also lead to hydrogen oxidation-- this needs to be considered. This approach is also adsorption, but after oxidation, where is the benefit?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.83** based on accomplishments.

- New carbon materials show high promise. If validated, this could be a significant breakthrough in sulfur management. Results obtained may be too optimistic because of insensitive sulfur detection methods.
- Would have given higher rating if H_2S concentration more representative of reformer.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- Good collaborations with NETL staff. Discussions beginning with major industrial players. Participating in important carbon conferences.
- Initial discussions but no substantial collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Analytical chemistry of sulfur in low concentration needs refinement. COS is an equilibrium compound in reformate along with H_2S and CS_2, and may be important in determining the ultimate S concentration that can be achieved. Some high temperature S traps work considerably less well with COS than H_2S.
- Should do measurements at lower P (H_2S), otherwise good.

Strengths and weaknesses

Strengths

- Project is working on a critically important problem. Approach is an alternative to high temperature trapping, which has received more attention. Good collaboration with others in field. Excellent results obtained so far with new carbon materials, assuming analytical chemistry is not skewing results. Good progress made over the past year.
- Interesting new material.

Weaknesses

- Analytical chemistry techniques employed probably insufficiently sensitive to sulfur compounds at low concentrations.
- Reaction conditions not that relevant.

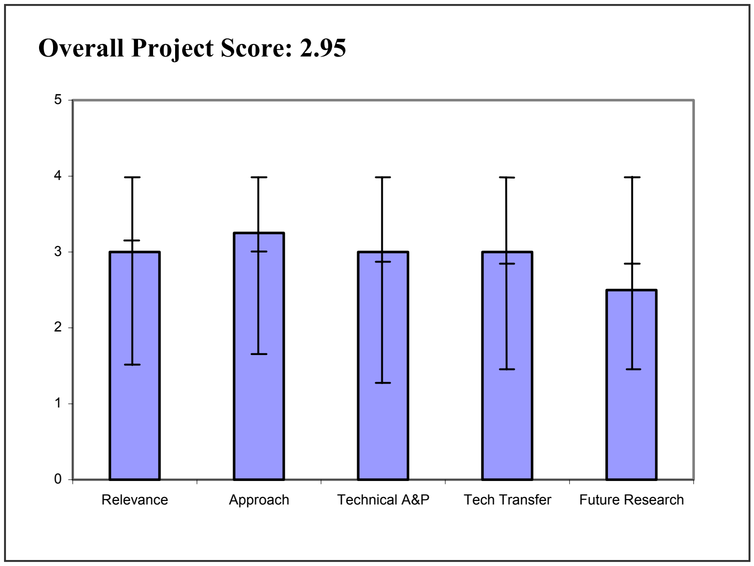
Specific recommendations and additions or deletions to the work scope

- Utilize chemiluminescence or pulsed flame photometric detection methods with gas chromatography to improve sensitivity to sulfur compounds. Comparison of selective oxidation of COS vs. H_2S could be important.
- Need to consider the implications of adding air into reformate -- excess O_2 needs to be managed-where, how, what impact?

Project # FC-31: Development of a 50kW Fuel Processor for Stationary Fuel Cell Applications Using Revolutionary Materials for Absorption-Enhanced NG Reforming
Stevens, Jim; ChevronTexaco Technology Ventures

Brief Summary of Project

In this project ChevronTexaco Technology Ventures will assist DOE in developing distributed hydrogen production technology with significant cost advantages in reduced reformer + PEMFC system operating costs through improved fuel efficiency, reduced capital costs through reduced system complexity, and reduced reformer + fuel cell system costs. The first six month objectives include samples of low temperature reforming and high temp shift catalysts, CO_2 fixing materials, integrated function materials; process simulation; efficiency analysis; capital cost estimates; and reactor tests.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Distributed hydrogen production required for initial implementation of the Hydrogen Economy.
- This technology could provide a solution for stationary fuel cells.
- Project appears to be well-focused on meeting performance targets for converting natural gas to high purity hydrogen.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Reduction in balance of plant, including PSA, noble metals probably best cost reduction strategy.
- Approach of using a carbon absorber with a steam reformer is certainly novel, and may be able to significantly lower the size of a natural gas reformation system. Significant break from traditional approaches to natural gas reformation. Experimental details not very explicit, presumably due to proprietary nature of work. Since a number of commercial reformation catalysts are available from major developers, it is not clear why this project should attempt to develop new formulations. The efficacy of this approach should be demonstrated by using a commercial catalyst for which benchmark data are available.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Uncertain how CH_4, to CO conversion data relates to hydrogen production efficiency. 1500 hrs or

2000 hrs durability still far away from 40,000 hrs where the current durability was measured using a used N_2 purge stream.
- On targets slide, show performance (status) to those targets.
- Some very promising results shown, with all but 1 or 2% of CO and CO_2 removed from the H_2 stream in prototype reactor.
- Cycleability of absorber materials appears quite impressive.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- This is hard to evaluate since most data is confidential.
- Appears to be a high level of collaboration and looking toward testing and operation of hardware.
- Collaborations established with CSMP. Other collaborations are proprietary so difficult to assess. Presentations made at national scientific conference.
- Working with Cabot Superior MicroPowders; program just started. Too early to have the universities/laboratories, etc. involved.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Will need to explore use of combustion gas and its effect on the material durability (CaO).
- This project looks fairly close to being beyond research and towards engineering development.
- Research plan consistent with need to meet performance targets established by DOE. Key milestone should be to show advantages of approach by using well characterized steam reformation catalyst.
- No clear plan to expand to large plant; or sequester CO_2.

Strengths and weaknesses

Strengths
- Novel approach to natural gas reformation. Approach could lead to significant simplification of the reformer system, and perhaps lower costs. Initial results look very promising. Absorber materials appear to survive many cycles without degradation.
- Desire to build 50 kW stationary reformer using natural gas is a good plan to produce hydrogen. Good to have major oil company involved.

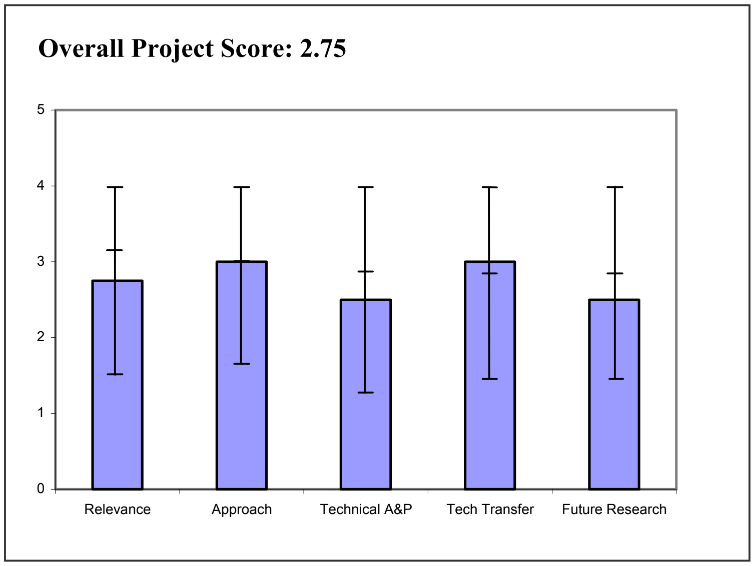
Weaknesses
- Durability is a key technical challenge, testing needs to be done under "real" conditions, including purge. Sulfur removal technology should be discussed.
- Project is in very early stages, so technical progress is similarly limited. Attempt to develop new reformer catalysts is unnecessary at this stage. Efficacy of approach can be demonstrated using well-characterized commercial catalysts.
- To make significant impact, reactor needs to be bigger than 50 kW.

Specific recommendations and additions or deletions to the work scope

- Focus on performance testing with commercial reformation catalysts to demonstrate efficacy of approach before moving on to novel compositions.

Project # FC-32: Advanced Buildings PEM FC Project
LaVen, Arne; IdaTech

Brief Summary of Project



The objective of the IdaTech project is to demonstrate high electrical and overall efficiency, reduced energy consumption, and reduced emissions for hotel and follow-on applications; overcome technical and cost barriers through the engineering, design and construction of an integrated system with advanced fuel cell, fuel processor, and balance of plant subsystems; validate a 50 kW PEM fuel cell system design through field testing at three separate properties to be co-selected by Marriott International, Sempra Utilities and Puget Sound Energy; and use the information provided from this demonstration to target early market entry opportunities.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Demos needed to help illustrate the value of and problems associated with fuel cell applications.
- Why is this project going forward when the stocks have high depreciation?
- Trying to reduce cost barriers using 50kW CHP using low temp membrane for hotel, etc. applications is a tough problem.
- This is a good application of PEM FC in a CHP application.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- 10/1 scale up when MEA optimization is required has high degree of risk. It is extremely difficult to use 5kW size to model parasitic and heat losses for 50kW system.
- But can they accomplish sulfur handling and catalyst longevity? Use of PSA good but requires high pressure. Can Idatech keep costs in hand?
- Approach of starting w/hotel application seems ideal.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- This is a new project, so results are not extensive yet.
- No real significant progress reported in detail!
- Hard to evaluate; they are only in design stage, early at that. The team has selected development sites.

- Clear statement of progress against DOE technical targets. Decent progress made…could be better, but it appears Idatech is being honest.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Should consider an A&E firm to help in beta demo. Scaling PSU seems lightweight?
- Good set of partners.
- Teamed with Hydrogenics using Gore Membrane. Portland State University is a consultant. There are many site selections.
- Good interaction w/suppliers, customers, utility and university.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Very ambitious.
- Details?
- Well planned future on paper; can they accomplish it?
- Future plans could be better flushed out.

Strengths and weaknesses

Strengths
- Well thought out plan to meet technical barriers.

Weaknesses
- Many aspects of technology are either unproven or weak in performance and will be scaled up and operated over some type of duty cycle.
- Details missing in accomplishments and future work. Fuel cell degradation is higher than presented data-what is real case?
- Plan may be difficult to achieve. The fuel cell system needs to be bigger than 50kWe to have significant impact on hydrogen production.

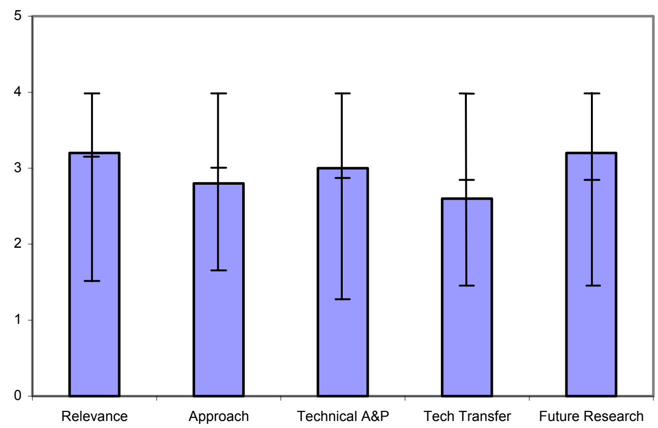
Specific recommendations and additions or deletions to the work scope

- Go/no-go decisions based on demonstrated verification of key elements in plan.
- Share more performance/cost data.

Project # FC-33: 150 kW PEM Fuel Cell Power Plant Verification

Clark, Tom; United Technologies Corp. Fuel Cells

Overall Project Score: 2.96



Brief Summary of Project

The UTC Fuel Cells and UTC Power Stationary Power Plant project will resolve critical cell component, cell stack, and power plant reliability issues. Testing will be conducted in 20-cell stacks, and 150 kW power plants.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Developing FC stationary power system to meet 2010 targets.
- Demonstrating integrated power supply.
- This has nothing to do with automotive but should be useful for stationary applications.
- If successful, clearly adds value.
- Fuel cell development and demonstration necessary.

Question 2: Approach to performing the research and development

This project was rated **2.80** on its approach.

- Working with small 20 cell CSAs to increase durability. Focusing on a novel humidification strategy that goes toward longer cell life. Sealing methods being investigated.
- Fairly straight forward. Could describe component performance. The team seems to have that capability.
- Understands the problems at hand.
- The project objectives seem to repeat UTC's long fuel cell commercialization with PC25 hardware. They need to build on this twenty-year base.
- With all the experience that UTC has in operating fuel cell power plants, why do test plans need to be defined and market analyses, etc. need to be done?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Not much actual data presented but 117 KNAC FC system is operational & testing. Durability of CSAs is being tested now.
- Delivered 160 cycles & 200 hours @ 139 kW CO from fuel processor. 32 hrs continuous power
- A little slow and conservative but definitely steady!
- UTC is describing a very conventional but adequate plan for getting their hardware operational.
- Tests conducted on a 20 cell short stack are important, but a verified acceleration test protocol is very valuable.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- Collaborating with local non-profits in Connecticut. Several power authorities are subcontracted.
- There are partners and some collaboration. However, how can this technology be transferred? It looks like it is a private funding for one company's research and development.
- Subcontractors appear to be vendors; may not be technology transfer.
- Although partners have been identified for demos, collaboration assistance in materials improvement, and applicability of information to other fuel cell suppliers and material suppliers is weak.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.20** for proposed future work.

- Planning on getting systems in use at three test locations. Continuing work in cell durability and 20 CSAs.
- Plan for seals seem straight-forward. Will continue testing.
- Sounds reasonable so far.
- The modeling activities are excellent.
- While the plan for demos appears sound and should be based on extensive experience, the overlap between what is learned in the short stack work and the demos is not clear.

Strengths and weaknesses

Strengths
- High power beta test system running, giving good data for optimization of system components. Bottom-up stack design for durability approach shows promise.
- Interesting work in humidification.
- Testing program appears to be on track to achieve requirements (other than perhaps power).
- Looks like a good transition for UTC with PEM as a stationary market.
- Systems demonstration Seal material improvement work with cycling tests.

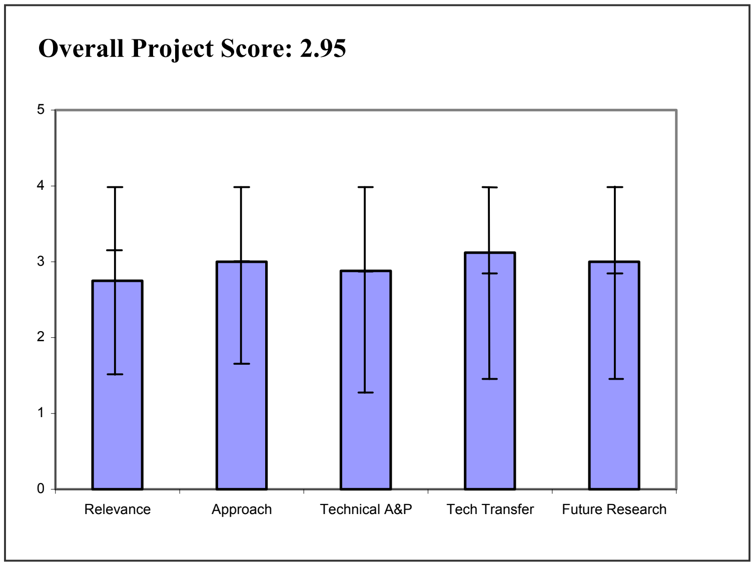
Weaknesses
- Looks like this will only benefit UTC in the power generation products.
- Not enough information that describes shortcomings and limitations found in demo/beta/power plant tests.

Specific recommendations and additions or deletions to the work scope

- Would like to see more collaboration with National Labs, new membrane work. Might aid durability work.
- What is really developed from this funding that contributes/transfers to the commercialization of stationary PEM fuel cells?
- Need to identify the split in resources and effort between materials and demonstration. Need to show relationship between advances in material results and demonstration operations. Isn't there enough information on market analyses?

Project # FC-34: Back-up/Peak-Shaving Fuel Cells
Vogel, John; Plug Power

Brief Summary of Project



The objective of the Plug Power project is to advance the state of the art of fuel cell technology with the development of a new generation of commercially viable, stationary, back-up/peak- shaving fuel cell systems. Project objectives are to develop, build and test three identical fuel cell back-up systems and field test them at three sites including an industry host site to identify technical barriers and objectives to develop a cost-reduced, polymer electrolyte membrane (PEM) fuel cell stack tailored to hydrogen fuel use to develop a modular, scalable power conditioning system tailored to market requirements to design a scaled-down, cost-reduced balance of plant (BOP); and to certify design to Network Equipment Building Standards (NEBS) and Underwriters Laboratories (UL).

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Focus on product development rather than advancing fundamental science and moving fuel cell performance to new level.
- Demos are a necessary part of maturing fuel cell technology.
- Good plan to produce power for back-up/peak-shaving fuel cell.
- Lots of challenges to meet telecom requirements.
- This project will bring hydrogen into the commercial market place. This could be an excellent place to work through hydrogen consumer acceptance issues.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good product development approach and have set up necessary partners to evaluate product in the field.
- Looks good but has several variables that must come together.
- Using industrial grade hydrogen powered fuel cell stack-5kW, but various voltage outputs required-48V and up.
- PlugPower proposes a rather conventional and sound program of product development.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.88** based on accomplishments.

- Plug Power has demonstrated 1000 hrs performance in the field with 1000 start/stops. No performance data shown in presentations to show degradation over 1000 hrs.
- Durability and dependability still have to be demonstrated to some confidence level.
- Made excellent power controller. Initially use batteries for fast start-up, looking at ultra capacitors.
- Early in program, looking at 3 generations; on first one now but have made excellent accomplishments in reducing number of cells, weight and volume by future design.
- 44 V DC backup – worked when telecom source went down.
- The planning is sound. Progress in permitting described. Electric power conditioning appears to be a major advance. It could be very important for distributed generation.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.12** for technology transfer and collaboration.

- For the target market, Plug Power has selected a good team to demonstrate the technology.
- The team seems appropriate for the tasks.
- Working with Bell South, Airgas and Telecordia Labs as NEBS testing agency.
- Market agreement with fuel supplies and customers is important.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Will advance the product design. Introduces electrolysis to generate on-site hydrogen and reduce O&M costs.
- May need to consider back-up in the event the dry cathode stack operation runs into difficulty.
- Continue to develop GenSys stacks, freeze/thaw tolerance evaluation, and dry carbide stack operation. Possible electrolysis made when GenSys not required.

Strengths and weaknesses

Strengths
- Leveraging their extensive field test experience.
- Good team.
- Runs on industrial hydrogen-provides back-up/peak power, when Telecom or other type systems fail. Indications seem to indicate that processes work so far.
- Good technical team. Excellent progress in market development provides story base.

Weaknesses
- Not clear that development of product for niche market with low duty-cycle operation advances the state-of-the-art toward long-term goals. Fuel cell community will not benefit from the learning.
- Several unknowns that should have some back-up or alternative plan associated with them.
- Need to select best GenSys. Have a lot of work to do. Some of their future work may not be feasible.

Specific recommendations and additions or deletions to the work scope

- Establish definite evaluation points for either go/no-go or back-up plan to be implemented.

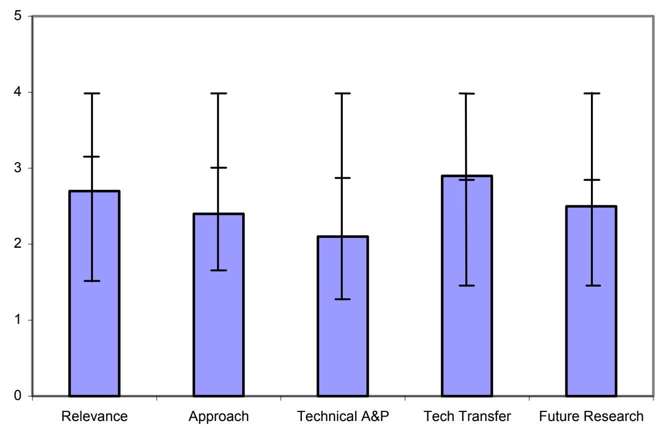
Project # FC-35: Economic Analysis of Stationary PEM Fuel Cell Systems

Stone, Harry; Battelle Memorial Institute

Brief Summary of Project

Battelle Memorial Institute and its team will develop an understanding of the economic, technology, and marketplace drivers needed for commercialization of stationary PEM fuel cell systems out to the year 2015. Their objectives are to evaluate potential stationary PEMFC applications; to identify critical success factors required for commercialization; to develop a technical targets table for each application (cost, reliability, size, response, emissions, electric load versus time, etc.); and to educate stakeholders and raise awareness of National programs.

Overall Project Score: 2.52



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.70** for its relevance to DOE objectives.

- I believe that commercial entities are best at directing the search for market opportunities. If technologies are available, endorsers will seek the best available products.
- Difficult analysis to undertake in a highly competitive emerging technology, but it is essential to try.
- Should have been done before DOE committed scarce resources to stationary electric generation (which involves technology development [low pressure reformers and reformate stacks]) that may not be useful for the main, transportation, goal. But it is better too late than never.

Question 2: Approach to performing the research and development

This project was rated **2.40** on its approach.

- "Expert" focus groups are one approach, but they tend to be opinion driven versus more quantitative assessments of market value & attractiveness. Focus groups can be used to evaluate quantitative analysis of technology benefits against market needs.
- All the objectives are on target and laudable. It is imperative to establish key factors that will create "market pull."
- Too soon to really tell. Project appears totally dependent on quality of input from stakeholders. Does the group actually doing the study have the fuel cell knowledge and experience to judge the quality of stakeholder input? (Though experience in the methodology of such studies [and general wisdom] may be more important than direct technical experience.) Project leaders bring in important experience in economic and technology development.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.10** based on accomplishments.

- Project just started, do not expect much progress. However, 1st expert group appears industry/ university/government weighted rather than end user. Did not show logic used to select back-up power.
- Anyone can do focus groups. Keep in mind that there are many different kinds of stationary power -- and each has its own market (back-up, portable, etc.). An internet sales site will pay significant premiums for 99.999% reliability.
- Early days yet, but baseline information (compelling technologies & benchmarking) will be extremely useful.
- Too soon to really tell. Choice of first panel appeared to ignore the presence of intelligence outside the State of Ohio, probably due to zeal to get started fast.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.90** for technology transfer and collaboration.

- Have lined up large number of participants.
- Well coordinated plan for stakeholder input is clearly in place.
- Nature of project makes it totally dependent on high-quality participation by many collaborators. Might want to draw Battelle's own fuel cell technologists into this process more formally.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- This program focused on market analysis and does not advance fuel cell technology toward targets.
- Let it happen.
- Plans look good provided that the transition is quickly made from designing process to addressing critical questions.

Strengths and weaknesses

Strengths
- Does provide framework for large number of inputs.
- Recognition that cost & reliability are the top two factors is reassuring.
- Project members have diverse experience in running such studies and in development of technologies into business.

Weaknesses
- Advances in fuel cell technology will be the most helpful in advancing commercialization. Commercial entities (developers) are most effective at leading or directing search for markets. Market analysis is based on "expert" opinion rather than quantitative analysis of technology/market fit.
- Results should be more obvious to the reviewer in terms of presentation.
- None evident.

Specific recommendations and additions or deletions to the work scope

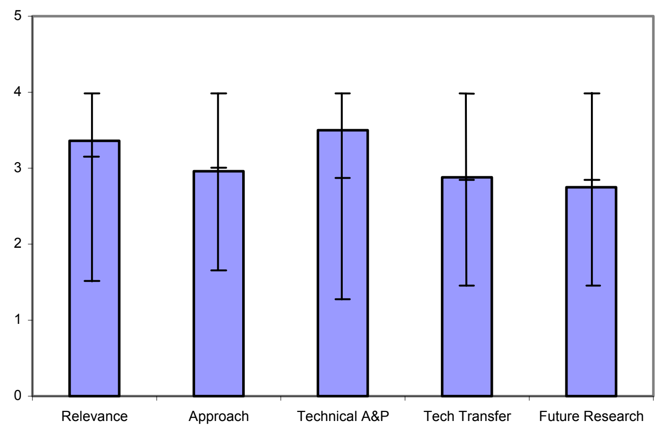
- Project may have to evolve from an apparent passive collection of input from stakeholders to an active exercise of the judgment of those running the study. Only if that educated judgment is actively and wisely applied will this paper study be worth $3 million plus.

Project # FC-36: Fuel Cell Systems Analysis
Ahluwalia, Rajesh; Argonne National Laboratory

Brief Summary of Project

For this project, Argonne National Laboratory (ANL) will develop a validated system model and use it to assess design-point, part-load and dynamic performance of automotive fuel cell systems. This effort is aimed at supporting DOE in setting R&D goals and research directions and establishing metrics for gauging progress of R&D activities. Objectives are to develop, document, and make available versatile system design and analysis tools, and to apply the models to issues of current interest.

Overall Project Score: 3.09



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.36** for its relevance to DOE objectives.

- The modeling capability of ANL provides DOE the capability to assess critical issues, evaluate/choose development paths, and assess performance of products versus theoretical performance.
- Solid work! May suffer on wrong solution of chosen simulated technology in terms of realizability.
- Good relevance overall, but portions (residential systems) not applicable to FreedomCAR.
- Extremely valuable modeling capability has emerged.
- This effort remains a keystone (after all, this is PA) of the FreedomCAR fuel cell program, providing guidance for many other projects.

Question 2: Approach to performing the research and development

This project was rated **2.96** on its approach.

- Integrates component to vehicle models in drive cycle analysis. Validation of models with data from industry or labs. Works with industry to aid in development and target setting.
- Selection of processes that have been simulated should be seen more critical and competitive. Some not promising technologies included from my point of view (e.g., enthalpy wheel).
- Seems too broad. Attacking different elements of the FC/H_2 challenge somewhat randomly (FP, automotive, humidity, CHP/home heating).
- The redirection of this systems analysis tool away from fuel processing focus to other aspects of FCVs will be most helpful & beneficial.
- Thoughtful evaluation of individual cases, and comparisons between them, provides useful guides to experimental programs. Make sure critical assumptions are clearly stated e.g., in slide of costs of CHP, what were $1kW$_e$ and life of fuel cell?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.50** based on accomplishments.

- Thermal & water management & high temp membranes are critical areas. Models help set development approaches and identify key parameters.
- Has quantitative results & characterizes benefits. Draws conclusions.
- Profitable application of ANL's analysis tools to diverse alternative FC system options was well demonstrated.
- Gave solid quantitative estimates on a number of important questions. "What If" analysis applied in productive directions.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.88** for technology transfer and collaboration.

- Involved with Tech Teams & individual development teams.
- Not much -- need to develop tech transfer mechanisms.
- Excellent support being given to other significant FC developers, etc.
- Useful communications with many DOE contractors. Would be good to take advantage of increased systems expertise on FC tech team to improve 2-way flow of information, targets, and assumptions between ANL and tech team.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Important topics selected.
- Consider separating into a couple of distinct projects. Lacks central focus.
- Future work well identified and appropriate. Effects of sub-zero ºC start-up and operation would be informative.
- Individual planned activities seem good. Activities still seem reactive and/or spur-of-the-moment rather than part of a coherent plan, but it's worked this far.

Strengths and weaknesses

Strengths
- Skills of PI and ANL modeling group. Collective experience and history of ANL activity in all aspects of fuel cells & system analysis.
- Solid and reasonable!
- CHP for home consideration very interesting.
- Good understanding of systems engineering trade-off is a big asset. Will pay off in terms of systems optimization.
- Good choice of problems to consider. Good analysis of those problems.

Weaknesses
- Chosen processes/techniques are not all state-of-the-art.
- Seems more about application of models rather than model development. If really about application, then need to work on #4 Tech Transfer/Collaborations.

Specific recommendations and additions or deletions to the work scope

- To bring down weaknesses, involve system engineering capability as well as monitoring and benchmarking competence!
- Narrow down to single theme.
- Link-up with technology validation program to provide real life validation of models would be valuable.
- Seek out mechanisms to get extant and relevant data from non-DOE development programs.

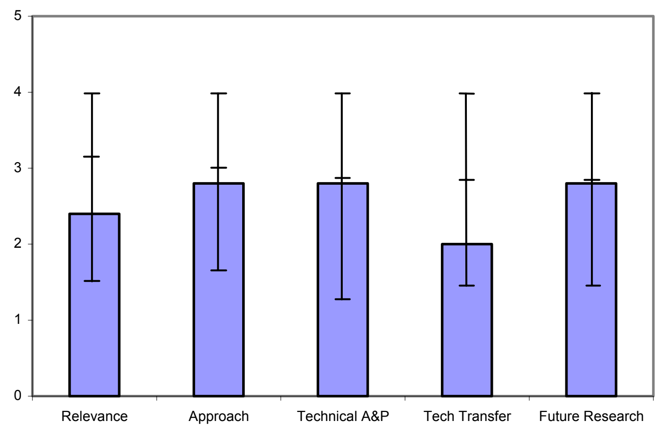
Project # FC-37: Development of a Thermal and Water Management (TWM) System for PEM Fuel Cells

Liu, Chung; Honeywell

Brief Summary of Project

Honeywell's project is to assist DOE in developing a humidification and cooling system for PEM fuel cells in transportation applications. Objectives of the project are to: focus on cathode humidification for a 50 kW fuel cell power system; study pressurized thermal and water management (TWM) system performance; analyze steady-state automotive operating conditions for comparison of concept schematics; establish TWM system/component specification; and demonstrate the performance of a breadboard TWM system with research hardware.

Overall Project Score: 2.56



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.40** for its relevance to DOE objectives.

- Balance of plant is too dependent upon stack design and drive cycle requirements to be developed externally. This work should be done by system integrators.
- Important topic for meeting the President's Initiative, but it is not clear that this project has the appropriate plans to be as effective as possible.
- Premise that such a system can be "outside" and not integrated into a stack system is flawed. However, if such a system is given, the approach is methodical and reasonable.
- Developing novel humidification systems for hydrogen fuel cell stacks.
- This issue is important when space is limited and no combined heat and power options nearby.

Question 2: Approach to performing the research and development

This project was rated **2.80** on its approach.

- Considering the constraints on scope of this project, the approach is good.
- Though plans seem a little vague, with some effort they could be improved.
- Comprehensive and systematic and ranking of development priorities is appropriate. Why "pressurized?" No critique as to why different W.M. systems being considered; some may not be mechanically suitable. So why consider them?
- Look first at SS up to 50 kWe concentrating on cathode humidification use. Going to look at various water management concepts, enthalpy wheel, membrane, porous plate cathode recycle. Emphasizing trying to avoid change of H_2O; also looking at advanced mix.
- The thermal management and water management necessarily are coupled-good approach. Volume is appropriate focus. Considerable experience is out there on membrane humidity and the enthalpy wheel. May not add value.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.80** based on accomplishments.

- Program seems too new to have demonstrated much progress.
- Not clear what performance indicators are being used that also align to DOE goals.
- Appropriate, given the stage (early) of project. No data yet. Development priority-appropriate? (More critical scrubbing is needed.)
- Program in early stages. Have established design criteria for various devices; investigated high & low temperature. Have completed some subscale tests on membrane; probably eliminate cathode recycle.
- Project is just underway. Analysis seems OK.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- This program needs to be much more closely aligned w/real system integrators (e.g., UTC, Plug, etc.). Otherwise the learnings may not translate into real systems.
- Collaboration with OEMs should be stronger. This could help the project to be stronger and more successful.
- No clear commitments from stack developers (or they are not well identified in presentation).

Question 5: Approach to and relevance of proposed future research

This project was rated **2.80** for proposed future work.

- In the future, you must have real valuation, not use "simulation data."
- Future research somewhat vague, but appears to be directionally correct.
- Research plan is appropriate, if premise that a thermal and water management could be effective "outside" of the stack.
- Down select optimum TWM system from 4 different options. Start full-scale "humidifier" test bench. Start component testing in 2005. Complete component testing & demonstrate bread board TWM system in 2006.
- Not much detail. Seems an obvious approach.

Strengths and weaknesses

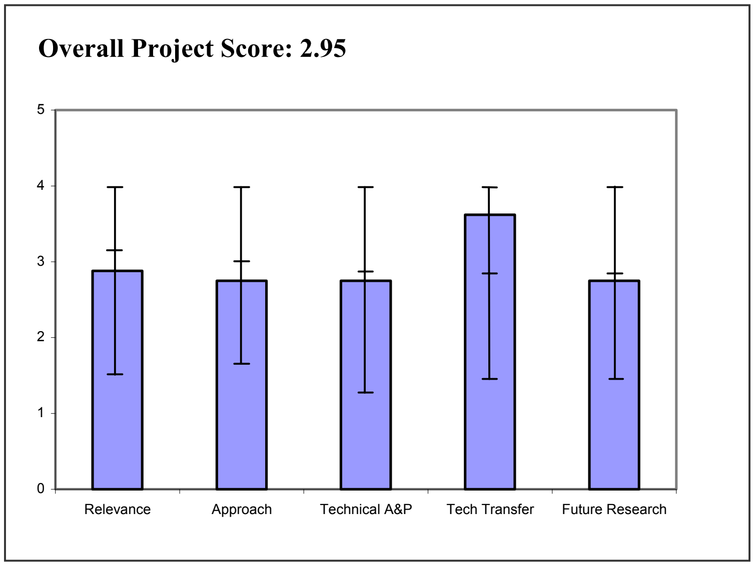
Strengths
- Good breadth in possible system designs.
- Research plan is methodical.
- New humidification systems for hydrogen, fuel cell stacks. Down select best of 4 options.
- Good technical staff.

Weaknesses
- Research too isolated from the real world.
- Premise of a non-integrated thermal/water management system may not be practical. Premature "rejection of cathode recycle option" practical systems may use this approach (in a more integrated fashion).
- Scale-up to large systems and dynamic systems in future.

Specific recommendations and additions or deletions to the work scope

- Adjust scope of collaborations to include state-of-the-art fuel cell system developers.
- Be more specific showing alignment of project performance to DOE targets and goals.
- Be specific about stacks to be needed (which technologies to be coupled with) and source of hydrogen. Project makes sense only when well integrated into entire system. Re-evaluate input criteria (current criteria may be too limiting).
- Work with ANL to establish interface with TWM system and PEM fuel cell stack, particularly absorbent wheel. Honeywell automotive division & advanced "aerospace" H/X i.e., micro channels.

Project # FC-38: Fiber Optic Sensors for Fuel Cell Applications
McIntyre, Tim; Oak Ridge National Laboratory



Brief Summary of Project

The objectives of this Oak Ridge National Laboratory (ORNL) project are to develop small, rugged and inexpensive fiber optic temperature sensors, develop a multi-point measurement capability, demonstrate sensors in an operating fuel cell, meet or exceed all program measurement performance requirements, and establish a path to a cost-competitive commercial sensor (i.e. <$5.00).

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- Temperature sensors are important but not crucial.
- Sensors important system components but not critical to core fuel cell technology.
- Absolutely imperative to develop sensors for automobile fuel cell applications given the large variation in temperature and fuel cell will be exposed to, especially on start-up from T<0 ºC.
- Could provide an important research tool to aid the development of fully-capable fuel cell systems.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- Presentation does not compare proposed technology relative to industry status. Did not see product specification to guide sensor development. Interactions with (stack) developers to understand how sensor would be used were not evident or discussed.
- Excellent approach. I worry how robust these sensors will be in a fuel cell environment.
- Program seems designed to develop this temperature sensor as a device for mass-production. This technology will likely remain a laboratory instrument. Significant advantage over competing sensors requires implementation of multiplexing schemes - these need to be brought forward and discussed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Very thin. Good response time.
- Difficult to judge. Would be informative to benchmark against available technology.
- Initial accomplishments are very good but should accelerate FC tests.
- Nice demonstration of stable, calibratable, fast response for single-point sensors. Still need to demonstrate cases of unique utility.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories
This project was rated **3.62** for technology transfer and collaboration.

- Very extensive.
- Talking to OEMs and have long list of collaborators. Should discuss results or insights gained from collaborations.
- Collaboration with Plug Power is good. Should show timeline on how this interaction will proceed since this work is critical to sensor validation.
- Have a major developer with whom to work closely. Have tried to kick-off significant interactions with other developers.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Logical next steps, including testing in an actual fuel cell.
- Should start testing under fuel cell environment immediately.
- Emphasize multipoint measurements more. Don't spend a lot of time on cost/unit unless a strong pull develops from demonstrated unique utility of prototypes.

Strengths and weaknesses

Strengths
- Good choice of technology to base temperature sensor on. Response time is outstanding.
- Fast sensor not dependent on metal wire leads. Potential for multiposition measurements from a single sensor. Demonstrated (if perhaps misdirected) ability to reduce cost of control electronics.

Weaknesses
- Need to discuss how sensor would be used in application, how application needs are driving development.
- Need to consider mechanical strength. How will sensors be incorporated into a cell platform? Will they be put into flow fields or sandwiched between components (e.g., GDL & MEA)?
- Still need to demonstrate cases where this is an enabling technology, allowing critical knowledge to be generated that couldn't be obtained by other means.

Specific recommendations and additions or deletions to the work scope

- Work with someone from automotive sector. These sensors will need to be robust enough to operate in auto fuel cell environment. Accelerate fuel cell testing.
- Emphasize multi-point temperature measurements. Forget about trying to make it cheap enough for use in production vehicles.

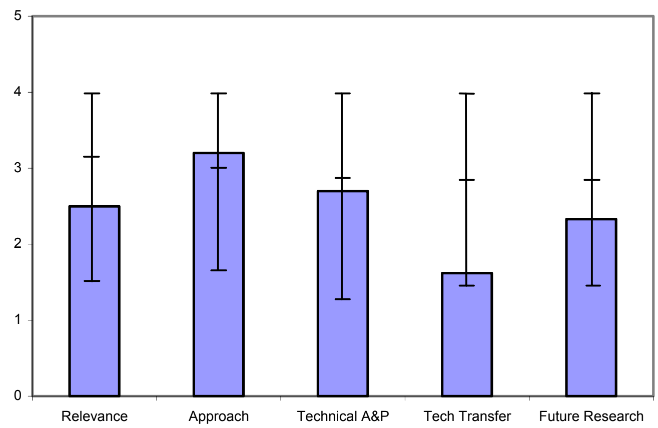
Project # FC-39: Atmospheric Fuel Cell Power System for Transportation

Tosca, Mike; United Technologies Corp. Fuel Cells

Brief Summary of Project

United Technologies Corp. (UTC) Fuel Cells will determine the feasibility of an on-board gasoline reforming 50kW fuel cell power plant for commercial transportation applications based on the industry and DOE targets for commercialization. Their Gasoline Fuel Cell Powerplant Phases include FP1: Integrated Gasoline Fuel Processor (FY02 - FY03) and PP1R: Integrated Fuel Cell Power Plant (FY03 - FY04).

Overall Project Score: 2.47



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.50** for its relevance to DOE objectives.

- Reference depends on go/no-go decision on on-board reformers. Transition path option to fuel cells in transportation.
- Well aligned with original plan but not sure if reformer technology part of the President's Plan.
- Project started before current hydrogen program was put in place. It ends in September 2004.

Question 2: Approach to performing the research and development

This project was rated **3.20** on its approach.

- Integrates reformer with stack into system.
- Discussed CO level increase with larger output (power) demand. Any possible solutions could be discussed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.70** based on accomplishments.

- Presenter clearly defined challenges to achieving targets and need for fundamental advances in catalysts & reformer designs to achieve start-up time and volume targets.
- FPS results right on. However, total power plant still appears to take long to come on-line.
- Running out of time! Especially in terms of system integration.
- Delivered integrated gasoline system weight, volume targets not met. Cost-unknown.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.62** for technology transfer and collaboration.

- No partnerships shown in this review presentation.
- No transfer of technology. No collaborations evident.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.33** for proposed future work.

- 5kW APUs find largest application in trucks and work would have to be targeted to diesel fuel.
- End of program -- not really relevant.
- Is the proposed "hereafter focus" a smaller application (APU 5 kW) a consequence of unhandleable complexity?
- None. Project ends in September 2004.

Strengths and weaknesses

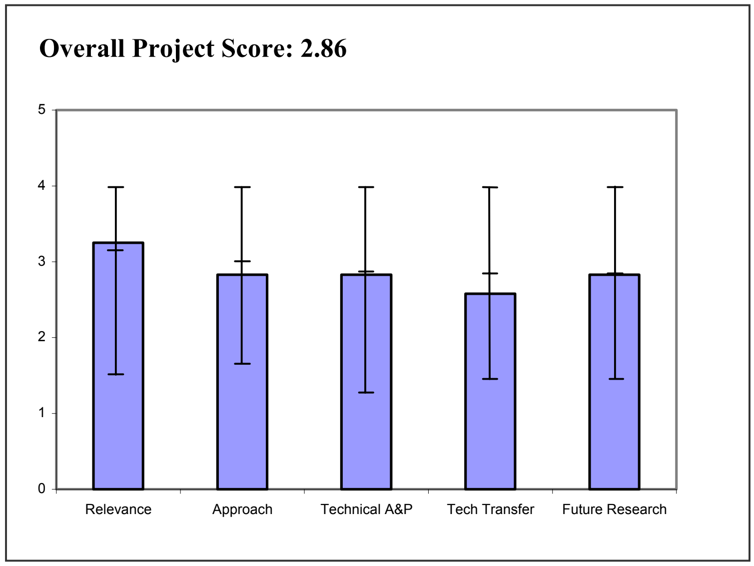
Strengths
- Builds on UTC strengths in system integration of reformers and stacks. Leverages UTC stack technology.
- Best safety slides of whole conference.
- Measurement data: Seem to be reliable and reasonable.
- Project demonstrated the difficulty in meeting target with on-board reformers.

Weaknesses
- Program does not advance overall knowledge of the fuel cell/reformer community.
- No "next step" suggestions of how to visualize the solution to 30 second start. No inclusion of cost projections.
- The review presentation does not show whether the goal of feasibility of 50kW Reformer is reachable or not.
- Breakthrough will be required to go forward with on-board processing. Start-up time is too long. Control of CO concentration difficult at higher power transients.

Specific recommendations and additions or deletions to the work scope

- Interesting to note that the best" "state-of-the-art" reformer technology is suggesting completely different approach to reforming problem of 30 second start.

Project # FC-40: Cost and Performance Enhancements for a PEM Fuel Cell Turbocompressor
Gee, Mark; Honeywell



Brief Summary of Project

Honeywell is developing an optimum turbocompressor configuration for integration into a PEMFC that reduces costs while increasing design flexibility. Honeywell is utilizing their expertise in automotive and aerospace turbomachinery technology, variable nozzle turbine inlet geometry, mixed flow type compressors, and contaminant/oil free, zero-maintenance compliant foil air bearings to achieve this objective. The final product will have a modular design, high efficiency, and variable speed motor-controller topology design.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- For transportation systems based on elevated pressure need an efficient compressor/expander.
- For the pressurized fuel cell systems, the air management subsystem is a critical component. Successful completion of this project would greatly help to achieve fuel cell system performance targets.
- Low-cost, durable, lightweight and compact air delivery machines are one of the key enabling balance-of-plant components for successful fuel cell commercialization.
- A new compressor (expander) can assist in many hydrogen technologies, i.e., addition to the target automotive fuel cell.
- This project is vital, as it addresses one of the major balance-of-plant issues for FC systems.

Question 2: Approach to performing the research and development

This project was rated **2.83** on its approach.

- Project started in 1996 still in redesign/build/demonstrate mode. Need to rethink deliverables of this project. Specific hardware or design tool to rapidly tailor compressor/expander for each developer.
- Building on their past experience, they have identified and are addressing the key performance issues, such as variable nozzle geometry for low-flow and low-cost motor and motor controller.
- Need to team with other experts who could provide unique insight to design and power aspects.
- Approach is sound. Likely requires flexibility in allowed operating conditions to apply to FC developer's system.
- Builds off of a quality technical base.
- Approach seems sound.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.83** based on accomplishments.

- Back to the drawing board again with further modified product available for test in near future.
- Based on discussions with fuel cell developers and their own analyses, they are addressing various details, such as liquid cooling, sensor-less control systems, high power density motor, very high transient response, all the while maintaining high compressor-expander performance.
- Unclear from slides: Complete weight (including controller) compared to target. Provide efficiency curves. Show power (mechanical and electrical) over design and turndown operating condition. Cost estimate? Provide data.
- Compressor/turbine seems to have met performance targets. Weight and volume also look hopeful.
- Excellent technical progress to date.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.58** for technology transfer and collaboration.

- Specific interactions with OEM not discussed. OEM inputs are needed to specify product for demonstration.
- Their discussions with automotive OEMs and other developers have led them to focus on issues of cost and durability/reliability.
- Interactions need to be improved.
- Appears adequate. Will C/M/E be supplied to developer using existing program funding? Provide more data.
- What is the content of the interactions with FC Power systems and automotive OEMs?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.83** for proposed future work.

- Work will bring project to conclusion.
- Their proposed activities should bring the project to a logical and successful conclusion, assuming that the hardware tests out as projected.
- Details lacking.
- Good but potentially relies on a FC developer well-matched to the turbocompressor. Either turbocompressor needs to be flexible, or should build test bench to simulate FC. Preferably both.

Strengths and weaknesses

Strengths
- Knowledge of turbo machinery design and manufacture.
- Use of automotive and aerospace expertise in development activities. Scalability is built into the design philosophy.
- Honeywell & Garrett's extensive background in aerospace and automotive air machines. Airfoil bearings promise of clean pure air to fuel cell. High speed leads to compact package.
- This project seems to be on track to be technically very successful.

Weaknesses
- Will the cost reductions be adequate for fuel cell developers to use this machine?
- No comparison to current state-of-the-art provided. Why is this approach better?
- Can air bearings achieve automotive stop/start/drive cycle durability requirements?

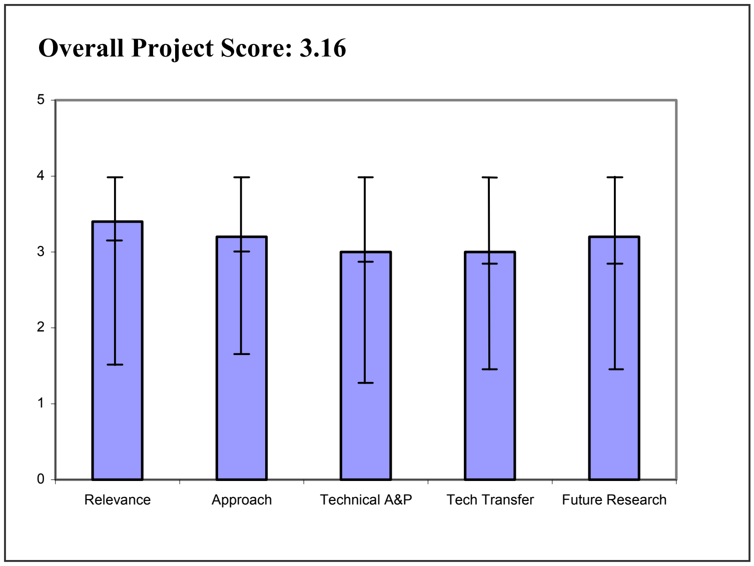
Specific recommendations and additions or deletions to the work scope

- Other labs have expertise in turbo machinery for air handling. Contact ORNL, SNL.
- Ensure that final design allows for the flexibility of various operating conditions: e.g. different pressures, system pressure drop, expander temperature and water content. Test bench should be capable of evaluating turbocompressor performance without need for actual FC integration.

Project # FC-41: Development and Test of the Toroidal Intersecting Vane Machine (TIVM) Air Management System
Bailey, Sterling; Mechanology, LLC

Brief Summary of Project

Mechanology's overall objective in this program is to develop the innovative TIVM concept into working compressor/expander/motor hardware that satisfies the FreedomCAR guidelines. Objectives include building on the prior demonstration of the basic functionality of the TIVM; developing a detailed design for a prototype compressor/ expander; and beginning fabrication of the prototype compressor/expander with the selected features.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- Better, cheaper, more efficient compressors are critical to increasing power density (and ultimately decreasing system cost) requirements.
- Air management is a key component of successful fuel cell system development. The TIVM approach is a novel one, and, if successful, may well find use in many other applications.
- Blower is often overlooked, while still an integral part of FC system. Fabricating design for brand new blower/compressor.
- Highly recommend to have a TC specific air supply due to its high impact to the overall efficiency.
- Develop TIVM C/E for hydrogen stacks. Designed to meet FreedomCAR objectives. Reduce parasitic losses.

Question 2: Approach to performing the research and development

This project was rated **3.20** on its approach.

- Nice approach: evaluate items critical to quality, fabricate and test on devices optimized through mathematical modeling. Actual working device to be delivered validates program.
- Conceptually, this is a high-efficiency positive displacement machine. The important focus areas are limiting air leakage without increasing friction losses, and improving aerodynamics to decrease entrance and exit losses at the ports.
- Taking concept blower from design phase to reality. Optimizing seals and machining techniques to assemble working prototypes. Very elegant design.
- Theoretically well done. Mathematically approaching and revising since 1985.
- Concentration on 80 kWe hydrogen system. Refining C/E prototype. Positive displacement on flow like turbo compression with turndown.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Modeling first and then testing is paying great dividends in the progress.
- Significant conceptual design improvement identified. Actual new design hardware is yet to be built and its performance verified.
- Amazing results if the numbers projected hold.
- Demonstrated low friction. Demonstrated can meet required pressure. Demonstrated can do this at low speed. Expander now does both compression and expansion.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Are adequate relationships established that will result in a drop-in replacement if program is technically successful?
- While no specific tech transfer contacts have been identified, it was clearly implied that there is considerable industrial interest in their machine.
- Technology has possible broad use implications for several applications. Closely connected with ANL and car OEMs.
- Many "private investors." Collaboration with program.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.20** for proposed future work.

- The proposed work is a logical progression from where they are to where they need to get to verify performance of their new design.
- Optimizing seal selection and final design. Fabricate and test blower. Already obtained a development contract for the technology for other applications.
- Comparison needed to other technologies of air supplying. There must be a reason that this idea just now begins to grow 20 years after its invention.
- Going to develop full machine by end of 2004. This will be proof of pudding.

Strengths and weaknesses

Strengths
- Very good technical progress in a critical area.
- The concept is flexible for a variety of pressure ratios. TIVM is a positive displacement device that has performance similar to rotary machines. Should offer high performance even at high turndowns.
- Elegant design, wonderful possibilities. Further development fund received for other applications.
- Requires only "compliant seals" to eliminate leakage. Expander vane now does both compression & expansion, lowers friction. Have porting device to allow "floating pressure."

Weaknesses
- If mathematical models are wrong, program may not meet goals within established timelines.
- Will cost targets be met? Does it require any motor development? Making pressure ratio flat with flow rate will decrease efficiency?
- Only if machine doesn't work.

Specific recommendations and additions or deletions to the work scope

- Keep up the good work.
- It is an imperative concept that should be pursued to completion.

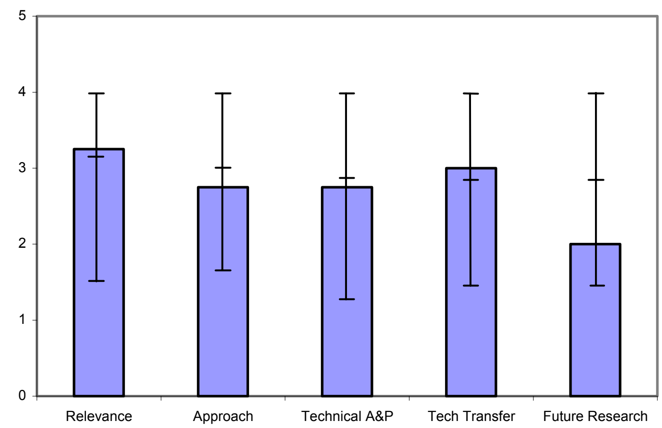
Project # FC-42: Development of Sensors for Automotive PEM based Fuel Cells

Knight, Brian; United Technologies Corp. Fuel Cells

Brief Summary of Project

United Technologies Corp. Fuel Cells (UTC) and its team are developing physical and chemical sensors for PEM fuel cell power plants for automotive applications aimed at low cost (<$20 / sensor) at 500k quantity. Work in chemical sensors includes process streams before, in, and after reformer and before and in fuel cell stack; CO, H_2, O_2, H_2S, NH_3 types; and safety (H_2). Physical sensors focus includes temperature, pressure, relative humidity, and flow.

Overall Project Score: 2.75



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- For widespread deployment of fuel cells in a variety of applications, it will be important to develop reliable, responsive, inexpensive sensors for a variety of chemical and physical parameters.
- Need for reliable, low-cost sensors is definitely relevant for industry to become "real."
- Sensors for diagnostics and controls for fuel cells are very important to meet efficiency goals.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- The approach seems to be to evaluate currently available sensors and determine what performance improvements are needed. There was little discussion of how these improvements will be attempted.
- Approach is broad and comprehensive (too broad?). Well coordinated. Need more information on sensor mechanism/chemistry, etc.
- A commercial sensor supplier list including recommendations for the best candidates is lacking. Targets for response times of chemical sensors not indicated.
- Although sensors development for fuel cell system functions is necessary, it is not clear that the requirements or goals are well-defined, and these goals/targets are commensurate with more efficient operations.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Hydrogen sensor response has been quantified. Some prototype safety-related sensors have been fabricated for testing. Process gas sensor work (for H_2O, CO, H_2S, etc.) is also progressing well.
- Data generated has identified future improvements/steps needed; also addressed previous reviewers' comments.

- Progress is shown, but hard to evaluate comparing figures with test results and project timetable. Results for physical sensor not shown. Sensing lowest level of H_2S (0.05ppm) is absolutely necessary.
- Still difficult to assess technical progress. Test conditions used to show sensor responses aren't correlated to expected "real" conditions and goals.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- The team itself consists of industrial, research, and academic organizations. Thus, tech transfer should be a seamless process as the sensors reach maturity.
- Strong collaborators with institutions "up" the food chain (materials, suppliers, research institutes); need improved partnerships with end users (beyond UTC).
- A database of the best existing sensing technology is lacking.
- In order to expand the cadre of contributors, and determine whether certain sensors can be improved within their limits, other suppliers could be valuable contributors.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- Although little specific detail was offered, it appears the team has a rational work plan for continued development of the sensors.
- Improvements well-stated, but need to flesh out more technical details (more specifics and deliverables and numbers).
- No plans for the future research presented.
- Not clear.

Strengths and weaknesses

Strengths
- The lead PI is a fuel cell developer so that the developed sensors should be consistent with real-world hardware needs. There is interaction with Honeywell and ORNL who are also developing sensors.
- Shows good progress; strong collaborations.
- Project covers all aspects of sensing for FC systems.
- Addressing need for sensors, both physical and chemical system, capable of testing sensors in a unified way.

Weaknesses
- The step-down response times appear to be long for some of the sensors.
- Need better definition of future programs, more end-users signed up for follow-up; more critical down-selects (where appropriate). Develop more specific recommendations, be more definitive in conclusions.
- Not clear separation between researching and evaluating sensors and sensor development.
- Not clear what goal is-refine targets for sensors? Refine sensor packages? Refine sensor performance?

Specific recommendations and additions or deletions to the work scope

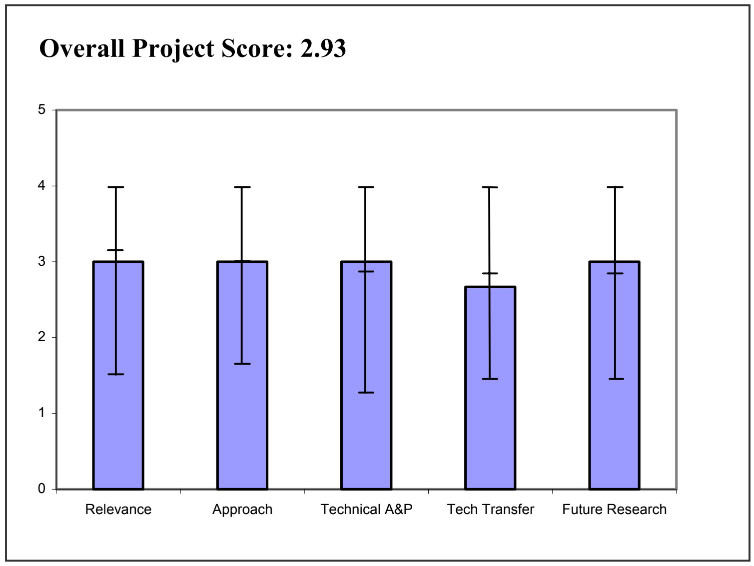
- This work is useful since the developed sensors may find use in other industrial applications.
- Develop more options, if data to-date show need for different technologies. Clarify future challenges; prioritize key challenges (e.g., are cross-sensitivity issues top priority? Or sensitivity? Or response times?).
- Define range of transient test conditions possible in testing. Describe performance with respect to proposed steady-state and transient targets and limits.

Project # FC-43: Sensor Development for PEM Fuel Cell Systems

Magee, Steve; Honeywell

Brief Summary of Project

This project is leading to the creation of physical sensors suitable for monitoring and controlling a polymer electrolyte membrane (PEM) fuel cell system. Key tasks include defining sensor requirements, developing sensors, building and testing prototype sensor, and field testing.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Sensors all seem directed at internal to systems -- inexpensive external safety sensors should be included in development.
- Have identified technical barriers for fuel cell system sensors.
- Successful development of process and safety sensors is necessary for fuel cell systems to be commercialized.
- PI appears to understand how fuel cells operate and what parameters are important to measure and control.
- This research topic is very important to the automotive industry.
- Project covers the key physical sensing needs in fuel cell systems.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good approach to define requirements.
- Use of existing technologies should speed development and limit costs. Some durability testing under H_2 environment/fuel cell should be performed to ensure embrittlement doesn't affect pressure sensors.
- This project is primarily addressing physical parameter sensors. The project is exploring how laboratory-type sensors can be modified/adapted as low-cost packages for field use.
- Understands the problems at hand. But the approach seemed uninnovative.
- Results of market survey not presented (in terms of current market products). Clear list of sensor targets.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Don't show much technical validation data, but indicate good progress. 3-4 s response with resistance temperature detector reasonable.

- Need better response time for temperature sensors, especially for control of fuel processor during startup. Tests in condensing environments and temperature compensation/control at the sensing die are strengths. Flow sensors less advanced than humidity sensors.
- Prototype sensors for humidity and flow have been developed. Same for pressure, pressure drop, and temperature. Response dynamics are yet to be verified.
- Acceptable progress is apparent.
- Progress seems slow for this project.
- Progress consistent with project timeline. Good modeling to support proper design.

<u>Question 4: Technology transfer/collaborations with industry, universities and other laboratories</u>

This project was rated **2.67** for technology transfer and collaboration.

- Should get field testing with UTC or other OEM ASAP.
- The project involves academic, industrial, and fuel cell organizations. The developed sensors should thus find ready transfer to fuel cell systems.
- PI has good set of collaborators especially UTC.
- Should have more than one fuel cell partner for this development. What about the automotive industry collaboration?
- Good collaboration network for addressing various aspects of sensor development.

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **3.00** for proposed future work.

- Looks like plan gets sensors field-tested in appropriate time line.
- Response time for temperature sensors need improvement. If temperature sensors are being used in the fuel processor, the temperature range needs to be expanded to go to at least 850ºC, preferably 1000ºC.
- Future work is consistent with developing the sensors to commercial readiness.
- Plan is good but needs to pick up some speed.
- Not clear when humidity and temperature testing will be carried out. Early testing is key for redesigning and modification.

<u>Strengths and weaknesses</u>

<u>Strengths</u>
- They are factoring in requirements identified by potential customers. Appears to be well executed project.
- Honeywell is a good company and the PI understands the program needs.
- Humidity sensors are the most important. Temperature sensors are not too critical.
- Sensor specifications are clear and cover all requirements.

<u>Weaknesses</u>
- Is there overlap or redundancy with other contracts, such as ORNL or UTC?
- Development rate seemed too slow for what has been delivered.
- Potential problems due to occasional sensor exposure to fuel and air impurities (H_2S, SO_2, NH_3, etc.) has not been addressed.

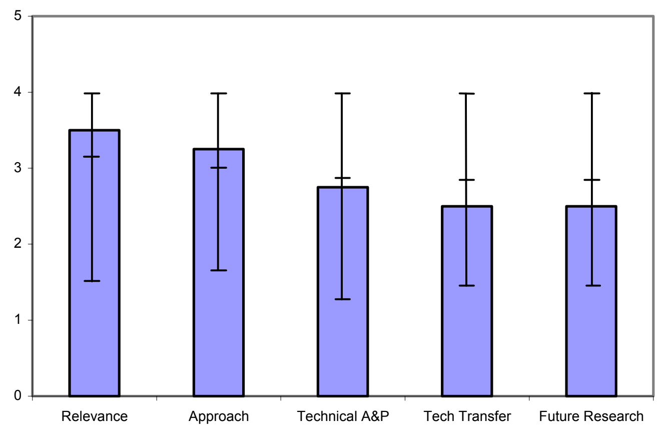
Specific recommendations and additions or deletions to the work scope

- Increase temperature range to include temperatures in high temperature membranes, WGS reactors, PROx reactor and reformer (i.e., increase to 1000C not 100C). Even if there is no reformer, would like T to ~200C if there is a high-temperature membrane.
- Do the target response times suffice for startup requirements (particularly for reformate systems)?

Project # FC-44: Neutron Imaging Study of the Water Transport Mechanism in a Working Fuel Cell

Arif, Muhammad; National Institute of Standards and Technology

Overall Project Score: 2.90



Brief Summary of Project

This National Institute of Standards and Technology (NIST) project is intended to develop an effective neutron imaging based non-destructive diagnostics tool to characterize water transport in PEM fuel cells. Objectives include: (1) providing research and testing infrastructure enabling fuel industry to test commercial grade fuel cell flow field designs; (2) providing training to industry enabling them use the imaging facility independently; and (3) transferring data interpretation and analysis algorithms/techniques to industry, enabling them to use research information more effectively and independently.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Addresses often overlooked aspect of bipolar plate design.
- Since water and its transport are key to PEMFC success, this program is important.
- Dynamic stack diagnostics are essential to advance the technology.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Neutron imaging is uniquely suited for looking at water. Capable of flow field study. Doubtful this can be useful for MEA study.
- Appreciate future goal of imaging entire fuel cell assemblies.
- This is a difficult experimental program to set up.
- Using beam time to assist developers is a good use of Federal resources.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- There is no capability improvement from last year based on the talk. MEA study remains elusive.
- OK-now for imaging of MEA & bipolar plate in real time.
- Progress looks ok but I wonder if it can be extended to understanding stack operation.
- Examples are interesting, but only a few examples were given.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Dramatic improvement over last year's collaborations.
- Not enough contact with stack developers who need to know the cell behavior in a stack.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Real time imaging will be a good improvement.
- Needs more interaction with stack developers.
- The emphasis on improving resolution is a good direction.

Strengths and weaknesses

Strengths

- Excellent work on flow-field imaging.
- Outstanding technology providing a rare but vital "glimpse" inside the flow field dynamics.

Weaknesses

- Continued concern over the true practical utility of this technique. Two years have passed and there is no indication there will be any MEA image capability.
- Cost. Unfortunately, the access of this technology for routine development will be prohibited…but still worthwhile.
- More collaboration.

Specific recommendations and additions or deletions to the work scope

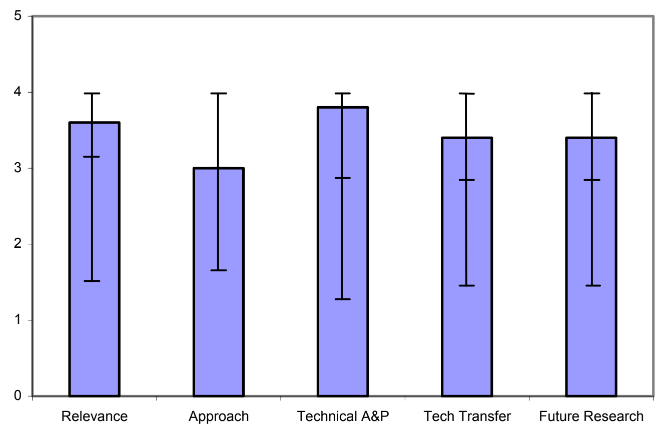
- Show some feasibility study on 10 μ resolution and the path/cost to get there.
- This important tool should also be aligned with modelers as it provides real data feedback to enable refinement of their models.
- The DOE should team NIST with a National Lab and work with a few non-proprietary stacks that allow for open publishing of results, with the purpose of improving diagnostics for the entire fuel cell community.

Project # FC-45: Microstructural Characterization of PEM Fuel Cells
More, Karren; Oak Ridge National Laboratory

Brief Summary of Project

Oak Ridge National Laboratory (ORNL) is working to elucidate MEA degradation mechanisms, including structural and compositional changes as a function of MEA processing, correlation of microstructure with performance, and morphological changes occurring during MEA aging/use. In addition, ORNL will collaborate with PEMFC developers/manufacturers to evaluate MEAs using advanced microstructural characterization techniques and provide feedback for MEA optimization.

Overall Project Score: 3.44



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.60** for its relevance to DOE objectives.

- Good guide on durability issues.
- Effort will help resolve critical mechanical issues. Best technical/analytical advancement of the meeting.
- Analysis of degradation mechanisms very important.
- The program is very important for developers to understand what causes cell decay.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Would have appreciated comparing X-Y direction slices. Is the uniformity in "XY" changing in the "Z" direction?
- Solid techniques developed. First time such analyses have been tied to PEM performance.
- Generally very well planned study.
- ORNL needs to provide better services to developers and encourage dialogue.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.80** based on accomplishments.

- Produced deep understanding of microstructure. Excellent initial durability results.
- Have shown great progress compared to previous year.
- Results critical to the understanding going forward. Excellent work.
- Great progress for the level of funding.
- Much progress made since last year.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.40** for technology transfer and collaboration.

- Great enhancement over prior years.
- Significant expansion of the list of collaborators. Great progress!
- More work needed with stack developers and component suppliers (membranes and electrodes).

Question 5: Approach to and relevance of proposed future research

This project was rated **3.40** for proposed future work.

- Look forward to adding chemical composition capability.
- Endorse future directions on GDL structure studies.
- Must expand effort and scope!
- Need to increase/continue funding for this project. Extremely valuable tool for long term stability/failure mechanisms.
- More focus on analyses of cell components as a function of: temperature, gas feed rates (STOICS), cell potential, cell current density, humidification, flow field configuration, electrode type, GDL type, cell test hours.

Strengths and weaknesses

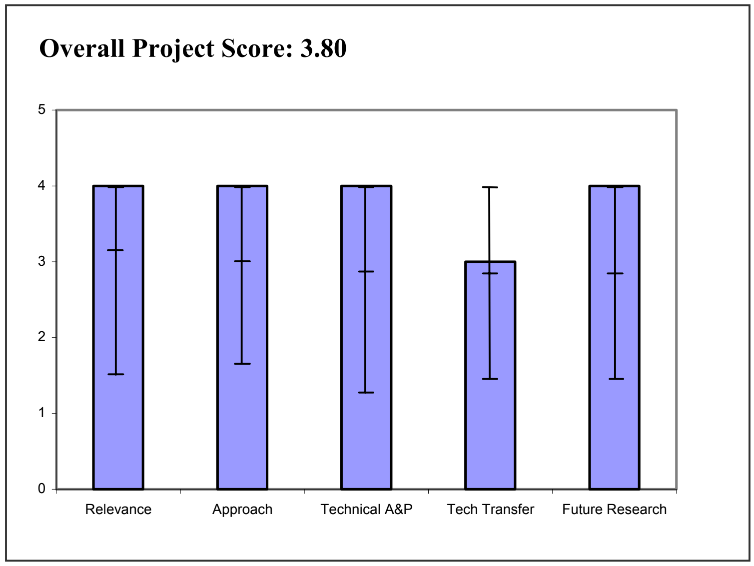
Strengths
- This team learned from the reviewer's comment last year and is now well connected with stakeholders to make this tool useful. Good job.
- Good study in correlating images with physical performance.
- Solid team, knowledgeable, willing to attack the more difficult issues.

Weaknesses
- Need to pay attention to how the "network" structure changes over aging. It could be important with respect to flooding and H_2 crossover. Nafion degradation needs to be studied.
- Should reach out with other analytical techniques such as, SEM, XRD, etc., to cross-compare TEM images.

Specific recommendations and additions or deletions to the work scope

- Analyze X-Y planes to identify "hot spots" for membrane/electrode failure and then perform detailed high resolution images around the failure mode.
- Increase scope to address membrane degradation issues, ionomer degradation issues, lifetime/catalyst screening.

Project # FC-46: Stack Durability on Hydrogen and Reformate
Borup, Rodney; Los Alamos National Laboratory



Brief Summary of Project

In this project, Los Alamos National Laboratory (LANL) will identify and quantify factors that limit PEMFC durability by measuring property changes in fuel cell components during long term testing (membrane-electrode durability, electrocatalyst activity and stability, gas diffusion media hydrophobicity, bipolar plate materials, and corrosion products) and developing and applying methods for accelerated and off-line testing.

Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

Question 2: Approach to performing the research and development

This project was rated **4.00** on its approach.

- The team seems to have the big picture well understood, which consequently elevated its capability to do this analytical focused project.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **4.00** based on accomplishments.

-

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

-

Question 5: Approach to and relevance of proposed future research

This project was rated **4.00** for proposed future work.

-

Strengths and weaknesses

Strengths
- Important work about durability. Excellent project execution with comprehensive set of tools.

Weaknesses

- Did not show any collaboration outcome even with LANL group.

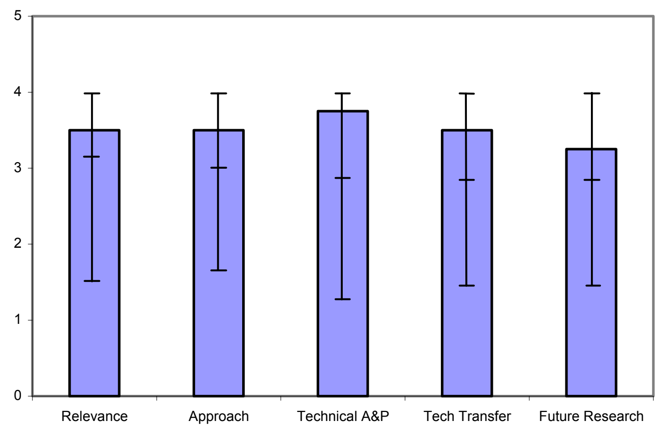
Specific recommendations and additions or deletions to the work scope

Project # FC-47: Direct Methanol Fuel Cells
Zelenay, Piotr; Los Alamos National Laboratory

Brief Summary of Project

This Los Alamos National Laboratory (LANL) project on Direct Methanol Fuel Cells (DMFCs) includes: determining the impact of Ru crossing over the membrane on the oxygen reduction kinetics at the DMFC cathode; developing methods for synthesis; demonstrating new unsupported DMFC cathode catalyst with average particle size reduced by at least 40% and performance superior to the best commercial cathode catalysts; and quantifying losses in the active surface area of the anode and the cathode over at least 200 h of DMFC operation.

Overall Project Score: 3.50



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Appears the overall plan stresses H_2 as a fuel overall. However, military applications may need liquid fuel.
- How can you argue with their advancements in portable power application of DMFC?
- Project has strong relevance if DOE has a sustained focus on portable systems. Project points to nearer-term realities.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- Good integration of catalyst membrane MEA work.
- Too product oriented (stack). Focus on technical fundamentals of key components.
- Can't argue with success.
- R&D approach is holistic with focus on relevant areas: electrocatalysts, membranes/MEAs, and stack improvements (integration).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.75** based on accomplishments.

- Continuing this group's tradition of identifying the core problem and providing a solution that achieves milestones.
- Good but not enough depth in the "whys." Why the stack development? Work on electrodes, membranes.
- Excellent technical progress.

- Impressive improvements in stack integration (practical) as well as in fundamental understanding of remaining challenges (basics), e.g., Ru migration issues, durability, membrane structural components.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.50** for technology transfer and collaboration.

- Maintains premier leadership in leading collaboration partners on state-of-the-art DMFC components/systems.
- Good transfer of technology.
- Excellent use of outside collaborators.
- Need to find stronger industrial partners who could capitalize on impressive work at National Lab level.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- Disagree with development of new catalysts. LANL appears to have numerous commercial and university collaborators to do that task.
- Focus on fundamentals. Develop stacks for analytical purposes only.
- Many obstacles to DMFC commercialization have been addressed and plan will continue this advancement.
- Key areas of deficiencies well-defined.

Strengths and weaknesses

Strengths
- Continue to be the pioneer in new materials and implementation of these materials in DMFC.
- Group knows the technical issues. Can build on knowledge base with units at Ball Aerospace.
- Excellent understanding of key issues of DMFCs with respect to durability and catalyst and membrane optimization and application of this understanding to build real working stacks.
- Very solid progress on many fronts, including a serious attempt to move towards practical deployment. Balanced, fundamental work along with practical developments. Good work on catalyst dispersion improvement.

Weaknesses
- Should LANL start catalyst preparation/research? Only if industry or universities are lacking in this key area. I believe LANL role should be in defining what is needed in the catalyst and letting others proceed.
- Too prone to hardware development.
- Needs more funding and better industrial partners.

Specific recommendations and additions or deletions to the work scope

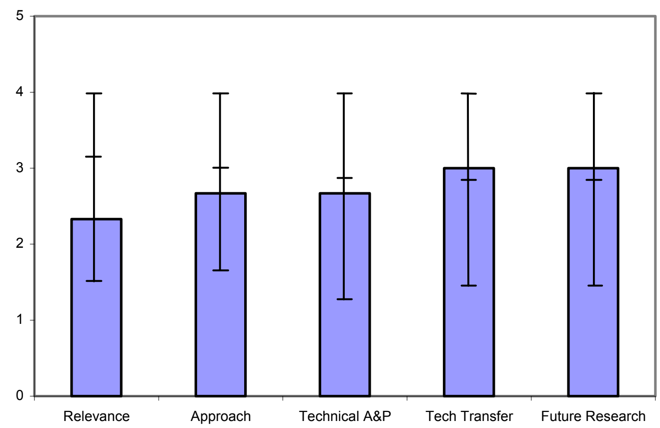
- DMFCs are not commercial and are unknown if "further ahead" or "further behind" PEMFCs. Yet portable applications are key. Recommend expansion of funding efforts.
- Perhaps become involved in high temperature membrane effort -- long term, but could be particularly advantageous to increasing anode kinetics. Apply TEM methods to understanding durability issues (as with PEM).

- Ensure that DOE sustains a program that focuses also on portable applications. Continue work to reduce catalyst loadings in DMFC (determine "limits" to how low?). Try to understand the mechanism of Ru "cross-over."

Project # FC-48: Modeling and Control of a Solid Oxide Fuel Cell Auxiliary Power Unit

Khaleel, Mo; Pacific Northwest National Laboratory

Overall Project Score: 2.73



Brief Summary of Project

This Pacific Northwest National Laboratory (PNNL) project provides SOFC-based APU development with 1) control algorithms to optimize fuel efficiency and operating life, and 2) models for stack response and structural failure under dynamic loading. Controls work includes developing dynamic system models, determining typical APU usage patterns, collecting electrical usage data from a working truck, and designing control algorithms to optimize fuel efficiency and operating life. Shock and vibration tasks are identifying failure modes under characteristic dynamic loading, determining guidelines for durable SOFC/APU systems, measuring truck excitations, experimentally validating the models, and defining requirements for APU isolation.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.33** for its relevance to DOE objectives.

- Areas for heavy duty trucks might have merit, but are not part of Hydrogen Fuel Initiative. Developing SOFC might be a component, however.
- Not clear how this project affects the Hydrogen Fuel Initiative directly.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Such model development is critical. Should expand model elements to include entire system.
- If you want to put SOFC APUs into trucks, these activities are important.
- Correlating material stresses from thermal/mechanical conditions of stack with the mechanical stresses of application is reasonable.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Good start. Lessons learned should lead to more advanced modeling.
- Shock and vibration models on components alone need to be extended to the entire APU if you want useful data.
- Seems to have made good progress in collecting real vibration data and modeling thermal stresses.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories
This project was rated **3.00** for technology transfer and collaboration.

- Have good collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Not clear why optimization of fuel efficiency equation is necessary.

Strengths and weaknesses

Strengths
- Gaining good understanding of thermal and vibrational shock associated with solid oxide APU.

Weaknesses
- Unclear how this fits in the Hydrogen Program.

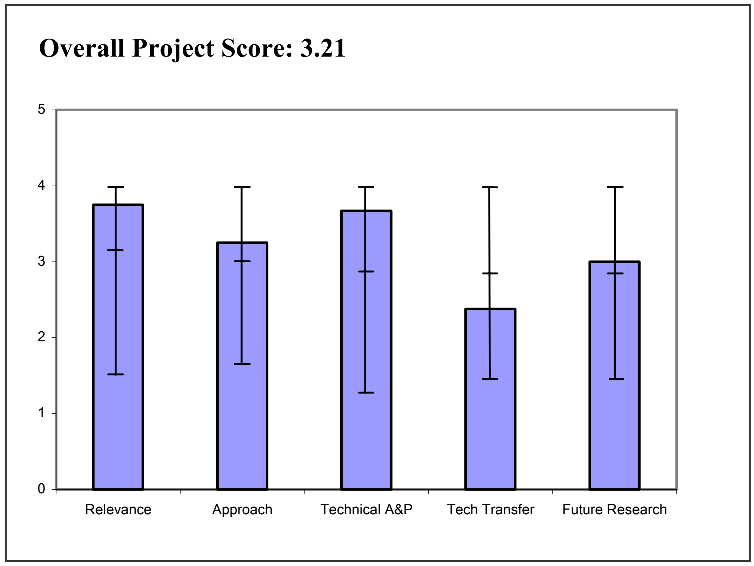
Specific recommendations and additions or deletions to the work scope

- Determining failure modes should be key focus.
- May want to expand into codes and standards that would be available for APU vendors.

Project # FC-49: Bipolar Plate-Supported Solid Oxide Fuel Cell "Tuffcell"
Myers, Deborah; Argonne National Laboratory

Brief Summary of Project

Argonne National Laboratory (ANL) is developing an improved solid oxide fuel cell (SOFC) for auxiliary power units (APUs) and other portable applications, addressing the following SOFC issues: startup time, durability to temperature cycling; vibration and shock resistance; and materials and manufacturing cost.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.75** for its relevance to DOE objectives.

- This concept could revolutionize SOFC design.
- Addresses many DOE technical barriers and targets. In particular, start-up time & durability are significant challenges here.
- If successful, an enabling approach for highly reliable SOFCs for transportation applications.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- PI needs to work with stack developers to better understand stack construction and gas manufacturing.
- Fabrication approach addresses performance and manufacturability.
- Novel fabrication approach. Not convinced that controlled atmosphere sintering is low-cost and/or scalable. Focus on relatively small cell components.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.67** based on accomplishments.

- Progress is very good in relation to the small amount of funding.
- Progress in meeting cost target demonstrated. Addressed a lot of issues for stack development, but test not successful. More issues to address at stack level. Progress in meeting power density goal.
- Making great progress, but not relevant to my automotive interests.
- Power density needs to be stated at 0.7 volts. Usable power densities lower than quoted. Demonstrated toughness. Power density needs to be increased. Disappointing stack test results, but this is extremely challenging.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.38** for technology transfer and collaboration.

- PI needs to talk with SOFC developers and other stack engineers.
- Independent evaluation of samples by Motorola good. Could incorporate more expertise at stack/system level to overcome those problems.
- Good to see interaction with Motorola. However, the durability 5000 hour target implies automotive applications. Is Motorola the best/appropriate partner?
- Collaboration w/organizations interested in supporting cell/stack testing work may help.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- PI must move from single cell to 3-5 cell stacks to study gas manifolding and how to apply the needed stack holding (compression force).
- Need to pull in some expertise to help with stack issues, but great on cell development.
- Focus on improving power density. Testing of large area cells, testing under high fuel utilizations.

Strengths and weaknesses

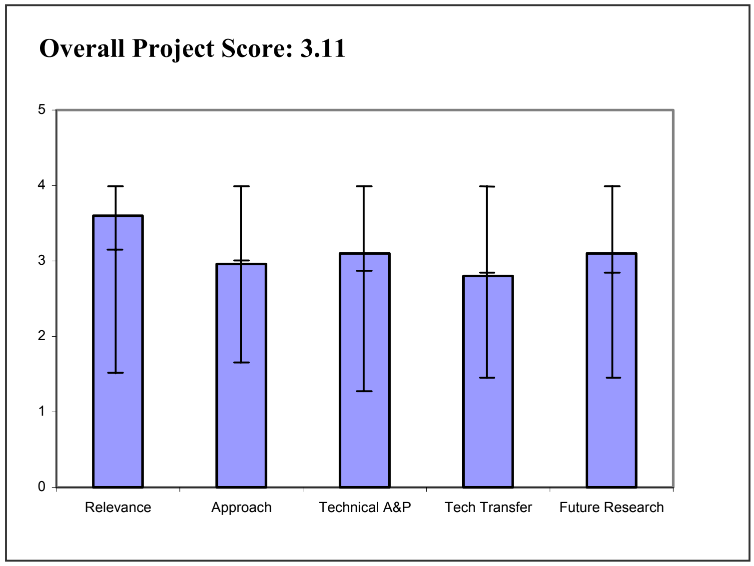
Strengths
- Significant progress made, given relatively small budget.

Weaknesses
- Need successful scale-up/stack test to attract additional non-DOE investment.

Specific recommendations and additions or deletions to the work scope

- Seek advice from stack engineers.
- Reconcile 5000 hr durability target APU with Motorola application.
- Increase cell area-minimum 100 m^2/gram. More detailed cost model to confirm cost advantages would be useful-materials cost by itself is insufficient.

Project # FC-P1: Fuel Cells Vehicle Systems Analysis
Markel, Tony; National Renewable Energy Laboratory



Brief Summary of Project

For this project, the National Renewable Energy Laboratory (NREL) will provide DOE and industry with technical solutions and modeling tools that accelerate the introduction of robust fuel cell technologies, quantify benefits and impacts of Hydrogen Program development efforts at the vehicle level (both current status and future goal evaluation), and highlight potential system level solutions to technical barriers.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.60** for its relevance to DOE objectives.

- Need these types of modeling skills and integrated approach to assess development pathways and to select areas for future investment.
- Provides a useful and needed tool to assess the impact of Hydrogen Program technical targets on overall vehicle performance. An excellent tool for public domain access and communication of program impact.
- Need to delete score. Project addresses critical systems issues.

Question 2: Approach to performing the research and development

This project was rated **2.96** on its approach.

- Integrates models at different levels, stack, component, system, vehicle, and drive cycle to assess performance against targets. Modular so individual models can be improved.
- The team seems well aware of the key challenges and has developed a good tool to address these
- Good forward thinking on projecting requirements for "robustness" of the FC operation across multiple ambient conditions.
- Perhaps a bit too much emphasis on making general modeling tools widely available (in the end, the tool developer is best equipped to make good use of it anyway), but also don't want to design specific components for individual customers. Increased depth of analysis of individual questions (not specific components) could improve the impact of this project.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.10** based on accomplishments.

- Focused on critical area of water and thermal management. Calibrated against vehicle data. Evaluation of new concept-O_2 enrichment to improve peak power. Vehicle performance over range of environments important to understand.

- The accomplishments in tool generation are very strong. The applications shown are less clearly so.
- Good work for the budget.
- Useful study of whether DOE targets would lead to available vehicle. Questions for study seem to be those that the model can handle, not necessarily the most technologically-pressing. Supercharged stack analysis did not seem to take into account the difficulties of providing enriched oxygen. Treatment of water in stack will have to become more complete before it can capture experimentally-predominant effects

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Tools developed clearly relevant to teams but I did not ask the extent or level of interactions that Tony had with industry. Not highlighted in poster.
- Excellent public interaction. Interaction with ANL modeling efforts and the FreedomCAR Systems Engineering & Analysis Tech Team needs further definition.
- Have provided valuable information on automotive drive cycles (and their effects) to a number of projects.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.10** for proposed future work.

- Need to undertake future work in context of interactions with DOE program managers and industrial teams. Design tool for increasingly complex systems (hybrids) and effect of environment. Valuable tool.
- Investigating more extreme environments (altitude, desert environments) is a good next step.
- Thermal/water management could be very useful to FCV. Not sure that oxygen power boost work is applicable.
- Future plans weren't made entirely clear. Plan to look at sensitivity of performance to expected ranges of operating conditions is good.

Strengths and weaknesses

Strengths
- Excellent modeling skills and integration of tools into a useful package targeted to answer critical questions.
- Very strong modeling and analytical skills and tools. Clear desire to work with the FC community.
- Quality of poster/talk in terms of content vs. "flash" has improved greatly this year.
- Connect vehicle drive cycles analytically to a range of important questions.

Weaknesses
- Potential lack of access to vehicle designs and performance data to calibrate model performance.
- Effects that are susceptible to modeling are not always those that exert predominant control.

Specific recommendations and additions or deletions to the work scope

- Increase interactions with industry teams and/or presentation of comparisons of model results and actual data.
- Recommend continued funding. Extend analyses to real-world operation to further guide tech targets and work. Must avoid a design that is too much a "cycle-beater" and instead comprehend real-world acceleration, grade and trailering, warm-up, and extreme environment. Suggest investigation of temperature vs. time after cold start on various drive cycles for various ambient temperatures -- to drive an understanding that high-T membranes must also be robust, efficient at lower temperature
- If supercharged stack (oxygen enrichment) is to be carried forward, check sensitivity of results, to mass transfer resistance of cell and add realistic analysis of what equipment and energy would be required to do the oxygen enrichment.

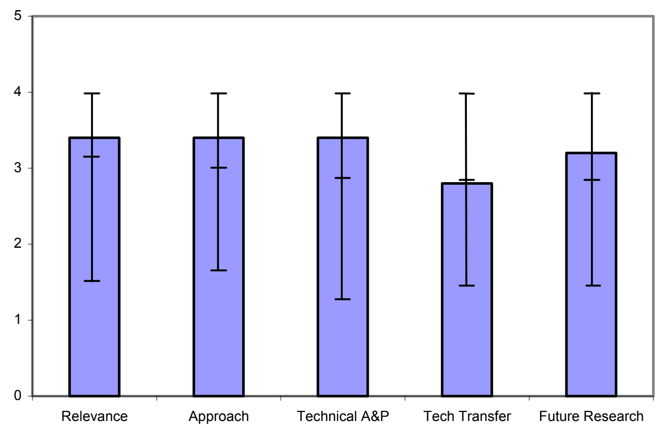
Project # FC-P2: Cost Analyses of Fuel Cell Stacks/Systems

Carlson, Eric; TIAX LLC

Brief Summary of Project

This TIAX LLC project provides cost and manufacturing analysis. Specific teaks are: to develop an independent cost estimate of PEMFC system costs including a sensitivity analysis (operating parameters, materials of construction, manufacturing processes); identification of opportunities for system cost reduction through breakthroughs in component and manufacturing technology; and annual updates to the cost estimate for the duration of the project. The FY04 focus is on the costing of compressed hydrogen storage.

Overall Project Score: 3.24



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- Cost modeling can help to identify critically costly components.
- A project of this sort is absolutely necessary for the Hydrogen Program set, to provide an independent assessment of the likely costs associated with PEM fuel cell technologies. The focus on compressed hydrogen storage is particularly appropriate this year.
- Cost estimate for CH_2 tank system consistent with Directed Technologies estimate.
- Knowledge of cost is critical for comparing progress to targets. Would be useful to benchmark current industry status (such as Plug Power's $3K/kW) against your cost projections from a few years ago to check forecasting accuracy.

Question 2: Approach to performing the research and development

This project was rated **3.40** on its approach.

- TIAX is taking a component-by-component (bottom-up) approach for materials and processing.
- The authors considered variations of both 5000 and 10,000 psi composite tank structures, with carbon fiber identified as the most costly item. Tank manufacturing methods from the natural gas industry provided the basis for projecting costs of each step. The authors considered realistic scenarios for an 80 kW_e system, which included coupling with a battery.
- Detailed component/system manufacturing cost estimates/assumptions.
- This project relied pretty heavily on a few key assumptions of tank L/D ratio, carbon fiber choice, etc. Recommend getting industry (auto) feedback on these assumptions and impact.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.40** based on accomplishments.

- Preliminary costing of compressed hydrogen storage systems completed.
- The authors showed quite conclusively that, though sufficient hydrogen could be stored to meet interim targets, the cost would be about double those targets. Meeting long range price and specific energy targets was shown to be much more remote.
- Results are interesting -- indicate that compressed gas approach still has 2-3x cost compared to DOE targets.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Tank developers need to be involved -- future work.
- The authors did collaborate with ANL in estimating system requirements, and presumably with composite tank manufacturers before beginning cost assessments. Feedback from compressed hydrogen storage systems developers is planned for the future.
- Interaction with tank developers is planned to vet the cost model assumptions.
- Would like to see significantly more industry involvement (review) of this project.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.20** for proposed future work.

- Compressed hydrogen storage developers will be consulted for refinement of preliminary results. Overall hydrogen fuel cell system cost model will be updated with final hydrogen storage system costs.
- The authors would seek feedback from compressed hydrogen system developers on current work, and would shift their efforts to an update of cost projections related to direct hydrogen production. Project appears to be in final year of five-year contract.
- Update full system cost estimate.

Strengths and weaknesses

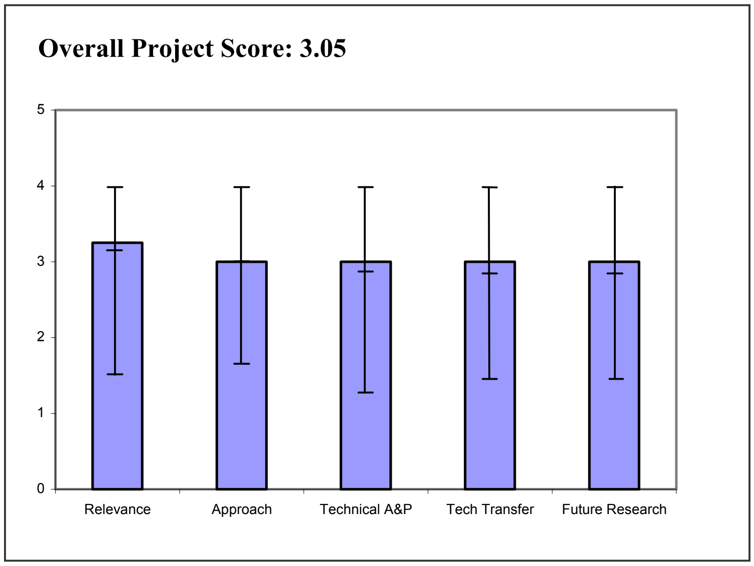
Strengths
- Project has provided valuable, independent review of technologies being developed by Hydrogen Program. Demonstrated strong technical basis for cost projections. Showed that compressed hydrogen will have difficulty meeting interim cost targets, let alone ultimate cost and specific energy targets.
- Cost estimate built on referenceable assumptions. No proprietary considerations.
- Despite the uncertainties involved, cost is an important thing to be analyzed.

Weaknesses
- None noted.
- Not clear whether costs include mark-up/profit.
- Results of nearly all cost analyses on fuel cells and their system have never been met. Not even close to ballpark.
- Results may depend too heavily on some of the key assumptions that do not appear to be from industry.

Specific recommendations and additions or deletions to the work scope

- Analysis of physical and chemical hydrogen storage options would be useful, including carbon nanotubes, sodium alanates, sodium borohydride, aminoborane, others.
- Complete full system cost estimate and change full cell operating conditions to standard 80C, 1.5-2 atm.
- Recommend holding a workshop with key industry stakeholders to discuss assumptions and results.

Project # FC-P3: Development of Novel CO_2-Selective Membrane for H_2 Purification
Ho, Winston; Ohio State University



Brief Summary of Project

This Ohio State University project is producing enhanced H_2 gas stream with <10 ppm CO at high pressure used for reforming, to overcome Fuel-Flexible Fuel Processors Barrier L (H_2 Purification/CO Clean-up) and achieve target <10 ppm CO in the product stream.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Technique will lead to higher efficiencies in fuel cells - good.
- Important goals are addressed.
- Supports development of cost-effective and volumetrically efficient fuel processors.
- Project not only helps to improve the production and purification practices but assists in CO_2 treatment methods.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Membrane separation science is a good approach. Needs to continue concept development with life and stability to prove out.
- Approach is valid.
- Novel approach with potential to downsize co-reduction components. Dependent on availability of suitable low-temperature WGS catalysts (that do not exist).
- Search for higher temperature materials that exhibit the same CO_2 transfer/H_2 impermeable properties is good.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Life and stability?
- Project milestones were met, work done on other/impurities such as H_2S; excellent results.
- 10 ppm CO level requires excessively low space velocities or separate methanation step. Capabilities of membrane not matched to WGS catalysts. Not demonstrated for syngas feeds with high CO content.
- Although improvements have been made in operating at higher temperature, rate of progress needs to increase in rate and alternative materials, etc., need to be identified.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Time to broaden field of use.
- Various interactions and attempts to license.
- Reasonable for university project. No evidence of collaboration with catalyst suppliers.
- Several companies have been actively involved. More interaction with fuel processor designers could be beneficial.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Should emphasize cost and failure modes.
- Logical extension of work plan for the remainder of the year ok.
- Plans appropriate. Is focus on methanation appropriate? Better to achieve better match between membrane and catalysts? Higher space velocities.
- Focus on polymer performance improvements for operation at higher temperature and not on catalyst effort.

Strengths and weaknesses

Strengths
- Good team approach.
- Novel approach. Membrane development progressing well. Side benefit of reducing H_2S content.
- Understand polymer and CO_2/H_2S transfer mechanism

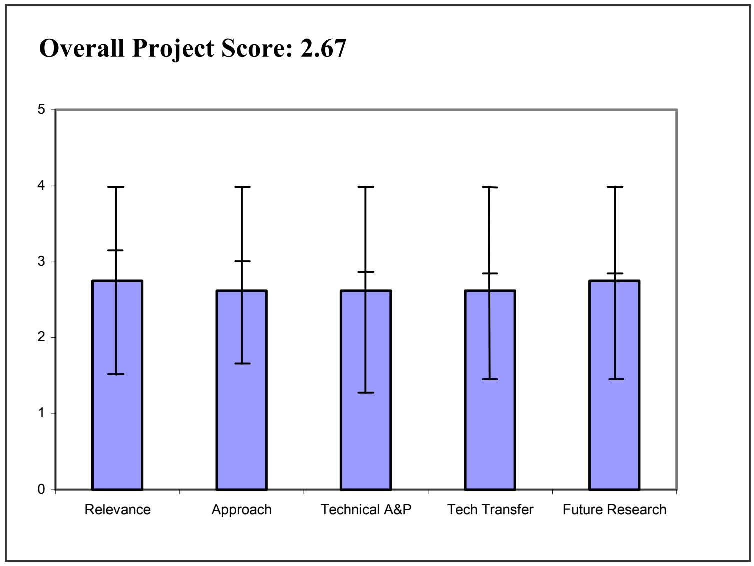
Weaknesses
- Needs better low temperature-WGS catalyst or higher-temperature membrane. Is success dependent on materials breakthrough?
- Apparent limitation of current polymer system in max temperature and CO_2 transfer rate.

Specific recommendations and additions or deletions to the work scope

- Focus on increasing space velocities.
- Membrane temperature of operation and effective flow rates need to be increased.

Project # FC-P4: Microchannel Reformate Cleanup: Water Gas Shift and Preferential Oxidation
TeGrotenhuis, Ward; Pacific Northwest National Laboratory

Brief Summary of Project



Overall objectives of this Pacific Northwest National Laboratory (PNNL) project are to apply microchannel architectures where appropriate in fuel processing for transportation, stationary, and portable applications to reduce size and weight, improve fuel efficiency, and enhance operation, and to develop a prototype microchannel-steam-reforming fuel processor at 2 kW_e scale that will meet DOE performance targets when scaled up to 50 kW_e. Specific tasks include demonstration of 90% CO conversion in a single-stage WGS reactor that scales to less than 3 liters at full-scale and determination as to whether microchannel architecture provides opportunities for size and weight reduction for PROx reactor.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- If successful, both the size of reactors and cost can be reduced.
- Microchannel reactors could be an important component in the hydrogen economy. This presentation does not present much new that might contribute to that.
- Helps to advance improvements in hydrogen production processes.

Question 2: Approach to performing the research and development

This project was rated **2.62** on its approach.

- Are the catalysts correctly loaded for WGS differential reactor? No CFD modeling information for the WGS & PROx reactors. Not enough data presented especially for differential WGS. How to control temperatures for WGS is not addressed.
- Helping to establish limits of usefulness of microchannel technology.
- Seems to be a review of the microchannel activities. Very little reactor performance information.
- Appropriate for initial proof of concept.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.62** based on accomplishments.

- Encouraging progress, but durability remains an unproven target.

- WGS 2KW_e reactor is very compacted. Kinetic equation for WGS differential reactor is useful. The result of microchannel PROx reactor by combinations of 1st & 2nd end stages is promising (10,000 ppm --> <10 ppm at 93,000/h).
- Creditable progress in last year -- particularly in power density increases.
- Should get thermal profile with respect to flow rates and conversion of CO.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories
This project was rated **2.62** for technology transfer and collaboration.

- More collaboration with fuel cell/fuel processor developers is necessary. A lot of companies like Nuvera have done a lot of work in these areas.
- Little interaction with transportation groups -- credibility issues?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Durability tests are necessarily needed to establish solid technologies of CO cleanup for real fuel processors. Scale-up from 2 kW_e to 50 kW_e. Integration with other components as key parts of real fuel processors.
- Durability of complete integrated system under repeated shut-down/restart still yet to be demonstrated.
- Not much vision or direction apparent.
- Need more information on activity and performance during startup conditions with varied H_2O, temperature and flows.

Strengths and weaknesses

Strengths
- Good approaches to reduce the size and cost of the CO cleanup reactors. Potentially, "quick start-up" for on-board fuel processor probably will benefit from these kinds of technologies if successful.
- Promise of achieving power density targets appears good -- but still only based on projections!
- The graphics for this poster were done very well. Mr. TeGrotenhuis presented his work professionally.
- Excellent capabilities for microchannel fabrication and testing in hardware development.

Weaknesses
- Durability is still missing. More data are needed for convincing that these are solid technologies.
- Need to progress beyond initial performance testing of microchannel testing and demonstrate both reliability and durability of operation -- otherwise credibility still in doubt.
- Catalyst emplacement. Range of operating conditions.

Specific recommendations and additions or deletions to the work scope

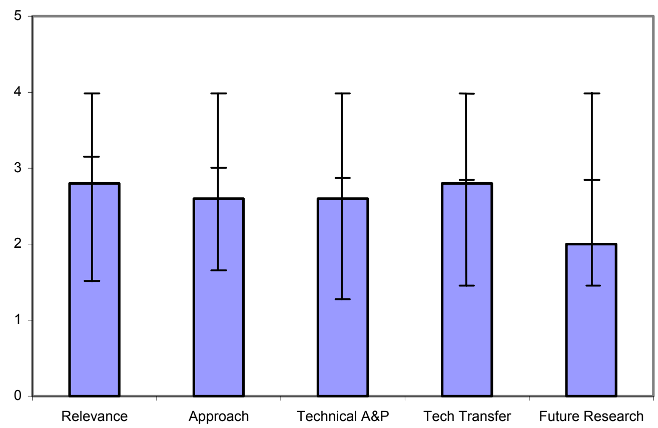
- More collaboration with fuel cells/fuel processor developer. Durability tests. Make a better approach to correlate theory and tests by different tools such as CFD modeling.
- Combine all microchannel projects into one focused effort, then validate or terminate!
- Expand operating tests to include startup conditions and various transients before coupling with primary reformer, i.e., off-design conditions. Improve catalyst life -- examine thermal profile relationship to catalyst activity (both performance and destruction).

Project # FC-P5: Effects of Fuel Composition on Fuel Processing
Kopasz, John; Argonne National Laboratory

Brief Summary of Project

For this project, Argonne National Laboratory (ANL) will determine how fuel composition affects reformer performance. ANL will determine how changes/variations in composition affect performance and how tailoring the composition can increase performance, find additives that can increase performance, determine how molecular size affects reforming, and study reforming of two renewable fuels.

Overall Project Score: 2.56



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- Since no H_2 infrastructure exists, reformed H_2 is needed to enable FC industry.
- Important to understand effects of fuel complexity on reforming.
- Important project but by no means critical.
- "Focus on new enhancers," there should be focus as well on enhancers are serious candidates as fuel additive in terms of costs, availability, complexity of production process, and mass production.

Question 2: Approach to performing the research and development

This project was rated **2.60** on its approach.

- Problems clearly outlined and approach well thought-out. Nice job in addressing last year's reviewers' comments.
- While approach is to look at complex fuels, little data shown. Not doing a through job of evaluating matrix. Must have a systematic approach.
- Solid. Improve mechanistic study -- start with simple ones like "what are the reaction steps and rates?"
- Systematic from research point of view, but missing availability aspects.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.60** based on accomplishments.

- Very good progress to date.
- Very few tangible results in 3-4 years (started '00).
- No real understanding of how fuel complexity affects reforming…just a few empirical observations.
- No indication of attempt to look at "synthetic" mixtures with controlled molecular weights.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Assembled strong team.
- Collaboration apparent but not defined.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- Does it make sense to continue producing hydrogen from hydrocarbons? Industry should move towards renewable H_2 production strategies.
- Why ethanol as an additive when ethylene is a problem. Unclear that work focuses on understanding results…just moves to a new system.

Strengths and weaknesses

Strengths
- Good progress. Well-planned research.
- Important project to reach real fuel reforming!

Weaknesses
- Hydrocarbon fuels still required. Still have substantial cost and performance hurdles to overcome.
- No systematic approach to understanding effects of complex fuels on reforming.
- Need to conduct experiment/modeling work to gain mechanistic understanding.

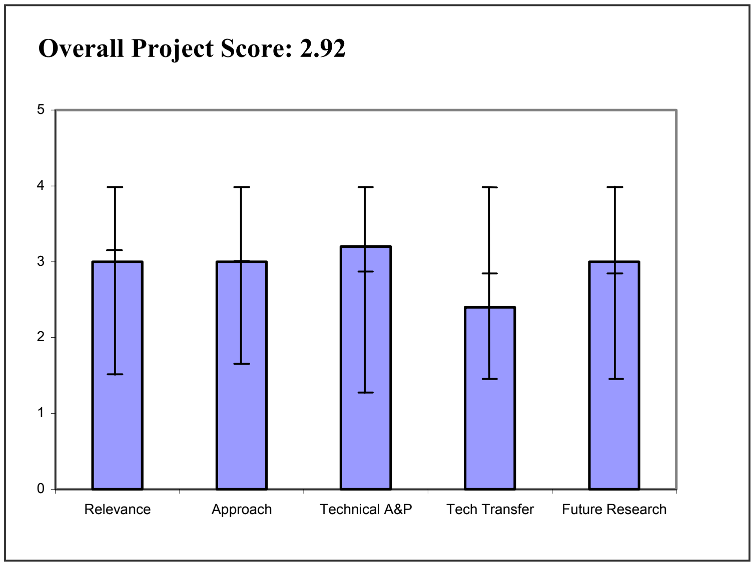
Specific recommendations and additions or deletions to the work scope

- Due to complexity of fuel processing, perhaps $$ should be directed to H_2 storage and not localized generation.
- DOE should focus H_2 production money on renewable sources of H_2.
- Must develop detailed testing matrix to follow through with matrix. Tedious, but critical. Add modeling to this. Contact ONR to discuss their MURI program looking at hydrocarbon oxidation and reforming.
- Computer modeling. Are there any new classes of gasoline additives that improve reforming? A scouting effort built on the learnings so far would give the project new life and importance.

Project # FC-P6: Development of Advanced Catalysts for Direct Methanol Fuel Cells
Narayanan, S.; Jet Propulsion Laboratory

Brief Summary of Project

The objective of this Jet Propulsion Laboratory (JPL) project is to develop catalysts for direct methanol fuel cells with substantially reduced amounts of noble metal loading. Specifically, JPL will try to reduce noble metal loading below 0.5 mg/cm2 and develop non-noble metal anode catalysts.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Aligned well with a basic need in DMFC -- more catalyst understanding.
- Technique could develop faster catalyst development.
- I believe that JPL and Narayanan have the correct approach to develop a more active PEMFC anode catalyst.
- If DOE maintains focus on portable systems, this project has solid relevance because DMFC systems are appropriate for portable applications.
- DMFC is only moderately relevant.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- PI intentionally left out MEA data -- but I think inclusion of this data would help.
- Good advancement of the technique. Time to focus on new catalyst systems.
- Adequate results have been generated to provide more support for this work.
- Search for reduced precious metals content is needed. Combinatorial efforts are used extensively. Caution: states produced by such methods may be metastable.
- Combinatorial style approach is very intriguing.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.20** based on accomplishments.

- Great progress in precious metal reduction.
- Add criteria for catalyst screening. Begin specific screening studies.
- I believe the progress made far exceeds the small funding ($100K). Please increase this if possible.
- Standard characterizations must be supplemented by tests in fuel cells. Need to quickly down select compositions and determine stability.
- With modest resources, it seems that the technique has been developed to a mature point. Ready to be adapted to solve important problems.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.40** for technology transfer and collaboration.

- Very few listed. May be worthwhile to contact a "DMFC" company.
- Now is the time to start working with DMFC MEA developers.
- OK for such a small funded program.
- Given limited budget, the program is handicapped in its ability to collaborate more widely. Creativity/innovations needed.
- Seeks to work with outside entities.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Include translation to high surface area catalysts -- maybe some of the underlying theory will change.
- Program plans are sound.
- Intentions, programs are appropriate. Need scale-up and actual fuel cell tests to determine whether heat of reaction could alter catalyst phase.
- This project should be given more resources.

Strengths and weaknesses

Strengths
- Great approach to adding more fundamental understanding to DMFC anode catalysts.
- Good technique development and follow-through.
- Methanol fuel cells use an easily transported H_2 media. DOE has too much focus on H_2 storage and is ignoring a great medium for H_2 storage and transport -- CH_3OH.
- Solid, sustainable approach using combinatories (but must determine whether compositions are lowest-energy state -- are these metastable?).
- Approach, good PI.

Weaknesses
- Would have preferred to see actual MEA comparisons to link "theoretical" findings to actual results -- not only analytical results.
- Would appropriate, down-selected, compositions be scale-uppable? Need fuel cell test data to compare with fundamental characterizations.
- Level of effort.

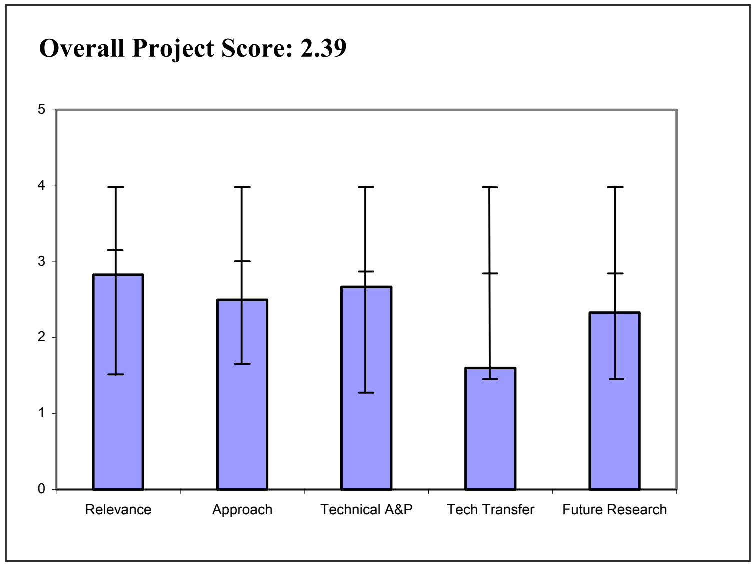
Specific recommendations and additions or deletions to the work scope

- Increase funding support in this area --> catalysts for DMFC.
- Funding level must be improved, if DOE intends to support portable applications.
- Expand program to allow collaboration/integration into larger catalysis-oriented efforts.

Project # FC-P7: Non-Precious Metal Cathode Electrocatalysts (new project)
Myers, Debbie; Argonne National Laboratory

Brief Summary of Project

This Argonne National Laboratory (ANL) project will develop a non-precious metal cathode electrocatalyst for polymer electrolyte fuel cells, promoting the direct four-electron transfer with high electrocatalytic activity (comparable to that of Pt). The four-electron process is desirable due to its higher efficiency and non-corrosive product. Goals are to be chemically compatible with the acidic polymer electrolyte and low cost.



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.83** for its relevance to DOE objectives.

- Low-cost catalysis options are required to enable FC industry; this program addresses these issues.
- Fair, because narrow focus on one critical barrier and limited budget.
- Very relevant towards the non-Pt/low-Pt/low-cost targets.
- Reduction of Pt metal costs is a worthwhile objective.

Question 2: Approach to performing the research and development

This project was rated **2.50** on its approach.

- As candidates fail performance validation, you remove them from the scope of project -- this allows focus on something that may work. Good scientific approach.
- Why are iron oxides being revisited yet again? Wide range of materials classes -- will anything besides electrochemical characterization be done? Metal centers attached to polymer backbone an interesting approach.
- Challenge of acid stability of spinels/perovskites. 3 very diverse approaches; might be better to focus on approach most likely to succeed.
- Duplicate work performed at other National Labs -- focus on carbides and nitrides probably more useful than on complex oxides.
- Choice of starting candidates and basis for them not well-defined thus making interpretation and value of results not clear.
- The approach does not appear original. Several researchers have attempted to identify ORR catalyst over last 20 years and it was not clear from presentation what was original in this work.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Switch to RDE measurements in perchloric acid not sulfuric acid. Good scientific fundamentals are basis of this project, so success can be easily defined and verified.
- New project, but validated electrochemical characterization methods. Initial results not very promising, but just getting started.
- Project just started. Work on technique development (RDE).
- Good baseline work and development of testing methods.
- The right tests for validation of equipment are being done, but seems to be slow. Priority of candidate catalysts for testing is not clear.
- Baseline reaction kinetics for Pt catalyst were well defined.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.60** for technology transfer and collaboration.

- If you achieve success, how do you envision implementation in commercial systems?
- No collaboration.
- None indicated.
- Seems like project just started -- too early to have such, might benefit from interactions with LANL group.
- Need more collaboration with people experienced in electrocatalyst development.
- Did not see cooperative efforts with universities.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.33** for proposed future work.

- Not much to build on yet -- addition of a modeling effort good.
- Better to focus limited resources on highest approach with highest probability of success.
- Focus on carbides and nitrides. Unlikely to be easy or achievable to stabilize metal oxides in acidic media, results to date discouraging. Fabrication of MEAs -- better to collaborate with someone with more experience.
- Prioritization of catalysts to be tested is needed to bracket the area/type of catalyst for focused effort.
- Not clear if original contributions are considered.

Strengths and weaknesses

Strengths
- Very good science-based program.
- Good history of materials research.

Weaknesses
- RDE measurements could be confounded by use of H_2SO_4. No scale-up contingencies have been proposed.
- Too diverse approach.
- Screening of catalysts for focusing and directing exploratory vs. detailed investigation has not been done.
- Well-traveled research area. No unique approaches identified. Need to team with universities.

Specific recommendations and additions or deletions to the work scope

- Fund this program at increased level to enable rapid evaluation of these new types of catalysts so industry can begin scaling up any new developed catalysts ASAP.
- Too soon to see if this project is on track.
- Select most promising approach and drop others. Leverage research by university interactions.
- Define a prioritization plan for screening and evaluating the different catalyst types.
- Not sure if funds are well spent: the transition metal catalyst approach is the topic of several R&D programs. Does DOE need so many programs? Consolidate efforts if possible. Form team to look at original approaches.

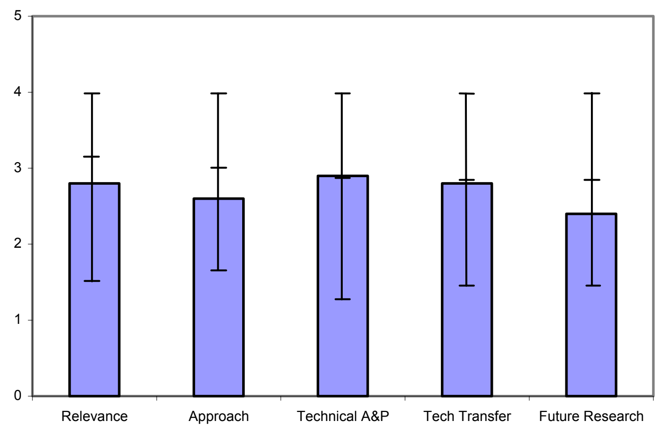
Project # FC-P8: Low-Friction Coatings and Materials for Fuel Cell Air Compressors

Ajayi, Oyelayo; Argonne National Laboratory

Brief Summary of Project

Argonne National Laboratory's (ANL) objective is to develop and evaluate low-friction and wear-resistant coatings and/or materials for critical components of air compressor/expanders being developed for fuel cells by DOE contractors. Efficiency, reliability and durability of such system are dependent on effective lubrication of critical components such as bearings and seals. Such components cannot be oil lubricated, since oil will contaminate fuel cell stacks.

Overall Project Score: 2.70



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- Very important niche often overlooked.
- Relevance is based on assumption that air compressors are needed (blowers, too, included in presentation).
- The program appears to support a small, minor issue for fuel cells.

Question 2: Approach to performing the research and development

This project was rated **2.60** on its approach.

- Based on written presentation, appears program is providing an analytical service -- not clear if expanding understanding of the needs of tribologically challenging materials.
- Good criteria for material selection.
- Approach does not question need for compressors; what if low-flow fans are needed for air feeds? Need to understand the melting points of the coatings (caused by surface roughness of substrates).
- Why wouldn't industry do this program for all compressor operations?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.90** based on accomplishments.

- As a past reviewer, I note real progress towards achieving overall goals.
- Progress remains at property-level; needs to be integrated into device consequences. OK for a property evaluation program (but understand polymer degradation issues and gas-phase contaminants).
- Continue to show progress and meet objectives.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Real improvement over last year. Providing key information to partners.
- Extend discussion to other developers of air-feed systems beyond compressor companies. No blower companies mentioned.
- Making contacts with industry. Results were not on slides and should be. Is industry not included in this material?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.40** for proposed future work.

- Would have liked an explanation of "direct hydrogen systems" for future work.
- Remains more a basic materials program. Must raise the bar into a device-in-system program. Must understand polymer chemistry.
- This program is at least 3 years old and should be transferred to industry for industry to use

.

Strengths and weaknesses

Strengths

- Developed outstanding methodology to guide selection process. Working with good partners -- making good efforts in technology transfer .
- Coating material characterization.
- Solid materials program.

Weaknesses

- Currently appears to be more empirical -- "try and see."
- Need to expand program to device level and how air composition may affect stacks. Expand base of collaborators -- name the blower companies.

Specific recommendations and additions or deletions to the work scope

- Has done a great job developing the method -- would it be within the scope of this program to develop the understanding behind why some coatings are more resistant to wear and low friction?
- Closer relationship with air compressor developer to transfer this technology.
- Work on chemistry beyond mechanicals (i.e., polymer rheology, polymer degradation at elevated temperatures).
- Terminate effort since program is 3 years old and should be transferred to industry.

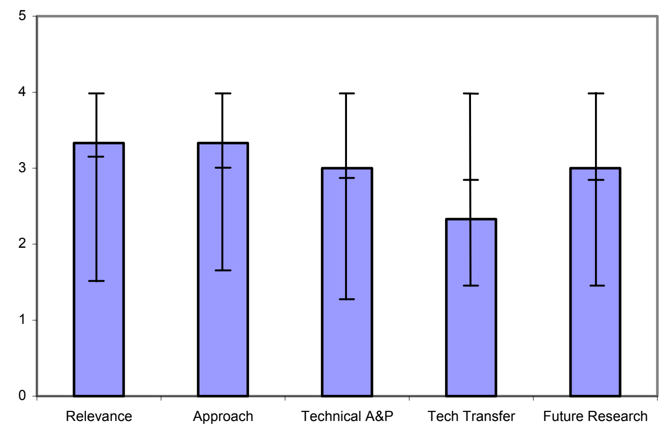
Project # FC-P9: Montana PEM Membrane Degradation Study

Spangler, Lee; Montana State University

Brief Summary of Project

Montana State University's overall objective is to determine membrane degradation mechanisms and how to prevent or mitigate them. Specific goals are to determine changes in membrane material properties as degradation occurs, determine if any electrical properties can act as a signature of developing degradation, and investigate the potential of advanced control systems to prevent degradation problems.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Understanding the mechanism for MEA failure is critical for improving reliability of PEMFC.
- Success in mitigating membrane degradation will greatly increase durability target. So far, not too much success shown in preventing degradation or why degradation occurs.
- Durability is a major barrier to fuel cell commercialization.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Use of NMR imaging to measure water diffusivity through MEA as tool for evaluating degradation is good idea. Would be beneficial if this project could investigate chemical degradation of MEA.
- Started with one cell to refine methods, currently measuring 80 cell stack. High number of data points providing excellent information to analyze -- gives a clear picture of 2 years of data to determine which, if any, events cause degradation.
- The concept could use some more focus. One should consider external effects and if there will be any combinatory effects of impurities along with normal usage thermal and water effects.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Appears that most of equipment is in place and are ready to begin collecting data.
- Have noticed degradation in cell performance, but have not clearly shown why it is occurring. Suggests reduced H_2 through membrane, yet does not say why this occurs. More work to be done with identifying and controlling degradation.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- It is unfortunate that a MEA manufacturer/stack manufacturer could not be convinced to participate in this project
- Little work with outside entities; however many papers have been published documenting work. NAMS has been contacted.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Expand scope (if possible) to investigate causes of chemical degradation of MEA
- The right steps have been outlined to reach goals, yet few clues are provided towards their success.
- Need to consider external effects such as start/stop, sub-zero temperature effects, and impurities from external environment and how that will effect the durability.

Strengths and weaknesses

Strengths
- Addressing issues such as transition metal poisoning which have not been previously addressed. (Would be beneficial if the source/cause of the transition metal could be identified?)
- Right approach to problem, great data collecting and documenting. Look to be working toward the right goals with their future research. Spatial resolution of NMR novel, giving good data
- Very important R&D.

Weaknesses
- Without interest/involvement from MEA and stack manufacturers, not sure of the overall project benefit-basically who will listen? -- Will they accept your approach/results? How sensitive is the water diffusivity to degradation -- could you see substantial degradation without significant changes in H_2O diffusivity?
- Long way with lots of analysis to accomplish before their goals are achieved; not much information given as to why phenomenon occurs (still to come in future work).

Specific recommendations and additions or deletions to the work scope

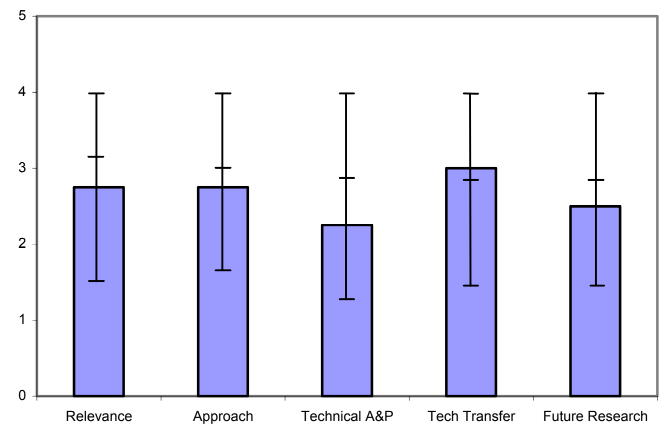
- Expand scope to characterize chemical degradation.
- Should conduct more parallel work to speed up year 1.
- Align your work more in parallel to move even faster.
- Need to collaborate with fuel cell manufacturers to make sure work is of value. It may be useful to have collaboration with NIST to see if the experimental work can be cross-correlated.

Project # FC-P10: High Temperature MEA for PEMFC Device Based on SPEEK Blends
Bellows, Richard; Oxford Perferature Materials, Inc.

Brief Summary of Project

For this project Oxford Performance Materials, Inc. has an overall goal to develop MEAs to operate PEMFCs at 120C. During the first six months, they will examine materials and processing by developing novel polymer blends for 120C and low relative humidity (RH), establishing their laboratory capability, and fabricating blends into membranes and catalyst layers. During the final 18 months, MEA feasibility at 120C and low RH will be the focus, through characterization of membrane resistance and strength; fabrication of MEAs from blends; and demonstrating feasibility, optimization of MEA performance, Pt loading, and MEA durability (100 hours).

Overall Project Score: 2.65



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- New project too early to evaluate.
- Higher temperature operation is desirable from CO tolerance and heat rejection considerations.
- High temp MEA significant for autos.
- Development of new MEAs is definitely critical and supports the RD&D plan objectives. However, it is not at all clear how this program will achieve this. The presentation gives no information at all about gas transport, surely an important aspect for an MEA. Similarly, how will the ion channels be formed in the presence of the electrode materials?

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- Similar materials, such as PEEK, have been reported in the literature. The probability of having some success is high, although it is not clear why these materials or hybrids of these materials would be superior to other similar materials
- Interesting concept but needs more thought to overcome barriers.
- Conductivity is one goal but gas transport is another and it is not mentioned. A major issue in MEA design and construction appears to be ignored. How will the connectivity channels be maintained in the presence of the electrode nanoparticles? The project is dependent on FC-P12 where the separator part is developed. The MEA system seems to be much more difficult to understand. There is not much detail given on this

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.25** based on accomplishments.

- This is a relatively new project. They have spent much of the time thus far setting up the laboratory facilities and conducting some preliminary tests.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- This is rated "good" in spite of it being a relatively new project because the prime contractor is a manufacturer of specialty polymers, and the team is a good mix of academics and consultants.
- Strong collaboration with UCONN to develop polymer blends.
- Modest program.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- The proposed future work is primarily to characterize material performance. Discussions with the poster presenter did not identify alternative paths if any, that they would follow if the tested materials do not pan out.
- Confirm feasibility of approach in fuel cell tests.
- Approaches like this are needed to attack problem.

Strengths and weaknesses

Strengths

- The project team has a good mix of industrial, academic, and consultant people. Membrane formation under an electric field is an interesting concept. If it is successful here (as it appears to be, based on slide 9), it may also be applicable to composite membranes being developed by other researchers.
- Good concept. Experienced PI.
- UCONN subcontract looks good -- pursues an interesting if risky concept. However, this is separately funded
- Collaboration with UCONN is excellent and the work there is pursing an interesting, if risky concept.

Weaknesses

- The only MEA performance data plot shown was obtained at fairly high humidities (75% RH at 800C, Slide 11). It would have been useful to report such data at 25% and low humidity, and at higher temperatures but still with low humidities. There is no discussion in either past or future work of dimensional stability of these materials.
- Not clear that approach covers all needs for high T membranes, e.g., system start-up.
- Lack of attention to gas transport. Effect of electrode particles on morphology of polymers needs to be specifically included in plans. Future plans are very vague.
- It looks as if methods used are for Nafion which indicates that this developer may not be that clear of what he is doing and is dependent on the UCONN subcontract.

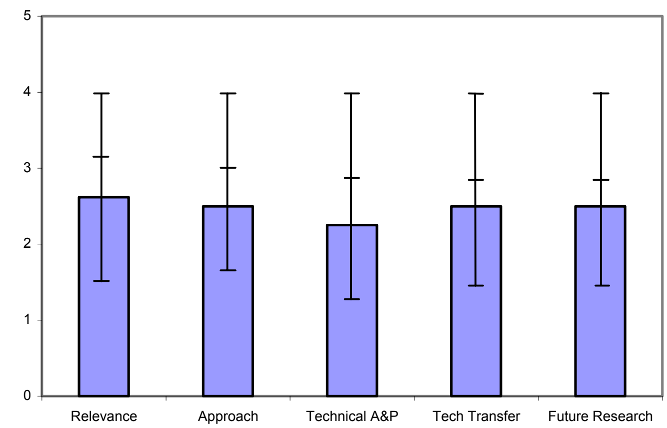
- The progress appears to be all at UCONN which receives different funding from this program. What has the contractor actually done?
- There is no provision for what to do if the blended polymers do not work in the presence of the electrode particles. There is no provision on what to do if the gas transport is inadequate. Not enough detail given to evaluate future plans. Impression given that there is not a lot of fundamental understanding.
- There is no collaboration planned on the electrode part which is the focus of this work. Seems to this reviewer that the contractor would benefit from help in MEA understanding, particularly in the area of gas transport.

Specific recommendations and additions or deletions to the work scope

- It is not clear why reducing the loading of Pt and Ru should be part of this project, at least at this stage or in the near future (i.e., in FY 2005). Is feasibility really demonstrated at 3 ohm cm^2 area specific resistance? The program target is 0.1 ohm cm^2.
- Determine how well MEAs perform at ambient condition and low RH. Durability testing needs to extend beyond 100 hrs under cycling operating conditions.
- Gas transport and surface effects on morphology need to be specifically include in plans.
- Even though the title is high-temperature membrane, the major focus should be on low-humidity operation. 30% RH @ 120C may still be too humid -- even lower humidity is desirable.

Project # FC-P12: Polymer Blend Proton Exchange Membranes
Weiss, Robert; University of Connecticut

Overall Project Score: 2.47



Brief Summary of Project

This University of Connecticut (UCONN) project is intended to develop new membranes based on polymer blends for operation at temperatures of 120C or higher.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.62** for its relevance to DOE objectives.

- This work is specifically focused on high temperature membrane development which is a "bottleneck" point for high temperature PEM fuel cells at low RH for both transportation and power system applications.
- Narrow focus on one aspect of one barrier. Fairly small budget.
- Higher temperature membrane is benefit for PEM. Data reported was at 80C or less, not high temperature.

Question 2: Approach to performing the research and development

This project was rated **2.50** on its approach.

- As far as funding ($95,000) for FY04 is concerned, the team's progress is good. SPEKK as a high temperature membrane material is not new but the SPEKK/PEI-blend PEMs are quite interesting which will provide a hope for DOE's high temperature, low RH PEM fuel cells for transportation purposes.
- Acid-base blend is a good idea, but which base polymer? At what concentration? These need to be studied first.
- Very interesting approach. Important to study process/film forming methods on film morphology
- Approach did not include electrochemical testing of membrane at elevated temperature. Why not?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.25** based on accomplishments.

- SPEKK/PEI-blend PEMs are promising. Good progress made on proton conductivity, methanol cross-over. If it is true that percolated path present before water is added, it is very meaningful for high temperature PEM fuel cell program for transportation applications.
- Good progress synthesizing and characterized condition. But, what is evidence for oxidative stability?
- Work reported at low temp. Direct methanol work reported -- how is this part of program?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- It is still in the early stage (first half -- 10/02 to present). This program's collaboration with other organizations is very small and limited. The collaborations with external fuel cell developers are very important for the success of this project.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Once the optimization of membrane development is done, the enhanced fuel cell performance tests at high temperature and low RH should be pursued in order to prove if the membrane material is suitable or not. Durability tests and crossover of H_2 should be addressed.
- Need to do concrete analytical work to understand the H-bond nature and impact on conductivity.
- Good focus on process conditions to control properties. Electric field orientations could be useful.

Strengths and weaknesses

Strengths

- SPEKK/PEI blend membrane has time properties of a relative high ionic conductivity, less cross-over of methanol, and less water for proton transport.
- Acid-base blend polymer is worthy of funding, but I doubt this team has the right skill sets to be successful.
- Platform understanding of these materials.

.
Weaknesses

- More SPEKK/other materials blend membranes should be pursued in order to have an optimized configuration. More PEM fuel cell performance tests under high temperature (>120C) and low RH. Durability tests. Collaborations with other organizations.
- PEI reduces SPEKK conductivity. The team lacks any strategy to either understand or mitigate this problem. Missing knowledge/insights on the basics of ion mobility and acid-base interaction principles.
- Carbon hydrogen bond is proposed weakness of this type of material. Researchers did not address this issue. Why not? Do they not know of this weakness?

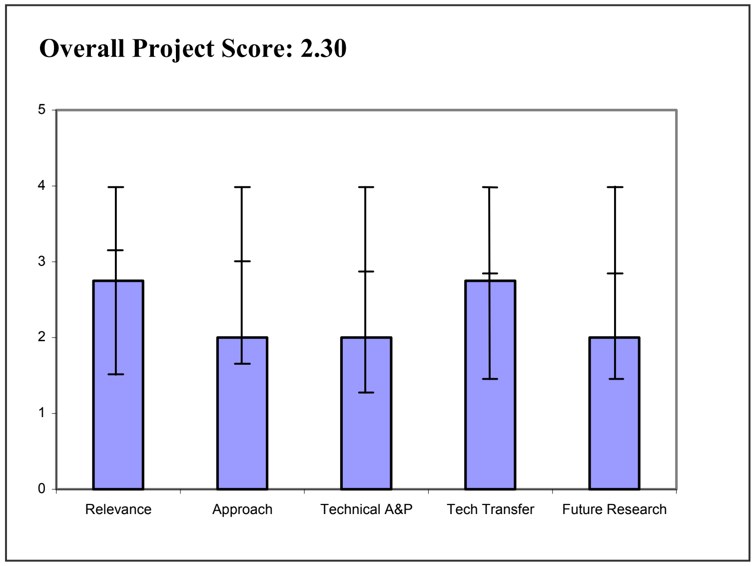
Specific recommendations and additions or deletions to the work scope

- This project is not going anywhere. Need significant revamp, maybe interact with physical chemists/analytical chemists who are working on membranes.
- Stay focused on high temperature properties of membranes and dry operation -- do not confuse with direct MeOH membrane properties. Consider non-aqueous electrolytes in combination with SPEKK/PEI blends.
- Characterize at high temperature.

Project # FC-P13: High Temperature, Low Relative Humidity PEM Fuel Cell Membranes
Nair, Bindu; Foster Miller

Brief Summary of Project

The objectives of this project are to develop a high temperature capable (150C) PEM fuel cell membranes that can operate at variable relative humidity, to develop PBO/acid membranes that might compare to PBI/acid membranes, the only viable high temperature membrane currently available, and to use polymeric acids instead of small molecule acids to improve the stability of the PEM to thermal/humidity cycling.



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- Not clear how PBO/PBI systems will enable fuel cell market faster than PFSA systems. Not clear how PBO may be better than PBI.
- The development of polymer electrolyte materials that can operate at a variety of temperatures and humidities would offer much greater flexibility in fuel cell system designs and their applications.
- Not entirely clear on the benefits of PBO vs. PBI. If PBI works, what are the advantages of PBO that make it better? Looking at non-leachable systems is definitely worthwhile but this is not made clear. We do not know if the non-leaching sample is PBO or PBI.

Question 2: Approach to performing the research and development

This project was rated **2.00** on its approach.

- Still scouting conductivity of sample membranes; the industry needs membranes now that can be scaled up at competitive prices. This project seems to seek improvement of some F.M.-proprietary technology solely to enable F.M.-proprietary membranes at the expense of developing the right membrane.
- It is not clear that PBO offers a uniquely different substrate from PBI -- why does it enable the use of stronger acids or polymeric acids any more than would PBI? The researchers need to be concerned about the chemical stability of their materials under fuel cell conditions.
- Difficult to evaluate this as the non-leachable sample is not described. A guess would be PBO plus Nafion which would be reasonable given the conductivities of the other polymeric acid. No information is given on how the conductivity will be further improved so it is impossible to judge the soundness of the approach. Furthermore only conductivity in the bulk membrane considered. What about gas transport (permeability) and how materials will behave in the presence of electrode material? The presentation gives no indication that this is considered and yet building an MEA is planned. Surely some thought should be given to this.

Question 3: Technical accomplishments and progress toward project and DOE goals
This project was rated **2.00** based on accomplishments.

- Showed no baseline data…how does PBO compare to PBI/PA at low temperature/low RH and high temperature/Low RH? This makes it hard to evaluate technical progress. Durability?
- Unimpressive results after 13 months of funding.
- The PIs have measured reasonable (but not yet adequately high) conductivities with phosphoric and sulfuric acids. The PIs have shown that membrane preparation methods can affect the conductivity substantially -- hopefully, they can exploit this to further advantage.
- The materials discussed are commercially available except for non-leachable sample which may also be. The conductivity of latter sample is not exactly stellar and no information is provided about gas transport, mechanical properties, or behavior with electrodes materials. Progress is slow for $150k in year 1.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.75** for technology transfer and collaboration.

- Good to be working with CWRU, inventors of PBI/PA.
- They have several academic collaborations. They are working with other potential sponsors (Air Force), which, if successful would leverage this work for other uses.
- The collaborations are good although the presentation does not explain what the participants are doing in enough detail. Fortunately, this reviewer is familiar with these participants and their capabilities. Otherwise the collaborations and other interaction are inadequately explained.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- Future expectations not clearly outlined.
- Since the method of preparation seems to have such a significant effect on conductivity, an investigation of the underlying reasons, e.g., morphology at the University of Akron, would be very worthwhile.
- There is no specific approach described to tell us how the conductivity will be improved. There is no approach to tell us how the MEA will be built. What properties of the membrane material will matter. What tests will be run besides building a cell and running it? What morphology tests will be used and how will they be related to structure etc.?

Strengths and weaknesses

Strengths
- They seem to have a membrane that conducts at high temperature/low RH conditions.
- The concept of using larger functionalized molecules, such as acidified polymers is a good one to reduce leach ability. The researchers must keep in mind, however, that such polymer backbones may not be stable under fuel cell operating environments.
- The concept of a non-leachable acid with PBO/PBI seems to be worthwhile and built upon a system that works.

Weaknesses

- No clear work plan. No clear methodology to scale-up (i.e., developmental partners) if membrane becomes successful. No durability data or plan to measure durability data.
- The measured conductivities are still at least 2 orders of magnitude too low. It is doubtful that simply modifying the preparation procedure would provide the needed improvement in conductivity.
- Gas transport is not considered. Nor is the effect of the electrode surfaces. Difficult to be confident this is going the right way when no details of the FMI sample is given.

Specific recommendations and additions or deletions to the work scope

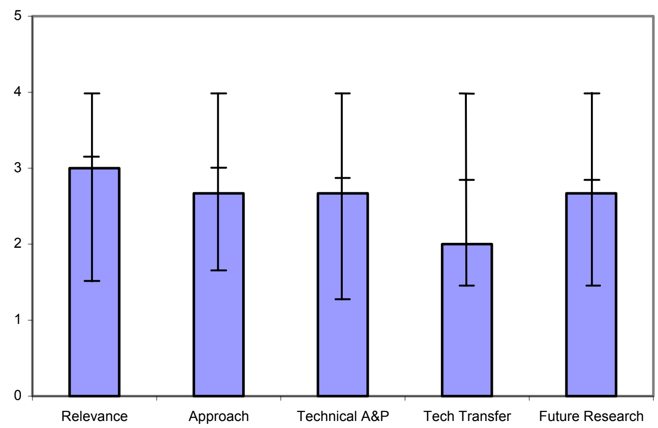
- Focus on durability (not just loss of acid) of these types of systems, or eliminate this program entirely.
- While improving the conductivity is, of course, a desirable objective, the first bullet under "Future Work" does not say what they will do to achieve it. Low temperature conductivities (i.e., at 250C, 500C, etc.) should also be measured and documented, all at low humidities.
- Gas permeability tests need to be run on both membrane and MEAs. More detail on fundamentals of how the morphology studies will be carried out.

Project # FC-P14: High Temperature Polymer Electrolytes Based on Ionic Liquids
Pivovar, Bryan; Los Alamos National Laboratory

Brief Summary of Project

Los Alamos National Laboratory's (LANL) overall objective is to develop high temperature polymer electrolytes for transportation applications. Specific goals are: to increase conductivity at high temperature (~120C) and low relative humidity (<50% RH); improve fundamental understanding of conduction in 'free' proton containing ionic liquids; develop robust polymer systems; and probe the dependence of properties on ion capacity, water content and temperature.

Overall Project Score: 2.60



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- High-temperature membrane.
- Development of high temperature PEM will help resolve many complex issues with current PEM technology.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Initial testing at 50% RH and 100C rather than 25% RH and >120C to gain understanding-but-mechanisms are likely to be very different in the 2 regimes.
- Approach is good. Moving to tethered cations and very promising approach. Tethered ion has been studied in Japan before in ionic liquid community…check literature.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Many electrolytes have been synthesized and tested but results are not very encouraging -- conductivity, stability.
- Making good progress towards identifying candidate system. Good scientific approach.
- Need to keep working on water solubility.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- No industry collaborations mentioned.

- Not described in poster.
- Some collaborations so far. Need to better address the future plan to working with industry.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- Next steps are logical although not certain to improve success.
- Has identified appropriate systems for future study. Proposed work based on good scientific grounds.
- Continue the work but look towards showing its application.

Strengths and weaknesses

Strengths
- Good science with innovative thought. System offers promise as anionic membrane.

Weaknesses
- Need to consider alternative polymer backbones…PI is aware of this and is considering options.

Specific recommendations and additions or deletions to the work scope

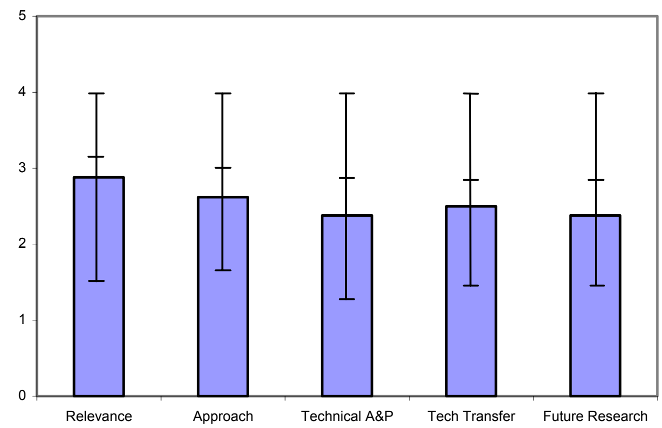
- Needs to expand testing envelope to lower humidity and higher temperature.
- Continue on same path.

Project # FC-P19: New Polymeric Proton Conductors for High Temperature Applications
Kerr, John; Lawrence Berkeley National Laboratory

Brief Summary of Project

Lawrence Berkeley National Laboratory (LBNL) will investigate the feasibility of solid polyelectrolytes for water-free, high temperature operation; measure conductivity; mechanical/thermal properties of Nafion® and polyether polyelectrolytes doped with imidazoles; determine effect of imidazoles on Pt catalysts; and covalently attach imidazoles to appropriate polymer backbones and test for conductivity; mechanical/thermal behavior and gas permeability.

Overall Project Score: 2.55



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- It is very important for the success of PEM fuel cells in transportation at the condition of high temperature (>120C) of low RH or no water.
- Narrow focus on one barrier and small funding level.
- Need for HT membranes is understood. Program must be aware of limitations above 120C where corrosion increases.

Question 2: Approach to performing the research and development

This project was rated **2.62** on its approach.

- It is a good approach to replace water-based electrolyte.
- Imidazole-based approaches are not new. In this aspect, the team's approach is ironically unimpressive in contrast to the presenter's self-confidence.
- Main outcome will be better understanding of potential solutions; not actual material solutions -- this is what National Labs should do.
- Approach appears to address basic issues but need to move toward fuel cell work.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.38** based on accomplishments.

- Nafion doped with imidazole or N-methyl imidazole is promising for HT operation without water. However, it is too early to draw any conclusion.
- Need also look at the conductivity and mechanical property in presence of some water/RH. Water exists in FC no matter what.

- Good progress relative to stated program goals, but poor progress toward over-coming the actual barrier. Very useful set of data on doped Nafion -- nice work. Good to measure catalyst ORR effects too.
- Data is confusing if Grotthus mechanism is observed concurrently. Not sure what statement about Schroder's paradox means if Grotthus conclusions observed.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Based on the project schedule, the level of collaborations is ok.
- Need to get active collaborations going.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.38** for proposed future work.

- The future plan is fine. Namely (1) water-free separator membrane prepared based on Nafion-imidazoles, (2) MEA fabrication, (3) real fuel cell tests (optimization & conditions), and (4) durability tests.
- The team has enough data to show that this project is almost done; there is no real potential to meet DOE HT membrane goal.
- Concern that efforts to optimize membrane properties will be for naught since they are hydrocarbons not fluorocarbons -- not stable.
- No statements about testing under fuel cell conditions. Expect to see allyl group fail. Polystyrene is well known to fail as a fuel cell membrane support. Not sure why this material is considered.

Strengths and weaknesses

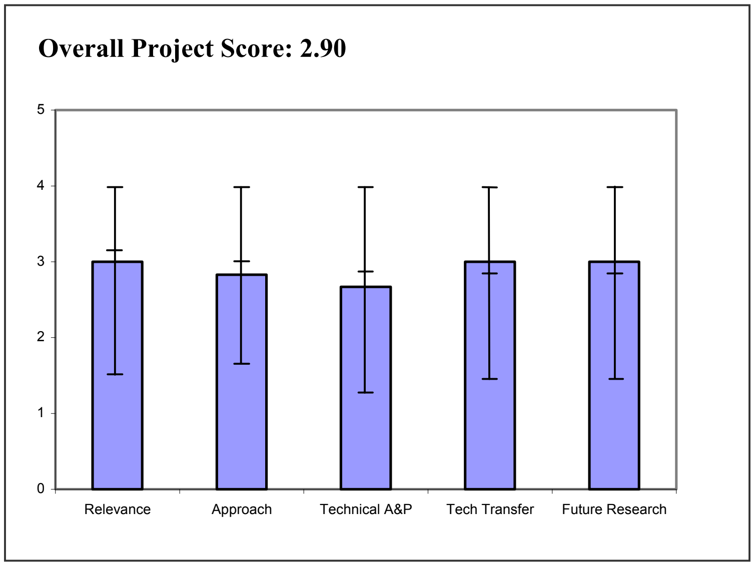
Strengths
- Scientifically, it is a right approach to make water-free polymeric electrolyte for high temperature, no water operation.
- Polymer architecture. Leverage Li-polymer electrolytes work. Future plan is fine logically.
- High level expertise, understanding.

Weaknesses
- It is still at an early stage of these kinds of electrolyte development. No data about real membrane, real MEA package, or real fuel cell set-up. No performance data of real fuel cells.
- The imidazole approach is fundamental to this work. 3 yrs ago, this approach would be interesting.

Specific recommendations and additions or deletions to the work scope

- Follow the future plan to make water-free, high temperature MEA package. Assemble the fuel cells for testing under the expected conditions. Have fuel cell testing results for evaluation. In addition, both of the original electrolyte (Nafion) and doped organic compounds should be extended to wider range to explore.
- From results to date, clearly the tethered polymer would not be nearly conductive enough to meet HT membrane requirement. Re-direct to basic science funding or use the learning and revamp the program with innovative concepts.
- Put more effort into working with materials that will have high temperature stability rather than optimizing ones that won't be stable.
- Recommend add fuel cell stability testing ASAP. Materials will most likely fail at 150C as fuel cell.

Project # FC-P20: Fuel Cell Reformer Emissions
Fable, Scott; TIAX LLC



Brief Summary of Project

The purpose of this TIAX LLC project is to quantify the emissions from fuel cell vehicles with on-board reformers. Data from fuel processors will be used to evaluate potential emissions from vehicles with on-board fuel processors.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Verification of claimed very low emissions is important to the transportation fuel cell industry and commercialization.
- Need data on emissions. Need solutions to reduce overall emissions.
- Important that fuel cells and fuel cell systems meet or exceed emissions requirements.
- Emissions from reformate-based fuel cell systems are expected to be very low, but it is important to measure and document them.
- Project started out during period when on-board fuel reforming was emphasized. Not as much relevance under current program.
- Analysis required to confirm low emissions of reformer-based fuel cell vehicles.

Question 2: Approach to performing the research and development

This project was rated **2.83** on its approach.

- Measurements on actual fuel processors although not over an actual drive cycle.
- This project concentrates on measurements only, should also come up with recommendations for reducing emissions.
- Measuring these emissions is not easy, particularly during start-up. These are among the first such reported data. Although further corroboration will be rated, particularly as fuel processors and fuel cell systems evolve, these data provide a useful first estimate.
- Comprehensive analytical techniques for measuring emissions.
- Test data obtained on "real" prototype reformers. Lag between test systems and state-of-the-art (by definition).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Measurement of 4 different systems nearly complete.
- Need to compare measurements with Tier 2, Bin 5. Question -- why are the NO_x levels measured so high? Suggest trying FTIR to check chemiluminescence technique.

- Some of the results are questionable and need further verification. Total emissions were given as a sum of start-up emissions and steady state emissions whereas the total emissions would be a time-weighted average of these two. After PROx showed NO_x emissions when reactors are filled with catalyst similar to NO_x reduction catalyst, and are under very reducing conditions at which NO_x should not survive -- perhaps they are measuring ammonia or something else.
- They will have made measurements on four different systems by the time the project is completed in the next few months. Their use of the data to model drive-cycle emissions will provide the first view of how clean these fuel cell systems will be.
- Progress slow primarily due to unavailability of suitable reformer systems for testing. Without fuel cell in system, results may be considered "worst" case measurements.
- Data collection and analysis well conducted. Focus of data collection on transients and start-up is sound.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Fuel processors were obtained from 2 developers.
- Please be careful in publications not to overstate the emissions, these measurements need to be made carefully.
- Collaborations with fuel processor developers are good.
- It is mentioned that they have discussed this work with technology developers and others outside DOE but no specific interactions were identified.
- Interactions with major fuel processor developers -- few.
- Seems to be communicating with developers.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Project is nearly complete.
- Could also include other fuel effects on the start-up emissions. Concentration on the tail-gas combustor is needed. In a real system, that component is going to define all (or nearly all) emissions. A detailed examination of the reformer/vehicle start-up is needed. Since this is probably not yet defined, need to explore all scenarios
- This is not really applicable as the project is nearing completion in the next few months (early in FY2005).
- Project ends in October-November time frame.
- Perhaps this project should be refocused toward stationary.

Strengths and weaknesses

Strengths
- Collaboration with Nuvera and McDermott.
- They have successfully developed measurement and analysis techniques, even for systems that are not quite complete fuel cell systems. They will use measured data to model emissions over drive cycles.
- Have obtained speciated HC emissions data. Will be useful in determining H_2 fuel quality requirements.
- Organized, well-thought out approach.

Weaknesses

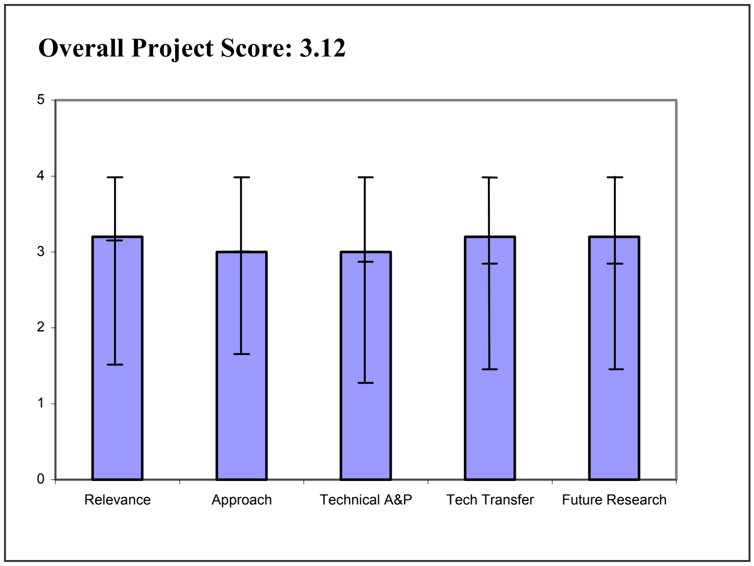
- The lack of an actual fuel cell in the test loop results in overstatement of emissions (although emissions still seem to meet targets). Unfortunately that none of the fuel processors were capable of load following during a simulated drive cycle.
- Calculation of emission example appeared to have a math error.
- Don't appear to have a good knowledge of how the tests were run (conditions, etc.) to be able to provide a correlation of emissions with operating conditions. There are some questions about the analytical techniques used, especially for NO_x measurements. It seems they see NO_x coming out of the PROx, which uses catalysts similar to those used for deNO_x and is operating under reducing conditions. In addition, the start-up procedure wasn't clear what the procedure was and whether the anode gas burner (AGB) was operating, this could have a huge impact on emissions. Start-up emissions will be determined by the AGB since the exhaust should be fed to this to limit pollutants.
- Since the measurements have been made on experimental systems, it is not clear how applicable the results will be to further developments in fuel processors.
- Current scope on-board reforming. Go/no-go decision pending.

Specific recommendations and additions or deletions to the work scope

- Re-examination of NO_x data and possible interferences worth looking at AGB efficiencies.
- The project is nearly finished, but if possible, particulate matter emissions should be determined. As indicated under "Future Work," emissions from direct hydrogen and stationary reformate systems (such as those from Plug Power) should also be measured (perhaps in a separate project since this one is almost concluded).
- Include in the final report, all information regarding different species that were identified.
- Re-focus toward stationary FC systems (or SOFC).

Project # FC-P22: Residential Fuel Cell Demonstration by the Delaware County Electric Cooperative

Schneider, Mark; Delaware County Electric Cooperative, Inc.



Brief Summary of Project

In this project Delaware County Electric Cooperative, Inc. will validate objectives of propane-fueled hydrogen fuel cells for edge-of-grid residences via a field trial demonstration to understand the technical and economic viability of fuel cell alternatives to new line construction. Specifically, they will measure and report technical performance, provide raw cost data and economic viability analysis, document maintenance and operations concept enhancements specific to residential fuel cells, share safety related vulnerability analysis and lessons learned, and promote education of state and local consumers.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Project designed to obtain actual field data in residential environment which is necessary for developing residential FC systems.
- Here's a program we'll really learn something from about linking the fuel cell to a typical American home.
- Demonstration projects are extremely important to facilitate technology commercialization.
- Demonstrates one of the key advantages of fuel cells, i.e., off-grid, distributed generation.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Well thought out approach for evaluating fuel cells for residential use in rural areas. Realistic understanding of likelihood of project success and the benefit of the study.
- It is not clear what the essential objectives are in terms of the DOE program.
- It's worth a few thousand dollars to tune the house to the fuel cell environment, e.g., better insulation, thermo pane windows (if not already in place). Let's make the fuel cell look good.
- Well thought out plan. Risk associated with propane, but now may be the time. Cost risk -- are there sufficient funds for fuel cell?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Difficult to evaluate because funding has not been released. Initial work plan is well developed.

- Making good progress; need to get the contracting process over with. Most details seem well thought out and planned for.
- Good plan established.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.20** for technology transfer and collaboration.

- Good collaboration between regional electric companies and New York State government.
- Interfaces and collaborations look appropriate.
- Collaborations with local and state organizations.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.20** for proposed future work.

- Sound research plan for acquiring data/monitoring site demonstration and for evaluating data. How will the local consumers "be educated?"
- Pure evaluation program.
- This project needs to be funded to completion without any cutting of corners.
- Well thought out plan.

Strengths and weaknesses

Strengths
- Very realistic in project expectation, objectives and benefits of the project. Like the idea that the fuel cell site demonstration will not be designed around the lifestyle of the test subject to "favor" success of the project but will be designed to obtain data in realistic setting where test subject sets requirements.
- Much needed demo project that could give the EERE fuel cell program "front page" exposure in the information media.
- Good approach/plan

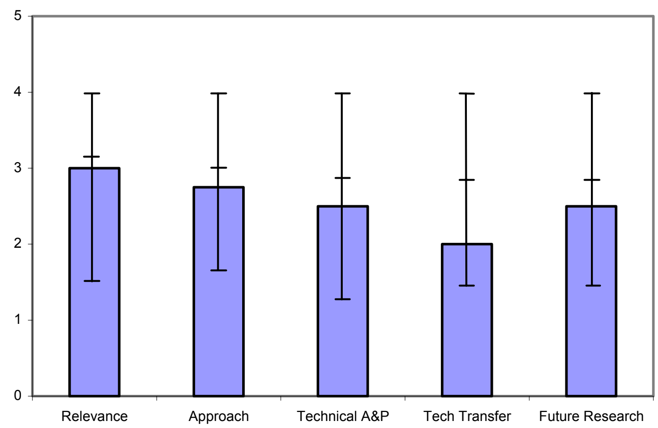
Weaknesses
- Need to ensure project is adequately funded.

Specific recommendations and additions or deletions to the work scope

- Identify plan for "educating the consumer."
- Contract or work with a university program to help with the data gathering and performance monitoring might (1) save money, (2) make for a rewarding educational experience, and (3) bring some fresh ideas to the performance tracking process.

Project # FC-P23: Fuel Cell Operated Smart Home
Alam, Mohammad; University of South Alabama

Overall Project Score: 2.55



Brief Summary of Project

The University of South Alabama project will demonstrate that a 5kW fuel cell power plant (FCPP) can satisfy the power demands of an all-electric home and that the FCPP can handle both transient and steady-state conditions.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Household energy management should help to improve the overall energy efficiency of residential fuel systems.
- Yes, we need hands-on experience of real world applications to ensure the acceptance of hydrogen technology.
- These kinds of projects could put fuel cells in the forefront of consumer thinking about alternative energy options.
- I don't see any value of this project to advancing technical barriers -- perhaps a philosophical difference.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- Approach is good -- however, how will the activities in the model home be established to model the general activities in a typical household?
- Phase I is necessary, but compared to Phase II. Phase II: overloaded, nice targets but impossible to fulfill all of them.
- I'm worried about the "managed load" approach. It looks a bit too managed. How well does the model home emulate a real (average) home?
- Extremely expensive approach for what industry eventually will do on their own nickel.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- What is the overall energy efficiency of the SMART house compared to a non-SMART house? Hope to see data from SMART house at next year's review.
- What has been done?
- Looks like this project is moving along at a good pace!
- Appears to be making progress against their goals, despite reservations described above.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- Tech transfer is not clear -- who is the end user of this project's data?
- What are the contacts made to other FC research groups for? This is more an education program, than an objective of research.
- Teaming could be stronger, but all the bases appear to be covered by the existing team.
- Collaborations not evident.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Question -- how are the ten homes being supplied by a single FCPP? Does not seem to be enough power. Why is hydrogen cogeneration being considered for this project?
- Focus it. Overloaded Phase II with the half funding of Phase 1.
- Phase II looks like a large but credible step beyond Phase I; and it's the kind of test that will teach much about fuel cells.
- Well defined plan, but…

Strengths and weaknesses

Strengths
- None provided.

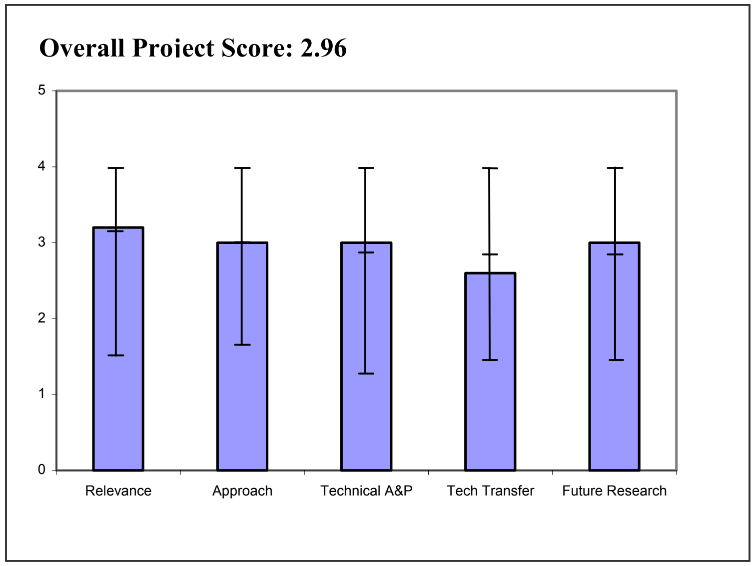
Weaknesses
- Not clear if project takes into account thermal/electric management especially in northern climates where thermal and electric demand are not in sync -- summer thermal-low, electricity high; winter thermal high, electricity low. How do you plan to educate the consumer?
- A house built inside a building is not the ideal model but it will probably do for Phase I.

Specific recommendations and additions or deletions to the work scope

- Should interact with residential fuel cell developers such as Plug Power to provide knowledge/lessons learned. Question -- since the model house is built inside a larger building, how do you account for the temperature moderating effect of larger building? Does this affect air conditioning demand? Studies by Argonne National Laboratory have shown that maximum energy efficiency requires a cogeneration system -- a fuel cell plus either natural gas heating or a heat pump -- do you agree?
- How about getting a utility involved?
- This is a ton of $$$ for a project that will not advance the potential for commercialization of fuel cells.

Project # FC-P24: Graphite-based Thermal Management System Components for Fuel Cell Power Systems

Lara-Curzio, Edgar; Oak Ridge National Laboratory



Brief Summary of Project

Oak Ridge National Laboratory (ORNL) will develop compact, low-weight, effective thermal management components for fuel cell power systems using carbon-based materials. The objectives include: the design of thermal management system components based on graphite foam and 3-D woven graphite fiber performs; synthesis of graphite foams with different pore sizes and assessment of the effect of pore size on heat transfer, permeability and mechanical strength; determining the feasibility of weaving high-stiffness graphite fibers into complex 3-D architectures; evaluating the effect of fiber architecture on the heat transfer and permeability of 3-D fiber preforms; and broadening industrial collaborations.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Project appears to be addressing one of the key concerns of using fuel cells in a vehicle. Make sure in future to show performance to the goals being addressed.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Approach identified looks well thought out.
- Weaving of low-cost carbon fibers could lead to low density, low-cost, high thermal efficiency heat exchangers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Though project has not been running for long, it does seem to be making progress.
- Project is in beginning stages and appears to be off to a good start. Real test will be when woven fibers are assembled if there is good thermal contact between fibers.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- Collaborations between carbon-fiber manufacture and 3D weaving will probably be a key to success of project.
- Need to identify a partner now who will do some real-world validation for performance.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Address durability by testing. May be a good project, but too early to tell. Will need to address cost soon.

Strengths and weaknesses

Strengths
- Collaborations are in place.
- For $129K, I'm supportive of letting ORNL try this and see what develops.

Weaknesses
- Consider an automotive or fuel cell integrator as a partner/collaborator.

Specific recommendations and additions or deletions to the work scope

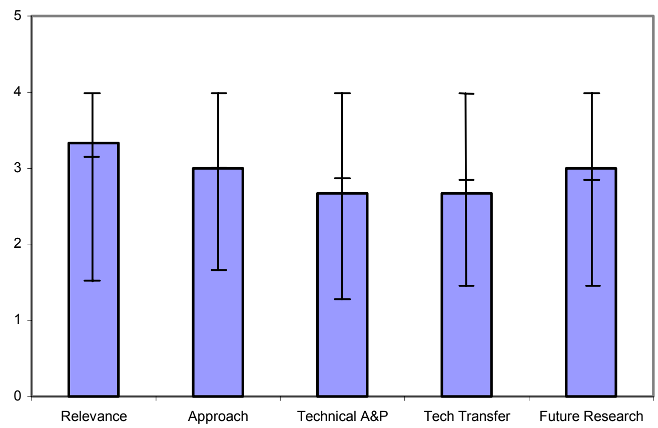
- Key to the concept will be the thermal conductivity from strand-to-strand in the weave. Work to improve thermal contact between strands or fibers should be added.

Project # FC-P25: CO Sensors for Fuel Cell Applications
Garzon, Fernando; Los Alamos National Laboratory

Brief Summary of Project

Los Alamos National Laboratory (LANL) will develop CO sensors that can detect carbon monoxide in a hydrogen-containing gas stream, specifically addressing the targets of 1-100 ppm CO at <150C, 100-1000 ppm CO at 250C, and 0.1-2% CO at 250C-800C. These sensors can be used to control the air bleed into the fuel cell anode and could also be used to control the oxygen input of the PROx reactor.

Overall Project Score: 2.93



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- This technology can be important in preventing the poisoning of FC stacks, if successful.
- CO in H_2 streams -- a real need in practice (even to support ongoing R&D projects).
- CO monitor is very important to the fuel reforming industry. There is a heavy need for this sensor. Since this has little to do with automotive systems, should be transferred to stationary systems.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Novel approach with consideration of all key factors.
- Accomplishments show that sensitivity and response time are still challenges to be addressed.
- Tough challenge; presenter was excellent. Need to clearly identify which sensors can work as "continuous" versus those that provide "cumulative" info. Good discussion on clean-up.
- Not really innovative.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Not clear there was lots of progress over last year.
- As response time and sensitivity are so critical, this is still a barrier to be addressed, though response time (post PROx) is good.
- Good data on known gas compositions on model/compositions. But how does system respond with "real-life" feeds? Examples: SO_2, H_2S, NO_x contaminants.
- Progress is good but is this the best technology to pursue?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Need collaborations with end-users also (current collaborators are "up" the food chain -- materials companies).
- Need to collaborate with fuel cell manufacturers to make sure work is of value.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Work on durability and stability as well as response time and stability.
- Need to extend into work with live feeds (where other contaminants exist).
- Need to focus on one development to accelerate the technologies. So far, none of the targets are met with any reasonable pathways to meet it.

Strengths and weaknesses

Strengths
- Well-developed basic program where need of such systems (of improved accuracy) is real. Presenter has solid understanding of current systems (including alternatives).
- Needed development for stationary approach.

Weaknesses
- Need to explore larger compositional space to observe multi-gas interactions.
- No longer applies to automotive and also too slow for automotive needs.

Specific recommendations and additions or deletions to the work scope

- Involve more end-use partners. Articulate challenges to such developments more definitively.

Technology Validation

Summary of Annual Merit Review of Technology Validation Subprogram

Summary of Reviewer Comments on Technology Validation Subprogram:

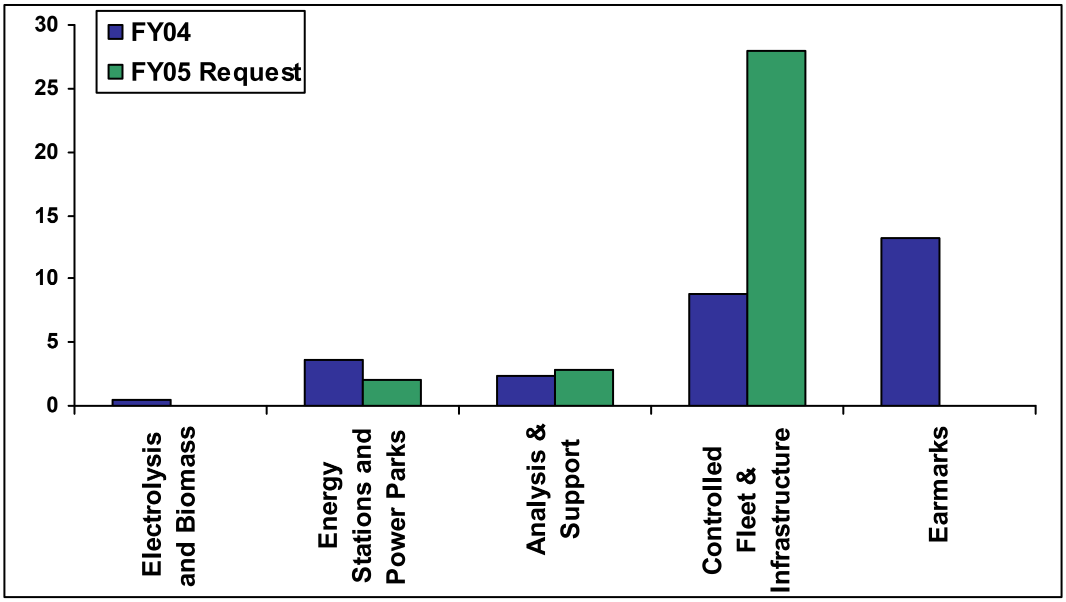
Reviewers identified the technology validation of key hydrogen energy technologies and systems to be an essential component of the Hydrogen Program mission, and critical to the President's Hydrogen Fuel Initiative. The projects were considered to be appropriately diverse and strongly focused on addressing key issues necessary to validate the technologies and/or technology durability. Reviewers noted that the projects that collected data and information and considered its applicability to future work were very valuable. The Reviewers also noted that the project Principle Investigators (PIs) should remember to consider the objectives of the HFCIT Multi-year RD&D Plan. Some of the projects initiated prior to the development of the Plan are focused on single issues; where recently initiated projects consider a broader picture.

The major criticism by the Reviewers was that the funding directed to the Congressionally-directed projects had a negative impact on the Program. As a result, the Program was unable to fund the Hydrogen Fleet Demonstration awards that were announced in 2004. The Reviewers also expressed concern that PIs did not present funding information on their projects. Reviewers found it difficult to assess the PIs' accomplishments because there was no indication of level of funding spent, and at what point in the year funding may have been received. Reviewers felt that it would be important to have specific information on the project funding level and the time-phase of funding presented by the PI or DOE management.

Reviewers thought highly of the Technology Validation Subprogram's approach of conducting ***learning demonstrations*** that emphasize co-developing hydrogen infrastructure in parallel with hydrogen fuel cell-powered vehicles that would allow a 2015 commercialization decision. Reviewers did express some concern regarding the interactions and communications between the Technology Validation and R&D activities, stating that they "are not clearly defined." Technology validation of hydrogen energy systems that crosscut into all technology R&D subprograms is an important facet of the Hydrogen Program. As such, there is a need for strong coordination between these subprogram elements and a clear feedback loop to ensure that lessons learned are translated to next generation technology designs in the shortest possible timeframe. Reviewers also expressed need for a strong linkage between the Technology Validation and the Safety, Codes, and Standards Subprograms to ensure that safety and liability issues are sufficiently linked and adequately addressed.

Technology Validation Funding by Technology:

The funding portfolio for Technology Validation addresses the need to validate integrated hydrogen and fuel cell technologies for transportation, infrastructure, and electric generation in a systems context under real-world operating conditions. The 2005 funding profile (subject to Congressional appropriation) addresses key aspects of the Hydrogen Program mission and the cross-cutting issues associated with the National Academies' Report and system integration activities.



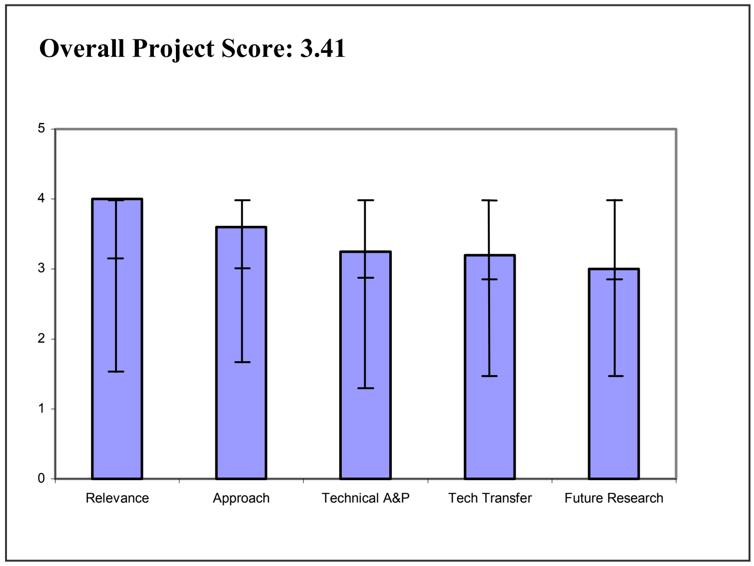
Majority of Reviewer Comments and Recommendations:

In general, the Reviewer scores for the Technology Validation Subprogram were on average with those of the other subprograms (the maximum, minimum, and average scores for Technology Validation projects were 3.53, 2.20, and 2.92, respectively). These compare to the overall maximum, minimum and average project scores of 3.92, 1.55, and 2.91, respectively. The Technology Validation project portfolio includes a mix of well-established long running projects and new projects with little to no progress or technical accomplishments yet to report. The major recommendations for the Technology Validation Subprogram are summarized below. DOE will act on reviewer recommendations as appropriate for the overall Hydrogen Technology Validation effort.

- **Power Parks Analysis** -- Focus on making available data public and expanding the analysis effort.
- **Hydrogen and Fuel Cell Demonstration/Analysis** -- Focus on reliability assessments.
- **System Analysis** – Reconsider evaluation of these projects in the Technology Validation Subprogram. Focus on increasing database of performance and reliability information.
- **Refueling Technology Development and Demonstration** -- Focus activities to ensure that lessons learned become public information. Introduce more state, local and corporate partners.
- **Vehicle Demonstrations** -- Focus on fleet assessments.

The reviewers also recommended specific projects (3) be considered for phase-out from the Technology Validation project portfolio. A general recommendation was to develop "lessons-learned" documents as technology assessment projects near completion.

Project # TV-1: Technology Validation Subprogram Overview
Gronich, Sig; DOE, Team Lead



Brief Summary of Presentation

The purpose of this Technology Validation Subprogram Overview is to describe goals/objectives, budgets, barriers/targets, approach to R&D, technical accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and puts into context the R&D and analysis projects which will be presented in this subprogram area during the Annual Merit Review.

Question 1: Relevance to overall DOE objectives

This presentation earned a score of **4.00** for its relevance to DOE objectives.

- Good synergistic effect; ties up components into systems.
- Looks at H_2/electric economy with autos, utilities, and energy companies.
- Tied clearly to DOE H_2 plan.
- Validation of key technologies is clearly critical to President's Hydrogen Fuel Initiative.
- Diversity of projects provides good opportunity for comparison of technologies.
- Highly correlated to overall DOE objectives.
- Subprogram was well covered as it exists currently. Could have used a little more info on time line activities beyond the 3 fleet regions (plus NY and Washington) that are being rolled out.

Question 2: Approach to performing the research and development

This presentation was rated **3.60** on its approach.

- Good approach.
- Ties in a number of users (utility, auto companies, energy companies).
- Well planned.
- Feedback from validation activities to technology R&D to identify needs could be clearer.
- Some concern on apparent redundancy in infrastructure costs for fleet vehicle demo.
- Approach is comprehensive.
- Not convinced CNG/ H_2 mixture projects should receive much attention.
- Approach is good, and doing well with trying to incorporate with and deal with problems by earmarks.

Question 3: Technical accomplishments and progress toward project and DOE goals
This presentation was rated **3.25** based on accomplishments.

- Mine project does not fit well - hard to see commercial application widespread.
- Could use a broader approach to look at other techniques.

- Still early.
- Clear criteria of success.
- Difficult barriers - there has been good progress.
- Early stage of this program seems to be moving along as expected.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.20** for technology transfer and collaboration.

- Did not see this addressed specifically on slide - did not see communication plan.
- Right track.
- Good orientation to inclusiveness.
- More high level coordination of communication between programs may enhance use of lessons learned.
- Seems to be very broad participation among industry and universities - but not other federal agencies.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.00** for proposed future work.

- Not sure of relevance of locomotive work/mine programs to consumer market.
- Task 4 - not sure of relevance of hythane vs. hydrogen fuel.
- Not yet planning for future challenges.
- Is plan realistic given realities of funding?

Strengths and weaknesses

Strengths
- Program has relevance to demonstrate more "systems" concepts and less "component" approach.
- Pragmatic.
- Organized.
- Diversity of projects provides evaluations/comparisons of many different technologies.
- Good mix of organizations.
- Broad-based measured approach.
- Focused on doable near term technologies.
- Good corporate participation.

Weaknesses
- Could use more details on safety.
- Not enough supporting detail about exactly what safety issues DOE will look at.
- Task 5 only biomass pyrolysis - no other renewables?
- Would like to see timelines to see how all these projects "fit" together.
- Liability still not addressed clearly in fueling station projects.
- Availability of funding to complete projects?
- Too many fueling stations?
- Large validation projects such as fueling stations/power parks require several years for lessons learned to contribute to next generation designs.
- Planning of projects should consider this especially in light of limited funding.
- Would like to see more collaboration with other federal agencies; DOT and DOD.

Specific recommendations and additions or deletions to the work scope

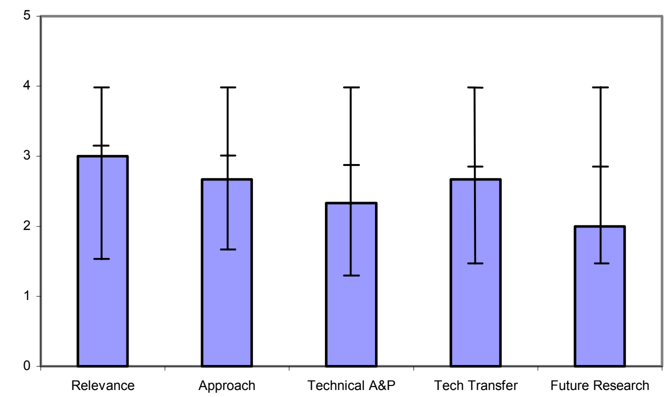
- Would like to see how DOE will communicate results - "success stories" to public.
- The clear target of addressing the insurability and public access (liability management) should be added to all technology validation projects.
- Look at off-road vehicle applications such as industrial trucks, ground service equipment.
- The talk had much more info than what is in the slides, e.g. critical role of data management in Task 6. Perhaps some of these important details could be put into the slides.

Project # TV-2: Power Parks System Simulation

Lutz, Andy; Sandia National Laboratories

Brief Summary of Project

Overall Project Score: 2.53



Power parks combine power generation co-located with a business, an industrial energy user, or a domestic village. In this project Sandia National Laboratories (SNL) will develop a flexible power park system model to simulate distributed power generation in energy systems that use H_2 as an energy carrier. This project will also analyze the performance of demonstration systems to examine the thermal efficiency and cost of both H_2 and power production. Deliverables include a flexible, computational tool to provide simulations of a variety of energy systems that produce H_2 and independent analysis of system performance, thermodynamic efficiency and cost of H_2/electricity.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Relevant to MYPP. Ties together H_2, electricity production, power parks, economics.
- Analysis such as this is critical to ensure best use of technology validation results.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Good description about simulink s/w.
- Use of simulink provides opportunity for outside use/collaborations is valuable.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.33** based on accomplishments.

- Looks promising.
- Good data analysis.
- No mention of safety.
- Parametric "what if" analysis provides valuable insights.
- Results should be valuable to DOE in setting goals/research priorities.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Good cross section of industry and universities.
- No discussion of how results would be communicated.
- Not a clear communications or feedback to H_2 community.
- Good collaboration with Power Parks partners.
- Would like to see expanded effort to add data base /systems analysis - more money?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- No cost associated with future work.
- SOFC utilized/considered?
- Lessons learned were not mentioned as precursor to future work.
- Refinement of model prepared.
- Would encourage expansion of communication effort.

Strengths and weaknesses

Strengths
- Leveraged internal SNL funding.
- Excellent protocols.
- Well qualified PI.

Weaknesses
- No discussion/mention of safety.
- Questionable utility.
- Unclear on potential impact of simulation.
- Limited by resources.
- Would be even more valuable if expanded and better communication included.

Specific recommendations and additions or deletions to the work scope

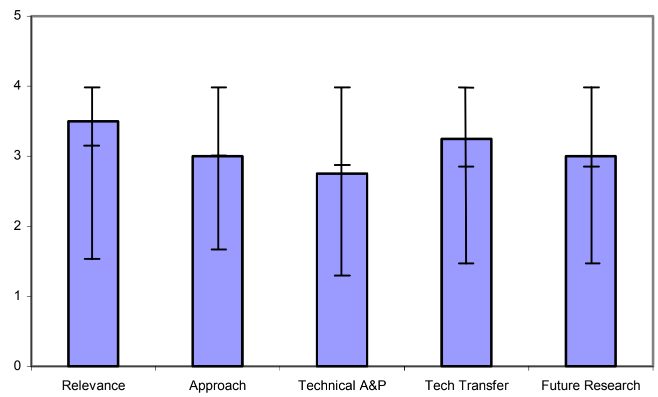
- Should be closed.
- Expansion of activities beyond Power Parks would increase data base and yield valuable analysis for DOE.

Project # TV-3: Hawaii Hydrogen Power Park
Kaya, Maurice; State of Hawaii

Brief Summary of Project

In this project, the State of Hawaii along with the University of Hawaii worked on demonstrating an integrated Hydrogen Power Park comprised of an electrolyzer powered by renewable sources, a hydrogen storage and distribution system, a PEM fuel cell and a hydrogen dispensing system for vehicles. Technical barriers as well as the economics for this project were analyzed along with gathering general public interest and support.

Overall Project Score: 3.10



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Validation of technologies developed under other DOE projects need a place to work to demonstrate their merits and receive feedback from others.
- The HI H_2 power park provides that place.
- It's versatile, has knowledgeable people and participation of diverse community partners.
- Broad-based and seems to be highly correlated to DOE objectives.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Project is conducted well but individual project goals and relevancy are weak in vision.
- Open architecture philosophy.
- Excellent example of leveraging funds from state, industry and DOD sources.
- Appears to have brought local officials into safety and training exercises - excellent.
- May need to narrow technical approach.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Solid progress shown; meeting schedule.
- Permits and site development progressing or complete.
- Having to change from 75kWe to 5kWe PEM cells may compromise local support for viability of PEM if adequate and appropriate electrical loads are not developed.
- Appears accountable.
- Limited success to date, but reasonable for this stage of project.
- PEM fuel cell system far behind schedule; power park site design too slow.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Excellent use of local partners; electric and gas utilities, local government, and OEMS.
- Good outreach and education attempts.
- Good mix of industry and government collaboration.
- Need to include PEM fuel cell manufacture in project team.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Future work possibilities and relationship to existing work have been thought through and planned.
- Flexibility demonstrated by changes incorporated when 75kW PEM was too expensive.
- Deliverables are not entirely clear.

Strengths and weaknesses

Strengths
- Technical knowledge and established relationships with diverse partnership base.
- Inclusive of community.
- Understanding of importance of international collaboration.
- Economically realistic.
- Good partner mix.
- Broad base technologies and approach.
- Leveraging approach to utilize U. of Hawaii personnel and facilities.

Weaknesses
- May need more focus in initial stages - or example just renewables for H_2 production instead of using reformers with multiple fuels.
- Fuel cell selection and delayed installation.
- No quantitative goals.

Specific recommendations and additions or deletions to the work scope

- Need to develop a staged approach with more narrow focus in early stages.
- Add fuel cell manufacturer to project team.
- Develop plans to install either multiple fuel cell modules or larger unit.
- Develop quantitative project goals and go/no go decision criteria.

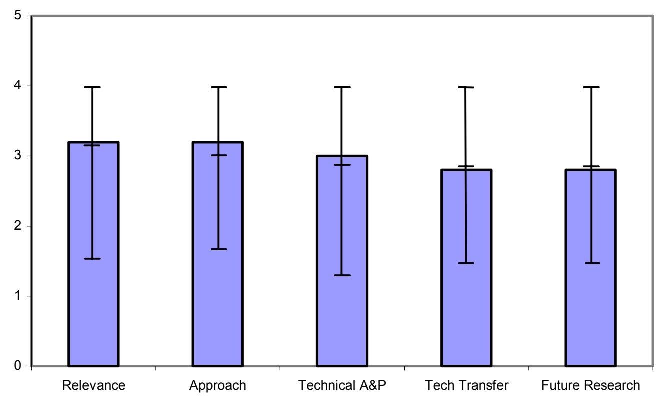
Project # TV-4: DTE Energy Hydrogen Technology Park

Regan, Rob; DTE Energy

Brief Summary of Project

In this project, DTE Energy will develop and test a working prototype of a hydrogen-based energy station concept that utilizes solar & biomass power combined with electrolysis and stationary PEM fuel cell technology to take advantage of low-cost power during off-peak hours to generate hydrogen for on-peak power generation and vehicle fueling. Using state-of-the-art hydrogen generation, storage, regeneration and control technologies, the project will evaluate opportunities to reduce overall system cost and maximize performance.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Park is designed to support vehicle infrastructure demonstration as partner to Daimler-Chrysler.
- Seems to have a high correlation to DOE objectives.
- Key project in key location.

Question 2: Approach to performing the research and development

This project was rated **3.20** on its approach.

- Detailed system design.
- Visitor center included - very positive.
- Most of H_2 production is from electrolysis using grid electricity.
- PV fraction is relatively small.
- Like the attempt to incorporate other emerging H_2 activities.
- CaFCP fueling protocols.
- Safety approach seems comprehensive.
- Would like to see a heat integration aspect to the configuration.
- Good use of multiple H_2 feedstocks, including renewables.
- Good to have electricity production and vehicle refueling at same site.
- Excellent understanding of electric utility needs and viable approaches.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Project in planning/permitting stage, on schedule.
- Have included existing PV collectors in system to be built.

- Emphasis on control system may be the most important aspect of this project.
- Progress with plans approved look good.
- Great to see you've procured all of the equipment needed.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Have established collaboration with local university for data analysis.
- Very little discussion on vehicle operations applications.
- Education and outreach effort seems passive.
- Data collection plans look good with web interface for public.
- Good connections with DCX, LTU, BP, and BOC.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.80** for proposed future work.

- Concerned about pace.
- Additional of Stirling engine will be an interesting aspect of the existing design.
- Vehicle operations, H_2 purity needs, system testing and reporting not discussed in great detail.
- Good timeline.

Strengths and weaknesses

Strengths
- Good SCADA approach.
- Good safety plan.
- Good leverage of resources.
- Good life of project - 2008.
- System design is thorough and control system will provide remote access.
- Controls emphasis.
- Codes and standards.
- Safety process.
- Plans look well laid out.
- Integration with other DTE facilities (operations center) and plans to test use of fuel cell electricity for DTE grid.
- Project is valid and worthwhile.

Weaknesses
- Renewable component of the system is relatively small but leverages on existing PV arrays.
- Partners seem too limited for such a broad based project.
- Deliverables are not clear.
- Many small FC vs. a few larger FC: not representative of likely longer-term installations.
- Lack of quantitative goals.

Specific recommendations and additions or deletions to the work scope

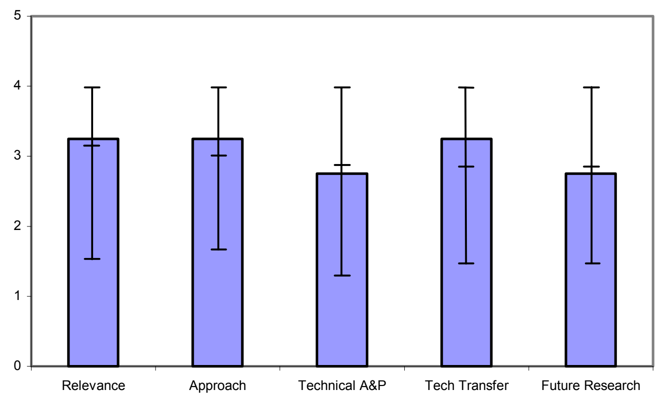
- Include discussion of data reporting to decide ahead of time what data will be released to public.
- More structured collaboration and tech transfer plan could be considered.
- Visitor center would be a good future addition, as suggested.
- Would like to see as much of the data as possible be made public (subject to agreement by your hard ware suppliers).
- Develop quantitative project goals and contingency plans if their goals are not met on schedule.

Project # TV-5: Hydrogen from Biomass for Urban Transportation
Yeboah, Yaw; Clark Atlanta University

Brief Summary of Project

Clark Atlanta University and its collaborators, focusing on producing hydrogen from biomass, produced 25 kg/day of hydrogen from peanut shells for urban transportation. This process involved pyrolysis of the biomass followed by catalytic steam reforming of the gas and bio-oil products to produce hydrogen. Successful operation of 100 hours demonstrated technical feasibility of the process, discovered agricultural uses of the carbon product, and identified economical co-product options for the bio-oils.

Overall Project Score: 3.05



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Demonstration uses entirely renewable feedstock.
- Biomass as proposed addresses critical transition/long-term need for renewable H_2.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Peanut shells as biomass feedstock is very practical and realistic.
- Approach includes fundamental experiments on the gasification and refining processes.
- Includes economic analysis.
- Good leveraging in co-product and rural economy needs.
- Systematic engineering approach.
- Excellent use of a local waste stream with hydrogen production potential

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- Pilot unit operation (100) hrs is completed (in previous year) with successful H_2 production.
- Longer term operation is to be done at new site.
- Significant technical progress but approach to resolve them not clearly identified.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Good partnerships.
- Collaboration with university and industry, laboratory partners.
- Established partnership addresses key elements needed for success.
- Qualified partners.
- Good use of local and DOE resources.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Don't build a complex model.
- Will be able to process other biomass materials (beyond peanut shells).
- Scale-up will be interesting.
- At risk, should be funded.
- Not clear what new info will result from scale-up.

Strengths and weaknesses

Strengths
- Value - modest funding yields good progress.
- Intent to map project into local economic development.
- Highly focused on biomass for CO neutral H_2 production.
- Well coordinated, clearly planned program.
- Very qualified PI and partners.
- Understanding of local resources and needs.
- Specialized experience in peanut shell pyrolysis.
- Detailed cost and efficiency goals.

Weaknesses
- Economic and community development.
- Economics depends on co-producing fertilizer which uses 30% of the H_2 produced.
- Funding-biomass may be the only near-term renewable H_2 option.
- Good program should be adequately funded.
- Limited systems safety and experience.
- Limited experience with hydrogen fueled vehicle.

Specific recommendations and additions or deletions to the work scope

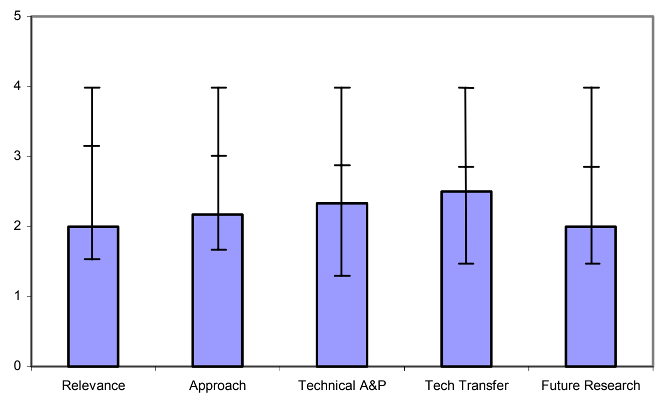
- Do not make an analysis project - the strength is in empirical nature.
- External design review to insure all issues have been addressed before moving to scale-up.
- Develop contingency plans if 1000 hours of operation introduces new reliability or safety issues.
- Do detailed reliability assessment based on 1000 hour operating experience.

Project # TV-6: Alkaline Fuel Cell-Battery Hybrid Systems with Ammonia or Methanol as H_2-Supply
Robert, R.; Apollo Energy Systems Inc.

Brief Summary of Project

Apollo Energy Systems Inc. is working to design an Alkaline Fuel Cell (AFC) system with circulating electrolyte for vehicles in intermittent duty service and small units for uninterruptible hybrid power supplies; develop a low cost ammonia cracker; optimize system performance and life; and reduce cost for accessories. The project is focusing on Pt-catalyst reduction and use of silver catalyst.

Overall Project Score: 2.20



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- Appears to be a good concept - ammonia as feedstock.
- But while meeting stated program goals, it's hard to imagine place of these specific products in program vision.
- Storing H_2 as ammonia is not relevant to the DOE objectives.
- Project does not describe economic relation to DOE targets.
- Lack of focus in the presentation made it difficult to assess relevance or accomplishments.
- NH_3 fuel for AFC technology appears to be a niche application technology.
- It's not clear how this project directly supports the President's Hydrogen Initiative.

Question 2: Approach to performing the research and development

This project was rated **2.17** on its approach.

- Identification of barriers.
- Integrates deep and continuing electrochemistry knowledge into applications.
- Ammonia cracker is a distraction from fuel cell development.
- Circulating KOH is a concept of questionable value.
- Unfocused.
- I couldn't determine what their key objective/approach was.
- Very little discussion on project technical process or safety procedures.
- AFC and ammonia advantages were described well.
- Disadvantages were not discussed.
- The overall approach was not clearly laid out.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.33** based on accomplishments.
- Hard to follow from presentation.
- Real progress among direct demo seems elusive.
- Improved capacity of electrodes.
- Accomplishments in line in funding but can't tell what else may have contributed to the program.
- Technical accomplishments were not clear.
- Looks like the project has accomplished most of what it set out to do. But, what was really learned?

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Did not get this from presentation.
- NH_3 "cracker" may be good reference work for small H_2 generations in future.
- Collaboration with U. of Graz.
- Some industry, university collaboration.
- Program would benefit from broader partnership/collaboration.
- Commercial applications or partners not mentioned.
- Interactions appear to be limited to the Technical University of Graz.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.00** for proposed future work.

- While demos are potentially continuing, upside progress is not really produced.
- Pathway for future development not clear.
- Future steps not clear.
- It’s not clear what steps will be taken next after the end of this project later this year.

Strengths and weaknesses

Strengths
- In depth knowledge of AFC's and battery chemistry.
- AFC technology has clear advantages over PEM or SOFC for some applications and some funding should probably continue to be directed towards it.

Weaknesses
- Talked about "problems" with handling and storage of hydrogen - should not describe in this way - these "problems" are being worked on by others and are not problems within the hydrogen community.
- Using alkaline does not give this company the ability to not look at handling of hydrogen.
- I don’t see this work being picked up by others for continued development.
- This project seems to be only weakly related to the DOE program plan.
- Needs to be better focused.
- Relevance/fit to DOE objectives not clear.
- AFC is currently outside mainstream work in H_2 and fuel cell technology development.

Specific recommendations and additions or deletions to the work scope

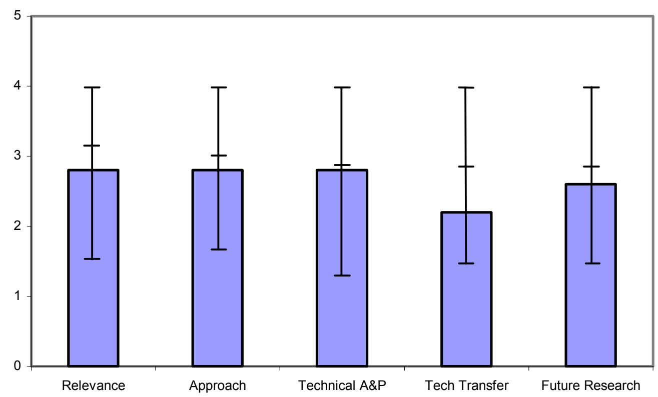
- Ran out of time - should use better time management - description of project.
- Need a clear definition of path to commercialization.
- Otherwise project looks like pure research and not suited to technology validation.

Project # TV-7: UNIGEN® Regenerative Fuel Cell for Uninterruptible Power Supply
Porter, Stephen; Proton Energy Systems

Brief Summary of Project

In this project, a team of Distributed Energy System and Proton Energy Systems will demonstrate a hydrogen fuel cell-based uninterruptible power supply with economic viability, real-world applicability, and regulatory code compliance. Performance goals include power output of 3+kW, storage capacity of 50 hours, instantaneous operation upon grid failure, and maintenance of digital equipment.

Overall Project Score: 2.64



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- 3kW range.
- Goals: technology validation, education, codes & standards.
- Backup system may well provide a niche market for profitable development through the commercialization "Valley of Death."
- Application of the system seems more like a niche application than for widespread use.
- Not aimed at DOE cost targets.
- Makes significant contribution to tech validation objectives.
- Good demonstration of use of fuel cells.
- While this is an example of an application for fuel cells, it is not clear how this advances the technology.

Question 2: Approach to performing the research and development

This project was rated **2.80** on its approach.

- Appears to be well thought through including safety aspects.
- Well thought out and exciting so far.
- Not clear if interconnection hardware, software, and controls are suitable to the task. (Not really a H_2 question but critical to mission).
- Design of system is good.
- Project benefit to DOE would be enhanced if approach included data release and analysis.
- Clear objectives and well-defined pathway to get there.
- Project focus seems to be on control systems and component integration - not clear.
- Little discussion of safety or project decision making.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.80** based on accomplishments.

- On track for Sept. 2004 end date.
- Good application at Mohegan Energy.
- Good back-up applications.
- I like development of high pressure generation of H_2, but role of this component in system is not clear.
- The need to supply steel (ASME?) storage vessels is potentially a significant feedback from society.
- A "sounding" of public fear of "plastic" tankage may lead to a better hydrogen and fuel cell program.
- Completed assembly and installation of FC system on site.
- The presentation did not present any performance data.
- Meeting objectives in a timely manner.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.20** for technology transfer and collaboration.

- State and Mohegan - what about DOE?
- What are plans for communicating outcomes?
- Work with community partners is good.
- Project solves a problem that Casino has with existing PC-25's, that's good.
- Interact with local government agencies.
- Education to visitors.
- No data release or analysis by outside academic partners.
- Sufficient to meet all objectives.
- Limited partners.
- Not clear on training and outreach benefits.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- What are plans for operation?
- Project nearing completion.
- Calls for completion of all milestones on schedule.
- Project is near completion.
- Monitoring and testing?

Strengths and weaknesses

Strengths

- Good ID of safety aspects - release of H_2.
- Putting tanks on roofs may be a general solution to many siting problems.
- System is apparently complete and ready for demo phase.
- High cost share ratio.
- Clear plan.
- Example of application and controls design.

Weaknesses

- Slides seemed out of order- accomplishments on several different slides throughout presentation.
- No apparent weaknesses.
- Needs more potential for training and outreach.
- Limited scope.
- No apparent heat application.

Specific recommendations and additions or deletions to the work scope

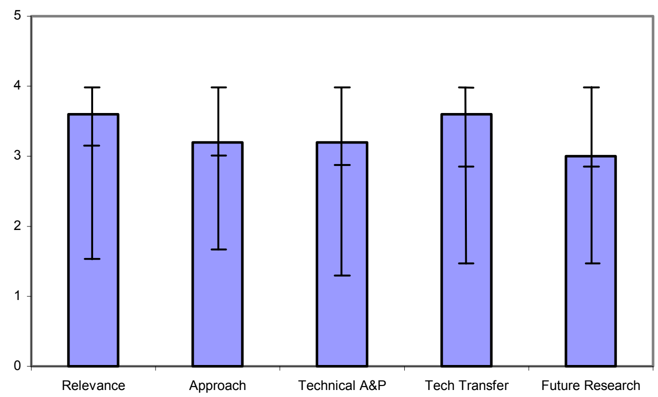
- Has the demonstration been collecting performance data?
- Complete project as proposed.

Project # TV-8: Controlled H_2 Fleet & Infrastructure Analysis
Wipke, Keith; National Renewable Energy Laboratory

Brief Summary of Project

Under this multi-year validation project the National Renewable Energy Laboratory (NREL) will assist DOE in demonstrating use of fuel cell vehicles and H_2 infrastructure under real-world conditions, using multiple sites, varying climates, and a variety of sources for hydrogen, including renewables. The primary activity over the last year was to support the DOE solicitation process and prepare for post-award work, while future activities will include analyzing data from vehicles and infrastructure to obtain maximum value for DOE and industry from this "learning demonstration. "

Overall Project Score: 3.32



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.60** for its relevance to DOE objectives.

- Fits with the DOE Multiyear RD&D Plan.
- Good speaker.
- Good slide to define tech validation.
- New project.
- Involvement of strong programmatic and technical expertise from a National Lab is imperative for public acceptance of the overall Hydrogen Program.
- NREL is providing a confidence building role.
- Target calibration.
- Appropriate plan/analysis is critical if multimillion dollar investment in fleet vehicle program is to benefit community at large. This project is attempting to do that.

Question 2: Approach to performing the research and development

This project was rated **3.20** on its approach.

- Good ID of technical barriers and targets.
- Good upfront thinking/planning.
- Emphasis on safety.
- Launch of program and completion of solicitation activities through the award phase looks good.
- Time now to begin assessment of data and progress of successful projects.
- Composite data on "non-secure" side of firewall may reduce effectiveness/value of data.
- Factors identified for analysis seem well thought out.

Question 3: Technical accomplishments and progress toward project and DOE goals
This project was rated **3.20** based on accomplishments.

- Good description.
- Have met schedule so far.
- This is excellent, but a little early to predict success on FC fleets.
- NREL supports the DOE conduct of program.
- Major objective - tech support for RFP process completed.
- Met schedule/deliverable.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.60** for technology transfer and collaboration.

- Good use of coordination with systems integration group.
- Great slide on collaborations and interactions.
- A clear need to have public entity at nexus of program technical evaluation; NREL appears to be doing well at this job.
- Tech transfer process is well thought out but more detail on how data is handled would be interesting.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Good slide.
- Detail is not readily available.
- Good feedback mechanisms.
- Procedures/process to insure feedback to technology/component development is very important.

Strengths and weaknesses

Strengths
- Good speaker.
- Brings trusted public technical oversight to overall program that to some would otherwise appear to be government subsidy of private development.
- Better at this than say NETL or LBNL or ORNL which might appear to general public as not as trustworthy for development of a "scary" new technology.
- Well planned.
- Technology gap identification important.
- Well thought out, well articulated plan.
- Qualified PI.
- Excellent, well designed program management process.

Weaknesses
- Slides should have been updated to show firewalls.
- Editorial and interpretive techniques used behind firewalls unclear and seemingly subjective.
- Will reporting of composite data only dilute value to rest of community of the largest of all the H_2/FC projects?

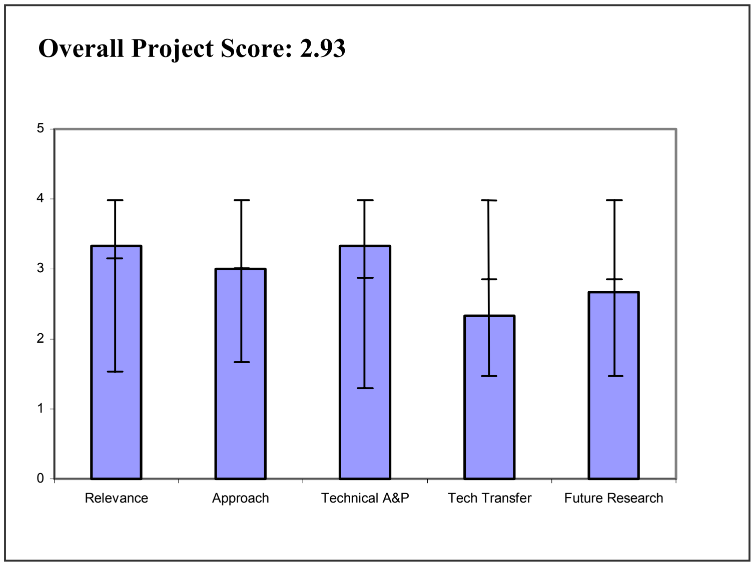
Specific recommendations and additions or deletions to the work scope

- Focus on analysis from fleet.
- Is GIS assessment critical at this time given funding constraints?
- What are contingencies for incomplete data, unresponsive program participants, equipment failures, etc?

Project # TV-9: Development of a Turnkey H_2 Refueling Station

Guro, David; Air Products and Chemicals, Inc.

Brief Summary of Project



Air Products and Chemicals, Inc. is working on a project to demonstrate the economic and technical viability of a stand-alone, fully integrated H_2 fueling Station based on the reforming of natural gas. Building on the learnings from the Las Vegas H_2 Fueling Energy Station program, the project seeks to optimize the system, advance the technology, and lower the cost of H_2. The demonstration will be done through the operation of a fueling station at Penn State University with the purpose of obtaining adequate operational data to provide the basis for future commercial fueling stations. The top priority of the fueling station is the maintaining of its safety standards in its design and operation.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Build on learnings of Las Vegas system.
- High correlation with DOE objectives.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good approach.
- Well thought through.
- Project seems very proprietary to Air Products.
- Would be nice to see more heat integration in system design.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.33** based on accomplishments.

- Looks like good progress from last year.
- Hardware chosen and developed.
- Good development based on lessons learned from previous projects.
- Improved pressure.
- Improved instrumentation.
- Good discussion of purification technology component and dispenser.
- Early in project so results are understandably limited.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- Tech transfer plan is not clear.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- Looks like on track.
- The next phase plan seems conservative and funding driven to the detriment of achieving functionality.
- Vehicle operations should be discussed – "not part of the work scope" is not an adequate response.

Strengths and weaknesses

Strengths
- Good safety slide.
- Good safety plan and codes & standards input.
- Good focus on component technology, i.e., dispenser and purification.
- Systems in integration well designed.

Weaknesses
- Slide "Approach for O_2" - colors hard to see.
- Unclear on how the hydrogen community gets any input or help from this project.
- Work tech transfer and collaboration plan.

Specific recommendations and additions or deletions to the work scope

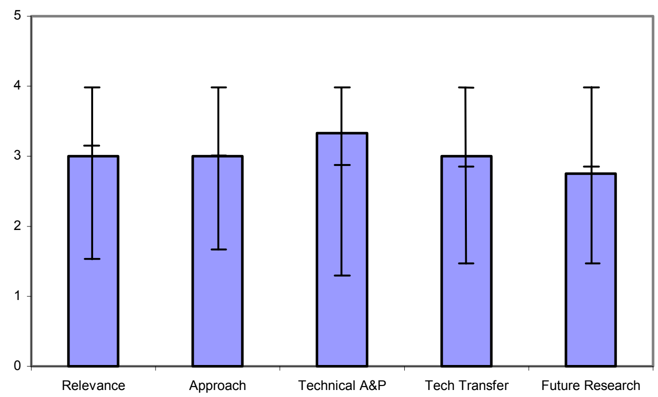
- A mechanism should be incorporated in this and other fueling stations to report the "self-insured" aspect to a real operator.
- Is there a way to introduce more state, local or corporate partners?

Project # TV-10: Development of a Natural Gas-to-Hydrogen Fueling System
Liss, Bill; GTI

Brief Summary of Project

GTI is designing a competitive, fast-fill natural gas-to-hydrogen fueling system with 40-60kg/day delivery capacity that meets DOE cost goals of \$2.50/kg of H_2 or less. GTI will undertake system design and analysis to identify potential pathways, conduct development and lab testing to confirm subsystem operation, integrate the system and incorporate controls, and conduct lab and field testing to validate performance and reliability.

Overall Project Score: 3.02



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Developed to reduce cost of H_2 - fits DOE's goals.
- Development of on-site hydrogen production and refueling stations is critical to program, but there is competition in the arena already.
- Distributed reforming at higher efficiency and lower cost is a primary goal of DOE program.
- NG-> H_2 fuel station is an important approach that needs to be fully investigated.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Appears to be well thought out, could use timeline to explain.
- Module development has progressed with significant milestones and evolutions.
- Cast of characters is impressive but perhaps hard to herd.
- Fast fill development does good job of combining experimental/modeling programs.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.33** based on accomplishments.

- Good list of accomplishments.
- Tech accomplish is good but have fallen behind on schedule.
- Should have finished phase 2.
- Good progress in developing components of the system.
- Meet 75% processor efficiency for future goal in compact system.
- Great compact design on your 50-80 kg/day H_2 generator.
- Excellent work on H_2 cylinder filling and dispenser validation.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Good list.
- Presenting capabilities at several public meetings.
- Industrial partnerships are not clear.
- Is the "confidential" work on a new PSA part of the DOE project?
- Would be nice to know more about this.
- Good interactions with others.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Slide was for "next steps"- but not for future research.
- Good so far but how well they deal with project delays will be critical in next 6 months.
- Look forward to completion of the refueling facility.

Strengths and weaknesses

Strengths
- Bounded, directed, important scope and goals.
- Good tech team.
- Providing competition for Air Products' effort.

Weaknesses
- I'm seeing modules that will probably work together but I don't really get the feel that the whole system has come together yet and has a whole system persona yet.

Specific recommendations and additions or deletions to the work scope

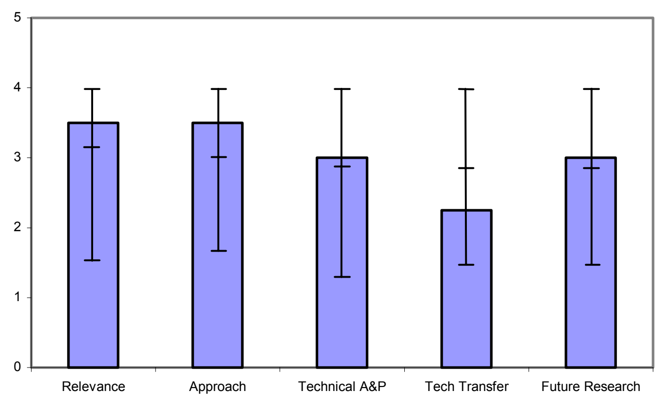
- How will "dispenser" be field tested before compression and PSA?
- Project plan needs to be adjusted for current progress and rethought for how whole system will operate.
- Present operating data for components in system (ex: reforming efficiency).
- Recommend that you work with Air Products, since they only appear to be = +/- 8% accurate on H_2 dispensing accuracy.

Project # TV-11: Novel Compression and Fueling Apparatus to Meet Hydrogen Vehicle Range Requirements
Carlson, Todd; Air Products and Chemicals, Inc.

Brief Summary of Project

The objective of this project by Air Products and Chemicals, Inc. (APCI) is to develop a novel compression and fueling apparatus to meet hydrogen vehicle range requirements. An isothermal compressor concept was designed, simulated and tested. High pressure automatic valves, 900 bar storage valves for cascade, flow meter, dispensing equipment and other instruments were also investigated for achieving this objective.

Overall Project Score: 3.05



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- A good idea that is being rapidly checked out.
- H_2 compression and fueling are directly relevant to the H_2 Fuel Initiative and Multi-year RD&D plan.
- Project aimed at meeting compression cost and efficiency targets.
- Near isothermal operation is good concept.
- Project is targeted at useful application.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- Identified both technical issues as well as status and impact of parallel development of codes & standards.
- Identified need and desire to participate in codes & standards development.
- Combines fundamental tests to understand H_2-liquid solubility with dynamic modeling.
- How does compressor interact with storage and dispensing systems?
- Is controls design for system integration part of this project?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Haven't seen hardware yet.
- Project plan is very focused with specific objectives that have been accomplished.
- Although there were initial funding issues, technical accomplishments are successful.
- Solubility tests were instructive.
- Dynamic modeling is showing design parameters that need to be optimized.
- Technical gains appear to be incremental.
- One might expect more tangible gains at this point in the project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.25** for technology transfer and collaboration.

- Because of patent or commercial proprietary information they are not sharing with others.
- This area was not addressed.
- Assumes the products developed in this project would be made available to market - good collaboration being done.
- Collaboration with groups inside APCI.
- Not much evidence of tech transfer plan.
- Appears to be strictly an internally focused project for APCI.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- A bit early for future work.
- Future plans are in line as second year of the project plan.
- On schedule to build prototype of the novel compressor.
- Plan to use prototype in service at refueling station.
- Reasonable time frame is key element.

Strengths and weaknesses

Strengths
- Novel; maybe it will work.
- It addresses compression to meet the 700 bar desires of the automotive OEM's.
- I see no show stoppers.
- Excellent project plan and implementation.
- Excellent safety experience and planning and testing evaluation.
- Project has a good combination of tests and modeling to develop a novel design.
- Targeted project on needed technology gap.

Weaknesses
- Liquid/gas interface is troublesome for contamination of H_2.
- Tech transfer not as defined as I would like to see.
- IP was discussed - it is not clear what will be available to the public vs. what Air Products will retain.
- Presentation did not show a schematic to explain how the novel process works.
- Tech transfer.
- Limited progress to date.

Specific recommendations and additions or deletions to the work scope

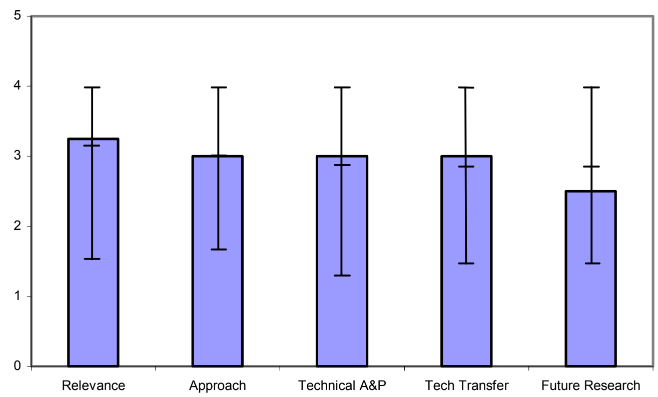
- Having a fluid system that is not all liquid or gas phase may present safety challenges that are different than either an all gas or all liquid system. Need to address.
- Public disclosure of these safety (and operational) cautions is the right thing to do.
- Fueling station location coordination with program goals would add value.
- I hope APCI will publish a paper on the performance of the prototype when data is available.
- Broaden collaboration.

Project # TV-12: Auto-Thermal Reforming Based Refueling Station at SunLine
Anderson, Lance; Hydradix/SunLine

Brief Summary of Project

Hyradix and SunLine are working together to develop an on-site natural gas autothermal reforming system for vehicle refueling. This reformer will advance sulfur removal technology, purify the fuel stream through pressure swing adsorption, compress and store hydrogen at 5000 psi, and demonstrate the refueling of fuel cell & HCNG buses, street sweepers, and cars.

Overall Project Score: 2.95



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- It's still early in development of on-site H_2 generation for refueling.
- Parallel development of concepts is very appropriate.
- NG reforming is directly relevant to the President's H_2 Fuel Initiative.
- H_2 production is produced compressed and stored for use - H_2 ICE vehicles currently used for HCNG buses.
- Future FC buses and specialized FCV currently.
- Demonstration of reformer is an important part of tech validation program.
- Relevant DOE cost goals for distributed reforming.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Meeting current production objectives.
- Autothermal reformer is interesting technical approach.
- Demonstration at SunLine provides real world experience.
- No discussion of budget.
- Little discussion of safety protocols.
- What advantages led toward use of ATR vs. SMR?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Achievement of operating hardware in the field.
- Successfully producing H_2 from NG reforming at below 2008 cost objectives.
- Current cost ~\$2.60/kg H_2 2008 target \$3.00/kg H_2.
- Unit is in operation and initial testing at SunLine.
- Presentation did not show any performance data.

- Have not shown reformer efficiency.
- What steps are taken to validate H_2 specs for auto OEM's.
- Cycling and unit operation was discussed minimally.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Working with SunLine is an open pathway to getting broader feedback from local operations and public acceptance.
- Working well with SunLine in training and public education.
- Collaboration with SunLine Transit Agency.
- Little discussion of tech transfer or partner collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Remote monitoring is appropriate.
- Future market plans not discussed.
- Presentation did not show plans for releasing performance data.
- Ongoing testing and reporting?
- How will learnings from this station impact future designs?

Strengths and weaknesses

Strengths
- Technology in demonstration phase - early commercial market introduction.
- Demonstration is important at a real transit agency.
- Supports multiple vehicle applications.

Weaknesses
- Potential for degradation of H_2 purity.
- Are emissions acceptable for wide-spread deployment in urban areas?
- Not clear how this technology will be introduced in the expansion of H_2 infrastructure.
- Presentation did not mention energy efficiency of the H_2 generation.
- Budget.
- Tech transfers.

Specific recommendations and additions or deletions to the work scope

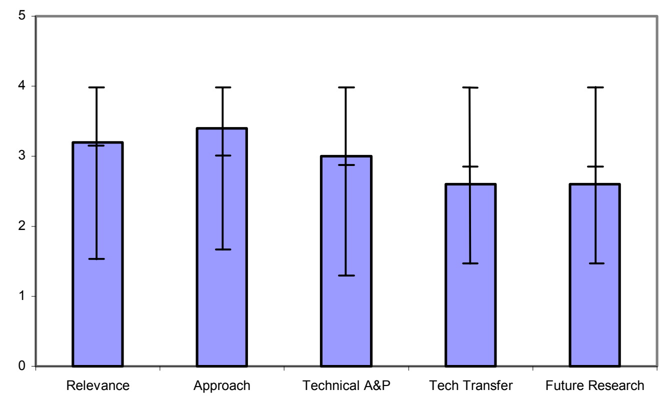
- Identify market introduction of this technology - not in business sensitive detail but in relevance to President's H_2 Fuel Initiative.
- I hope as project proceeds that Hyradix or SunLine will collect and publish performance data for the generator.
- Include more info on operations and future development.

Project # TV-13: R&D of a PEM Fuel Cell, Hydrogen Reformer, and Vehicle Refueling Facility
Wait, Mark; Air Products and Chemicals, Inc.

Brief Summary of Project

A team of Air Products and Chemicals, Inc. and Plug Power will: demonstrate small on-site H_2 production for fuel cell power generation and H_2 fueling stations; demonstrate a multipurpose vehicle refueling station to dispense H_2/CNG blends and pure H_2, demonstrate a H_2-fueled stationary 50kW fuel cell; evaluate operability/reliability/economic feasibility; certify integrated power generation and vehicle refueling designs; and expand the current facility to serve as the first commercial facility when sufficient hydrogen demand develops.

Overall Project Score: 2.96



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Technically relevant to the President's H_2 Fuel Initiative.
- NG reforming is a critical transition technology for H_2.
- Organization/link to MYPP clear.
- This station concept seems to have focused on technology without giving sufficient thought to how and by whom it would be applied in an operating environment.

Question 2: Approach to performing the research and development

This project was rated **3.40** on its approach.

- Project plan for fueling station focused and aggressive.
- Unfortunately FCV availability is limited - great model for working with local officials for permitting.
- Interesting "Power Park" design (FC).
- $13M program.
- 50 % cost share 5 yr project.
- Proven 3 stage approach.
- Work followed plan.
- A lot of money was spent without an adequate follow through with how the station should be used.
- Project approach was good from a technical perspective.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Tech accomplishments - FC testing not completed as a direct result of funding reduction low project scope.
- Undergone DOE safety review 3/04.
- Integrates stationary and mobile H_2 systems.
- Good summary of H generation performance fuel station performer dependent on fleet establishment.
- 50 kW Plug Power fuel cell.
- Excellent progress toward DOE goals.
- Lessons learned valuable to H_2 community.
- Technical progress and learning has been impaired by lack of operational use/applications.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.60** for technology transfer and collaboration.

- Fleet availability is necessary for successful outcome of this project.
- Good collaboration with code and 1st responders (permitting).
- Looks like a proprietary pilot project which is hesitant to put information into the hydrogen community.
- With the exception of visitor traffic and interaction with PSU, not enough discussion in play of tech transfer/collaboration.
- Partnership demonstrated integration of fuel company with fuel cell company.
- How has this station influenced code development?
- Fueling protocols?

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- Working towards H_2 fleet.
- Seems like this project has matured to be commercial.
- Besides continued operation and note that the site has potential for long term usage in cooperation with DOE longer term plan for R&D its continued operation is not clear.
- Good use of DOE investment to support future work.
- Project will be enhanced if it is integrated into DOE validation program but it is unclear how that will happen.

Strengths and weaknesses

Strengths

- Fueling station technologies- H_2 production and dispensing excellent.
- Utilize operating performance data with technology validation H_2 Fleet and Infrastructure projects and C&S activities.
- Plug Power teammate appears frank.
- Very objective discussion of development barriers and technical challenges - for both H_2 generation system and 50 kW FC.

- Well qualified team.
- Use of results for PSU design.
- This project was well run and provided valuable lessons which are being used in next generation design.
- Good 1st example of energy station concept.

Weaknesses
- Air Products had no representation about how it leverages other EERE projects to support this project.
- Additional discussion of how project overcame regulatory challenges - e.g., grid connection, local permitting, would be useful.
- Need better articulation on how this project can be positioned to help achieve MYPP - use the investment already made to take advantage of future RD&D needs.
- Poor application planning-especially for vehicles.
- Projects at this cost level need a high hurdle for planning and application relevance.

Specific recommendations and additions or deletions to the work scope

- Pursue HFCV opportunities to use.
- Vendors who have multiple projects should discuss the complimentary nature of the work vs. overlaps and double dips - which this project seems to include for Air Products.
- Much can be gained from tech transfer of experience gained from this project. Recommend more attention to tech transfer collaborations.
- Need to focus on application and expanding operations.

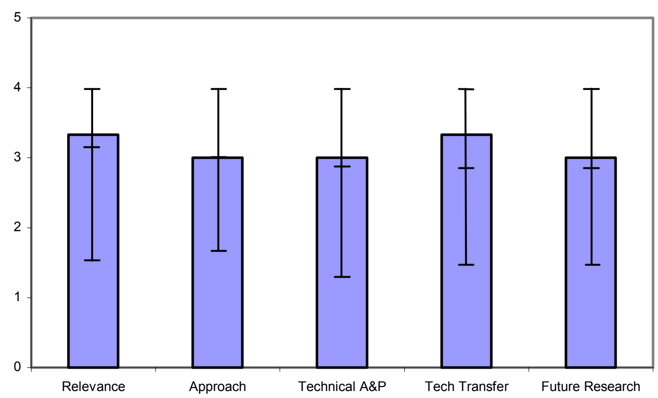
Project # TV-14: LAX Airport Hydrogen Fueling Station - Small Footprint H_2 Capability at the Corner Filling Station

Rachlin, Aaron; Praxair

Brief Summary of Project

In this two year project, Praxair will design, develop, install, and operate a H_2 fueling station that features integration and packaging of existing technologies electrolysis based on-site production, up to five light-duty vehicles per day, five minute "fast fills," growth flexibility to meet demand, and enabled for heavy-duty fills. Praxair will also provide a demonstration of a hydrogen based fueling infrastructure capable of supporting a small fleet of hydrogen fueled vehicles in order to meet the California Fuel Cell Partnership's goal to introduce up to 60 HFCVs by 2003 and that is compatible with other fueling stations.

Overall Project Score: 3.13



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Distributed H_2 fueling stations.
- Fueling technologies.
- Real-world demonstration is important.
- Small station and focused application is appropriate for this stage of H_2 technology.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Important location and small size station.
- Electrolysis technology is interesting.
- Economics will be an important outcome of this project.
- Small foot print design allows for installation in airport site.
- Station configuration seems to have been well thought out considering: safety, operations, training and outreach.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Early in project - difficult to assess tech accomplishments.
- Project design is on track despite delays beyond the control of presenter.
- Front end project activities seem to have taken a long time.
- Most meaningful accomplishments are contract and financial rather than technical.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Excellent partnership collaboration and cost share.
- Working with agencies to get project demonstration ready for construction.
- OEM's will be included to bring vehicles.
- Does not seem to advance any new technology installation designs.
- Strong collaboration and partner potential.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Plans include expansion of H_2 dispensing opportunities beyond original plan.
- Will provide practical experience in fuel station construction and operation.
- Primary future research seems to be on supported vehicle technologies - not actual fueling station.

Strengths and weaknesses

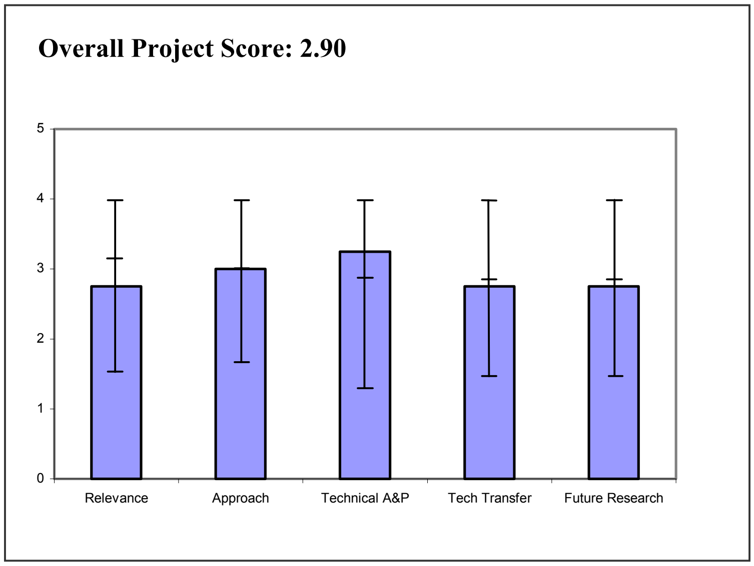
Strengths
- Great collaboration.
- Participation in CA H_2 Highway Program.
- Visibility.
- Size - appropriate for application.
- Education and outreach potential.

Weaknesses
- Uses little or no new technology.

Specific recommendations and additions or deletions to the work scope

- Plan to provide data on cost of H_2 and the electric-to- H_2 efficiency in the system.
- Include air traffic off road (ground service equipment) vehicles.

Project # TV-15: Hydrogen and Natural Gas Blends: Converting Light and Heavy Duty Vehicles
Collier, Kirk; Collier Technologies



Brief Summary of Project

Collier Technologies is developing a low-emissions, heavy-duty vehicle engine package to seamlessly repower today's buses and trucks with existing natural gas and diesel engines that will exceed DOE's goal of reducing 1998 emission standards and maintain or enhance vehicle drivability. This will be accomplished through the addition of hydrogen to the natural gas fuel mixture.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.75** for its relevance to DOE objectives.

- This program continues to provide a valuable bridge to a H_2 future.
- Introducing a use for H_2 that can reduce emissions and introduce H_2 familiarity to broader society will help justify H_2 generators while we wait for more FCV's.
- Important work to provide vehicles and H_2 demand in transition to H_2 economy.
- Emission targets align with goals.
- A very good idea.
- Was there any consideration of going to synthetic diesels from natural gas?
- What is the efficiency gains/loss compared to the hydrogen and natural gas blends.
- What are the compression pressure benefits?
- HCNG offers incremental improvements over CNG on emissions but at a reasonable cost?

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Exhaust gas recirculation is the best way to control emissions with H_2 combustion.
- Super charging recovers power density that clean/dilute mixtures produce.
- What about the issue of cost of fuel?
- What is the compression benefit of this mix?
- Technical approach seems sound but overall cost/benefits of HCNG should be part of project.
- Staged approach is good.
- Safety plan is not well defined.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Results are consistently high at low cost.
- Demonstrated success in LDV conversions.
- Achieved emissions reductions for CO and NOx with good efficiency.
- Project would be stronger if hybrid configuration was used.
- Progress seems to be consistent with overall project goals.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.75** for technology transfer and collaboration.

- This project reaches a segment of society that is larger and different from other technology validation activities.
- Conversion "kit" is available for commercial sale.
- Industrial partners with OEM.
- Tech transfer plan is not clear.
- Limited collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Designed system for future bus conversions.
- Should try to get it into the hands of normal users and not just fleet users.
- Specific future targets are good (many other projects only have general future plans).

Strengths and weaknesses

Strengths
- Practicality with real world application in every community.
- This is vital work for helping to promote the growing fleet of H_2 fueled vehicles.
- Good idea. Should expand users to get a better understanding of approach.
- Targeted, focused scope.

Weaknesses
- It's viewed as low tech or only transitional.
- Project relevance to DOE objectives.

Specific recommendations and additions or deletions to the work scope

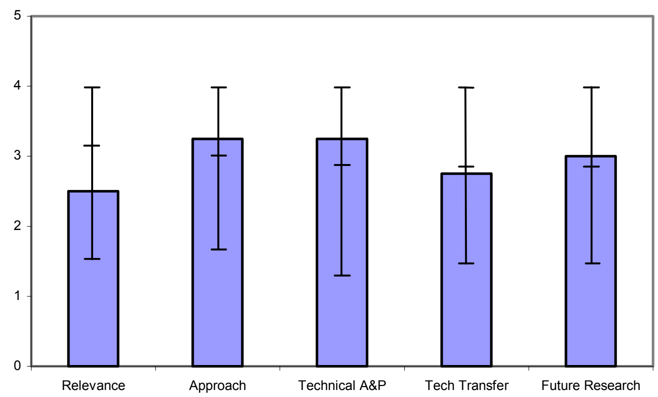
- Hybrid technology would make this a more interesting, relevant project.
- Consider using customers to really understand the benefits of this application.
- It would be good if normal customers can be used to really understand the benefits of this application.

Project # TV-16: Fuel Cell Powered Underground Mine Loader Vehicle
Barnes, David; Vehicle Projects, LLC

Brief Summary of Project

Vehicle Projects LLC is developing a zero-emissions, fuel cell-powered metal-mining locomotive that operates on a 14 kW fuel cell power plant. Hydrogen will be stored in metal-hydrides. Vehicle Projects will evaluate the locomotive's safety and performance, primarily in surface tests, and evaluate its productivity in an underground mine in Canada.

Overall Project Score: 2.95



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.50** for its relevance to DOE objectives.

- Application seems poor choice for demonstrating fuel cells.
- Interesting project with lots of technical challenges.
- Application seems good one for demonstrating metal-hydride storage, but even if successful will have limited public visibility.
- Niche application, but one where unique economics make sense.
- There are more cost effective ways to demonstrate the integrated storage/fuel cell system.
- Good focus on specific applications.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Design follows success of previous program.
- Hybrid vehicle design is good.
- Removable hybrid storage is unique idea for this application.
- Multiple sites add to cost- why?
- Sound approach that considered specific application, economics, focused technical configuration, and safety.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- FC procured and in bench scale testing.
- Not clear how lessons learned will transfer to community at large.
- Technical design is very appropriate for the application.
- Progress seems appropriate for this stage of project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.75** for technology transfer and collaboration.

- Collaboration is good on this complex system.
- Due to limited operational environment it's not clear that much valuable feedback can be recycled into broad market products.
- Industry/OEM partners suggest a good team is in place.
- Would like there to be adequate testing of storage/FC system prior to installation.
- Good mix of collaborators and partners.
- Tech transfer plan is not clear.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Strong integrated team.

Strengths and weaknesses

Strengths
- Good metal hydride storage application.
- $5 million of DOE funds for 1000 hrs demonstration is costly.
- Bench testing (more) could address many issues addressed by costly mine vehicle and prevent problems onsite.
- Well thought out design configuration for a specific application.

Weaknesses
- Limited market.
- Project seems more focused on vehicle system design, while H_2 storage and FC performance are secondary.
- Narrow application - project should spend some resources on considering this technology configuration for other applications.

Specific recommendations and additions or deletions to the work scope

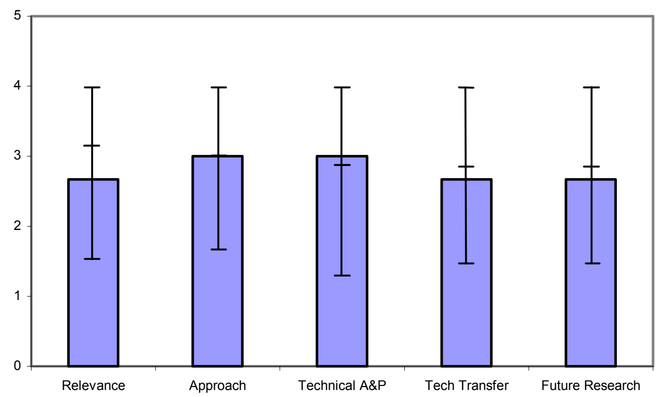
- Would like to see data from the bench-scale tests on the FC stack.
- Future performance of vehicle (H_2 mileage) should be compared to the conventional alternative.
- Should consider other applications for this technology configuration such as ground service equipment or industrial off-road trucks.

Project # TV-P1: Validation of an Integrated System for a Hydrogen-Fueled Power Park
Keenan, Greg; Air Products & Chemicals, Inc.

Brief Summary of Project

Air Products and Chemicals, Inc. is conducting a project to complete a feasibility, technical, and economic analysis to determine the optimal fuel cell system for the co-production of power and hydrogen from natural gas (power park) with a reformer / PEM System, High Temperature Fuel Cell (HTFC). They will optimize the system for lowest total energy cost, and develop a cost estimate to demonstrate a prototype natural gas based power park at a suitable site.

Overall Project Score: 2.80



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.67** for its relevance to DOE objectives.

- Commercial understanding applied.
- Co-production is a method that strongly supports the President's Initiative by making the technology economically viable sooner.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good use of previous data. Started as PEM FC but economics led to change of scope.
- Simplistic.
- Very focused on DOE's technical barriers of cost.
- Should more fully address how H_2 off-gas would be recovered from high-temp FC.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Good recognized new goals.
- Unclear milestones.
- Technology combination looks very promising.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- None provided

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- Excellent.

Strengths and weaknesses

Strengths
- Good redirect of project ideas and learning to using SOFC/MCFC.
- Good identification of safety aspects.
- APCI understands topic.
- Focuses on economics.

Weaknesses
- Communications products.
- Feedback to community.
- Doesn't get into enough technical detail on how this would be done.

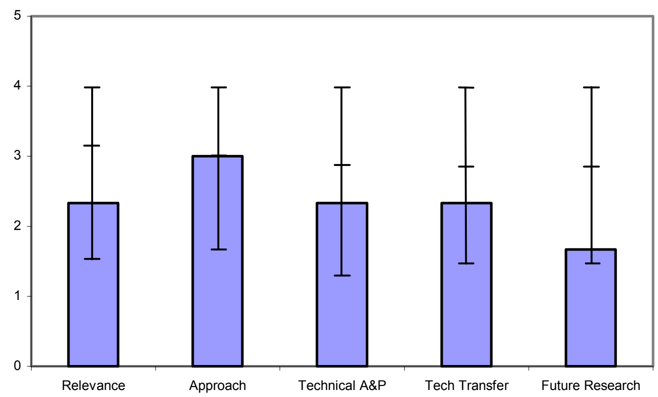
Specific recommendations and additions or deletions to the work scope

- Not worthy of continuing.
- Include a technical demonstration on the next phase.
- People may see this can't be done economically. Show that they are wrong.

Project # TV-P2: Fuel Cell Installation and Demonstration Project In Gallatin County, Montana
Nelson, Bruce; Zoot Enterprises Inc.

Brief Summary of Project

Overall Project Score: 2.33



This project by Zoot Enterprises Inc. is intended to demonstrate operation of a fully integrated distributed generation system consisting of a fuel cell generation plant, interconnection equipment and microgrid to provide the hydrogen industry and the general public with a real world application of such a system. Additional goals are to determine the degradation rate of the fuel cells and the point at which it becomes economically necessary to "restack" by essentially replacing the fuel cells themselves; provide operational data to Montana State University to assist in the development of control equipment to optimize fuel cell performance when combined with other electrical sources; and maximize efficiency of the heat recovery (cogeneration) system.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.33** for its relevance to DOE objectives.

- Project looks at fuel cells in a "credit-processing" application.
- Molten carbonate fuel cell from Fuel Cell Energy.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Oversized fuel cells with grid system - intent to "build up" system as new tenants go into facilities - seems like an uneconomic way.
- System is not economically optimized - extra redundancy.
- Great to see fuel cell being used in a high reliability situation.
- Will give fuel cell a good name in the premium power sector.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.33** based on accomplishments.

- Not specific in posters.
- Some communication with outside communities.
- Functional system.
- Strong progress appears to have been made to date.
- Amazing decrease in electric grid utilization.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- Not identified.
- Very simple approach to communications.

Question 5: Approach to and relevance of proposed future research

This project was rated **1.67** for proposed future work.

- Good idea but seems like bad upfront engineering.
- Future work seems focused on operational details.
- Focus on bigger issues of more importance to DOE if possible, such as performance data.

Strengths and weaknesses

Strengths
- Practical application.

Weaknesses
- Fuel cell tripped over 2 dozen times the first year.
- Presentation was simply too long - 39 slides in total.
- Be more concise.

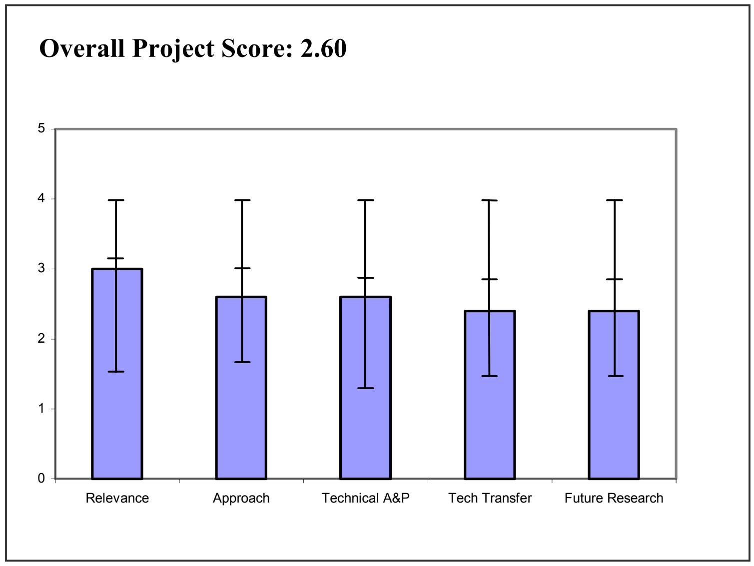
Specific recommendations and additions or deletions to the work scope

- Only continue with very high commercial cost share! Microgrid for "local" service augmentation.
- This is a sales gimmick for FCE and unworthy of additional taxpayer input.

Project # TV-P3: Global Assessment of Hydrogen Based Technologies
Fouad, Fouad; University of Alabama, Birmingham

Brief Summary of Project

The University of Alabama, Birmingham and Argonne National Laboratory (ANL) team will evaluate performance and emissions characteristics of hydrogen-fueled vehicles; assess impacts of hydrogen vehicle deployment on Southeast regional air quality; evaluate the use of hydrogen fuel cells for stationary power generation; and assess infrastructure needs and costs for production and distribution of hydrogen in the Southeast.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- This project is growing the H_2 knowledge base in an area with environmental challenges and an as yet undeveloped mitigation strategy.
- Project is regional.
- Engine emissions are relevant to use of H_2 in vehicles at practical cost in near term.
- The regional focus of this project (Southeast US). Contributes to the relevance of this project which otherwise might not be as great.
- I don't see how this project differs from previous HCNG engine performance studies, nor do I see how this will promote hydrogen technology acceptance.

Question 2: Approach to performing the research and development

This project was rated **2.60** on its approach.

- Well-focused and on track.
- Using Argonne as source is a great transfer mechanism.
- Very dependent on ANL.
- Project tasks are not tightly related.
- The regional analysis and stationary power tasks are a bit of a stretch from the vehicle testing.
- PI recognizes that they need assistance from established H_2 program participants.
- By using only a single blend composition (30% H_2, 70% CNG), project will not necessarily evaluate optimism conditions for HCNG use.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.60** based on accomplishments.

- Not a lot of original technical work, but growing the knowledge base is the real focus new projects will come.
- Project is making progress on tasks 1 and 2.
- Others are scheduled for future year.
- Project is early in its implementation and has understandably not made a large amount of progress.
- New fuel supply system installed, and some test data collected.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.40** for technology transfer and collaboration.

- Effective model use and tweaking with ANL.
- Collaboration with ANL is allowing tests and modeling the university could not do.
- There appears to be a lack of collaboration with the engine conversion people.
- PI knows that interaction with others is needed but has not yet made progress in this area.
- Fuel delivery system was designed and built by ANL but no private sector collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.40** for proposed future work.

- Project has a clear but limited scope that's achievable, and a schedule that's reasonable.
- It faces a decision on where to go from here, and could use interaction with other centers like ITS Davis or Hawaii.
- Poorly planned.
- Proposed tasks on regional infrastructure seem unrelated to the vehicle work.
- PI has plans for expanding program to a broader partner base.
- Success in this area is key.
- Too many ANL analytical tools, should develop methodology and priorities pertinent to southeast concerns.
- Need more focus on validating new technology and new infrastructure.

Strengths and weaknesses

Strengths
- Embedded in educational infrastructure, uses link to ANL.
- H_2 use will positively impact air quality.
- Clean cities connection sought.
- Focus on H_2- combustion for vehicles is an important part of H_2 transition strategy.
- Introduces H_2 and fuel cell technology in geographic region where little work has been done and little public exposure.
- Pragmatic evaluation of hydrogen/CNG blends for light duty vehicle ICEs.

Weaknesses
- Undeveloped future vision.
- Question is whether timing is right to try to develop an education/knowledge center without near term access to fuel cell vehicles.
- Fleet which is going to be associated with established H_2/Transportation centers in FL, CA, & MI.

- Seems to be "sample oriented" in that the empirical testing of equipment based on incomplete selection criteria.
- The 5 tasks are not strongly related.
- The emissions testing are not coupled to the people doing the engine conversion.
- Repeats technical work that has been done by others.
- Modeling focuses on CNG/ H_2 mixture fuels which appear to only have transitional benefits.
- No new or innovative technology is being validated.

<u>Specific recommendations and additions or deletions to the work scope</u>

- I suggest the emissions testing program be coupled to engine experts to explain the results.
- Focus on educational and consortium building activities.
- Bring in industrial partners which can introduce commercial application potential to the project.
- Just focus on PEM fuel cells vehicle performance and power generation potential for southeast region of US.
- Close project.

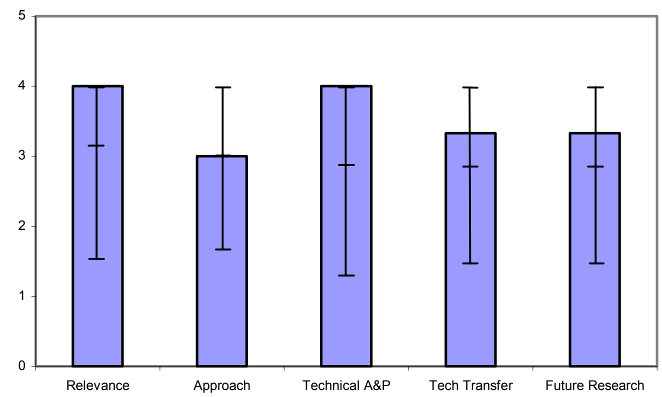
Project # TV-P4: Hydrogen Power Park Business Opportunities Concept Project

Hobbs, Raymond; Pinnacle West Capital Corporation

Brief Summary of Project

In this project, Pinnacle West Capital Corporation conducted studies on economic hydrogen production, renewable energy opportunities, integration of distributed generation and transportation fuel production, incorporation with existing energy assets, scalability, integrated business opportunities, identification of technical barriers, and identification of market opportunities. Under the economic production of hydrogen, the options investigated were (i) solar reforming of natural gas, (ii) low cost electrolysis, (iii) hydrogen purity requirements (iv) heat energy recovery, and (iv) chemical by-product value.

Overall Project Score: 3.53



Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Project well thought through.
- Dramatic development H_2: $2.25/kg pure product - open to public.
- Great to have data collected on performance testing of H_2 components.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good use of management buy-in.
- Good iterative process. Iterations make adjustments.
- Self insured.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **4.00** based on accomplishments.

- Good use of program funding.
- Website (real time) is good idea for communication.
- Very safe design of station.
- Strong regulatory relations.
- Amazing to see how low the marginal cost of electricity (to produce H_2) is for APS-this should be expected now.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Good connections with others in collaborations (ex. BC Hydro)
- Good licensing prospect with fueling station.
- Decent interactions with others.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Understands work needed be to accomplished.
- It would be excellent if you could add another fuel cell to be tested such as Ball and Nexa/Airgen.

Strengths and weaknesses

Strengths
- Excellent safety identification leading to patentable ideas.
- APS strong internal support for establishing H_2.
- Website has performance data in real time.
- Real world testing of H_2 components.

Weaknesses
- None provided

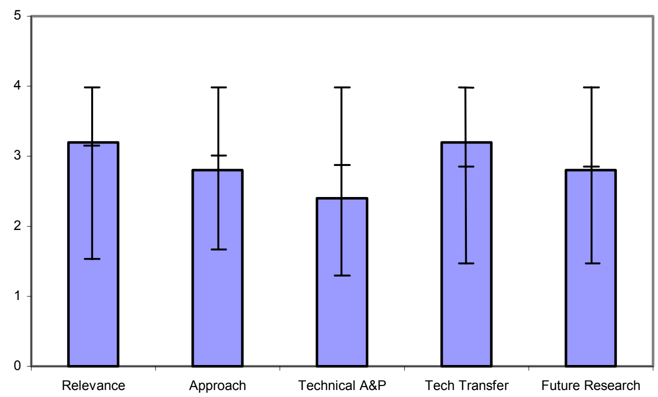
Specific recommendations and additions or deletions to the work scope

- Continue project.
- Provide details. Are all the components hooked into the system at once? How would they interact if they were?

Project # TV-P5: NextEnergy Microgrid and Hydrogen Fueling Facility
Quah, Michael; NextEnergy

Brief Summary of Project

Overall Project Score: 2.88



NextEnergy's project objectives are to support the DOE "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" in the Detroit area, collect and analyze data with existing codes and standards, establish a "Best Practices" training, educational program, integrate critical hydrogen infrastructure components and systems for multi-use operations within a core urban environment, optimize system solutions/integration to advance the hydrogen infrastructure for vehicular and stationary use, provide hydrogen to vehicles at 3,600 psig and 5,000 psig (for demos in the Detroit area), and study the system interactions/integration for power generation (~ 1 MW) in a Microgrid with fuel cells, ICE generators, Stirling engines, and solar PV.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.20** for its relevance to DOE objectives.

- Program focus on integration of prime movers (powered by H_2 and other sources of energy) with a local interconnection is an essential component of the program.
- Danger is that H_2 program is diluted with too many other technologies.
- Downtown Detroit site.
- Open architecture.
- Facility emphasizes power generation and some components do not utilize H_2.
- Project will produce useful data on cost of electricity from fuel cells and engines.
- Approach focuses on proving a power system with many components controlled to match grid electronics.
- Good overall logic to the plan.
- Should be a very good demonstration of technology gains and benefits as a fueling station.
- Ambitious goals and scope, particularly because it is intended for a densely populated urban area with high Big 3 vehicle manufacturer visibility.

Question 2: Approach to performing the research and development

This project was rated **2.80** on its approach.

- They are making very good progress, but scope is ambitious and keeping costs within range that will allow the technical aspects to move forward is going to be a challenge.
- Inclusive philosophy.
- Good leverage on state support.

- Approach focuses on proving a power system with many components can be controlled to match grid electronics.
- Focused on problems that need to be resolved.
- Choice of basement storage creates extra barriers that will inevitably delay completion and increase cost.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.40** based on accomplishments.

- Site prep on a brownfield.
- Team recruitment.
- Project is new so progress is in planning, design, and overcoming regulatory barriers phase.
- Could go faster but current rules and regulations prevents it.
- Only preliminary conceptual design completed to date.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.20** for technology transfer and collaboration.

- Project building hand-in-hand with Wayne State and development of H_2 and DER curriculum for MI colleges is great.
- Intent is stated to use web.
- Project plans to make data available on website, so public will have rapid, convenient access to performance data.
- Could improve on collaboration but the process is good.
- Many important collaborators.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.80** for proposed future work.

- Project is just starting and needs to stay focused but plans for adding biomass fuels show interest.
- Future plan to produce H_2 by reforming makes the project align better with DOE goals for tech validation.
- Should provide a good set of data for all to see regarding the benefits of the various power generation systems.

Strengths and weaknesses

Strengths
- Projects are high profile and interactive with educational infrastructure providers.
- Premises are sound.
- Spin-off envisioned.
- Scada system will put unedited data on web.
- The project is ambitious regarding producing real world data and demonstrating power technologies from a variety of fuels.
- Should provide a good service to all Michigan related activities.
- This is heavily needed.

- The project site is as real world operating conditions as one can get.
- There is a good mix of different hydrogen uses in the DTE H_2 microgrid.
- Scope okay.

Weaknesses
- Tough initial cost barriers.
- Need to develop workforce with right skill sets. (Challenges not really weaknesses).
- Potential for dilution of focus and emphasis on H_2.
- Technical layout issues, including basement.
- Not online yet.
- Basement site for liquid H_2 tank and associated vaporizer and piping.

Specific recommendations and additions or deletions to the work scope

- Make implementation of H_2 production by reforming a priority in acquiring components.
- Expand the partnership to build greater strengths.
- Employ a hydrogen safety specialist to conduct in-depth safety analysis to address Detroit Fire Department questions and concerns.
- Conduct risk analysis with quantitative results and uncertainty analysis to compare risk of alternative tank locations.

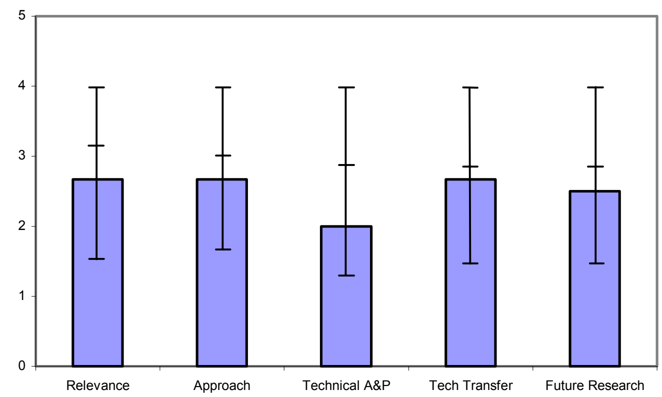
Project # TV-P7: Hydrogen Fuel Project

Morse, Derick; Regional Transportation Commission of Washoe County, Nevada

Brief Summary of Project

The Regional Transportation Commission of Washoe County, Nevada is to develop integrated, geothermal energy powered fuel production and use a cycle that has essentially zero criteria emissions, zero green house gas emissions, scalability, and reliability comparable to today's mature fossil fuel technologies. A companion objective is to foster public and regulatory agency acceptance of hydrogen fuel technology as a safe, effective and desirable path. This R&D effort should contribute significantly to the commercialization of hydrogen fuel technologies for mass transit applications.

Overall Project Score: 2.50



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.67** for its relevance to DOE objectives.

- Renewable geothermal production of H_2 is directly relevant.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- Project is still in project planning process.
- No clear rationale on why and how geothermal energy is suited for H_2 production.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.00** based on accomplishments.

- Too early in the project to assess.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Again too early to assess.
- Need to collaborate with at least other Nevada fueling stations.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- None provided

Strengths and weaknesses

Strengths

- Connection to community.
- Good mix of experienced hydrogen companies and key local government agencies and potential hydrogen users.

Weaknesses

- Project does not appear to have collaborative efforts with other DOE H_2 program projects.
- The Nevada fueling stations appear to be stand-alone projects.
- Public education component is poor.
- No articulated cost goals and go/no-go decision criteria.

Specific recommendations and additions or deletions to the work scope

- Projects in Nevada should begin collaboration.
- Continue with cost share.
- Abandon para transit vehicle application.
- Focus on hydrogen production system design and economic analysis.

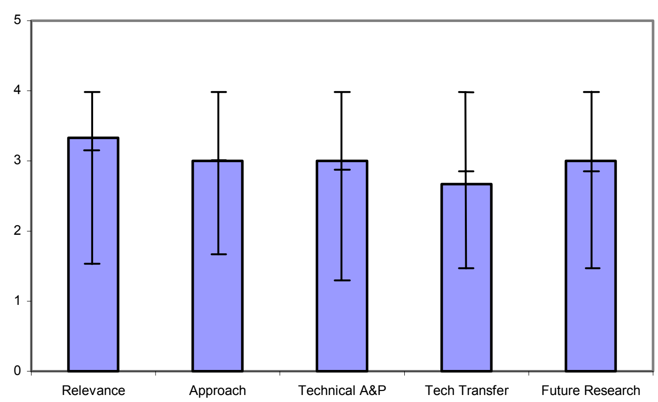
Project # TV-P9: Renewable Hydrogen Fueling Station System

Boehm, Robert; University of Nevada-Las Vegas (UNLV) Research Foundation

Brief Summary of Project

As a first step in the development of a hydrogen utilization network, University of Nevada-Las Vegas (UNLV) Research Foundation will install and analyze the performance of a hydrogen fueling system powered by the solar energy. Objectives include development of the requirements for the fueling system, survey of potential sites and determining favorable/unfavorable characteristics of each, selection of the site with site plan and support to the site permitting process, design of the fueling system layout, installation of the fueling station in Las Vegas, monitoring operation of the fueling system and characterizing performance.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Looks at renewable aspect.
- Electrolysis is directly relevant to the Presidents H_2 Fuel Initiative.
- Cost share strength.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- "Chicken and egg" process-also building/using utility vehicles as well as building station.
- Good concept.
- Project is in initial stages of implementation.
- Interesting renewable production of H_2 technologies, PV, and wind.
- Focus on codes & standards participation.
- Permitting engaged.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Could use more detail on poster.
- Better photographs showing entire site.
- Flow chart detailing process would be useful to explain concept.
- Technical aspects of this project have not yet been started.
- Most activities have been site review and coordination.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Didn't see a lot of collaborative efforts.
- Could use more integration.
- Tech transfer and education activities have been included in the project plan.
- Las Vegas water district engaged.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Looks good-funding appears adequate.
- Fairly new project future research not clear.

Strengths and weaknesses

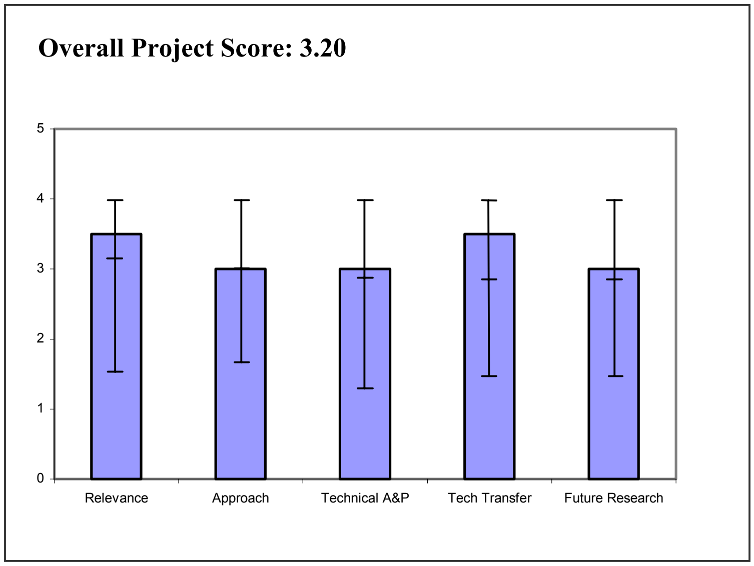
Strengths
- Renewable H_2 production.
- Proton self insured the site.
- Warranty for 1 year/7 year stack life.

Weaknesses
- Better detail on poster to explain concepts.
- Three H_2 fueling stations in Nevada-all seem stand alone projects.
- Doesn't know the context of solar H_2.

Specific recommendations and additions or deletions to the work scope

- Increased coordination with other Nevada fueling station.
- Continue this-good value.

Project # TV-P11: Hawaii Hydrogen Center for Development and Deployment of Distributed Energy Systems
Rocheleau, Richard; Hawaii Natural Energy Institute



Brief Summary of Project

On this project Hawaii Natural Energy Institute (HNEI) will: (1) produce an integrated program for the development and deployment of hydrogen based distributed energy systems, and (2) advance key technologies, consistent with DOE plan, to advance hydrogen production technologies and infrastructure research and testing.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- The program is bringing (has brought) together diverse H_2 supplier technologies and applications and demonstrating them in close association with local and civil and infrastructure stakeholders.
- Project plan is still being developed and finalized.
- Fuel purity.
- H_2 from biomass.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Project planning is striving to collaborate/partner with DOE H_2 program activities.
- Responsive.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- For most projects within program, measurement of results against goals in relatively easy and is embedded in funding requests from project sponsors.
- Too early in project to assess technical accomplishments.
- Facilities functioning and taking data.
- Training and learning underway.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.50** for technology transfer and collaboration.

- This is a critical function for this program.
- Keeping the website current, though important, is only one aspect.
- They could use a PR department; not to blow their horn but to let others (especially the public outside HI) know about their work.
- Again project plan is still being developed.
- Good collaboration with Hawaiian utilities and sugar companies.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- They seem to have a good pipeline of projects and are not dependent on a single project for success.
- Cannot be assessed.
- Renewable H_2 pertinence.
- Testing may overlap with industry.
- Good local source of biomass, good plans for hydrogen use in Honolulu.

Strengths and weaknesses

Strengths
- Good quality technical work with physical systems.
- Diverse disciplines are brought together.
- Great leverage on other government investments.
- Experienced PI and project team.
- Realistic understanding of potential hydrogen renewable sources and relevant applications in Hawaii.

Weaknesses
- Communicating success and failure with outside.
- Not clear what DOE funding will support.
- Need to choose specific goals and focus rather than just opportunistic.
- Need to transport biomass hydrogen from other lands to Oahu.

Specific recommendations and additions or deletions to the work scope

- Continue to develop collaboration and partnerships with DOE H_2 program.
- Focus on Energy Park.
- Defocus on testing generally and define mission more tightly.
- Develop quantitative phased goals and go/no-go decision criteria and contingency plans.

Safety and Codes & Standards

Summary of Annual Merit Review Safety and Codes & Standards Subprogram

Summary of Reviewer Comments on Safety and Codes & Standards Subprogram:

Reviewers considered hydrogen safety and codes & standards to be critical to the President's Hydrogen Fuel Initiative. The projects were generally deemed to be highly relevant and addressing issues on the critical path to commercialization and the development of a hydrogen economy. Reviewers indicated that projects were well planned, focused and had well understood barriers.

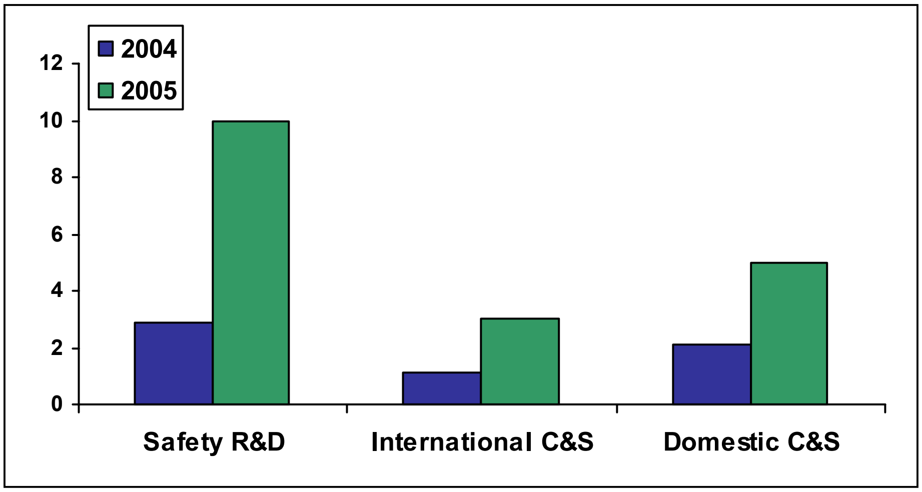
Beyond suggestions for improvement of individual projects, overarching criticism was related to the relatively low level of funding supporting some of the activities.

Additional recommendations and observations by the reviewers included:

- Codes and Standards activities are very long-term in nature. The program needs to keep focused on the long-term.
- There is a general lack of emphasis on safety R&D, instead emphasizing the codes and standards activities. Would like to see clearer definition in the funding that supports each.
- Sensor R&D needs to keep in mind key criteria of cost, durability and stability of output signal.
- Attaining an array of specific sensor performance attributes (operating conditions, linearity, etc.) will be very important in developing useful sensor technology. Also a strong message was delivered that sensor R&D for on-board automotive applications may be misguided and at a minimum should be conducted only as one option for safety engineering, recognizing that the preferred and traditional method for managing fuel safety does not involve reliance upon on-board sensor technology.

Safety and Codes & Standards Funding:

The funding portfolio for Safety and Codes & Standards addresses Safety R&D as well as both International and Domestic Codes & Standards efforts. The planned 2005 funding profile (subject to congressional appropriation) addresses the National Academies' Report recommendations and provides increased funding in all three of these areas.



Majority of Reviewer Comments and Recommendations:

In general, the reviewer scores for the safety and codes & standards projects were average to high (the average score for projects being 3.28). Lower scoring projects were related to sensor technology where specific technical deficiencies were cited and where automotive utility is uncertain or doubtful. Major recommendations are summarized below. DOE will act on reviewer recommendations as appropriate for the scope and coherency of the overall safety and codes & standards effort.

- **Codes and Standards development:** Need to remain focused on engaging the right people and organizations. Need to stay focused on the long-term goals.
- **Sensor Technology:** Not clear if all sensor criteria are being addressed as needed (cost, durability, sensor drift, reliability, start-up time, linearity, range, performance or degradation at extreme concentrations). A strong message that on-board sensors have significant shortcomings and are not the preferred method of managing safety on-board vehicles.
- **Safety R&D:** Needs to be expanded, increasing funding. Needs to be broader in scope, and engage appropriate partners.

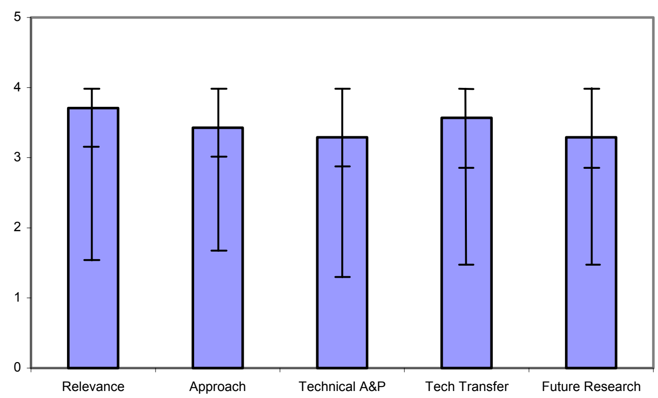
Project # SCS-1: Safety and Codes & Standards Subprogram Overview

Davis, Pat; DOE, Team Lead

Brief Summary of Presentation

The purpose of this Safety, Codes & Standards Subprogram Overview and introduction is to describe subprogram goals/objectives, budgets, barriers/targets, approach to R&D, technical accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and puts into context the R&D and analysis projects which will be presented in this subprogram area during the Annual Merit Review.

Overall Project Score: 3.46



Question 1: Relevance to overall DOE objectives

This presentation earned a score of **3.71** for its relevance to DOE objectives.

- Clearly a top priority to support the Nation's plan.
- Necessary for planning/ building facilities to support H_2 based economic sector.
- Project is very relevant to what is needed in order to establish Safety, C&S.
- There are a number of areas where there are "holes" in this area that need to be filled before hydrogen powered vehicles and power plants are implemented.
- Much needed for continued growth.
- Goals should be tied to project safety performance and safety results.

Question 2: Approach to performing the research and development

This presentation was rated **3.43** on its approach.

- Comprehensive- well planned.
- Barriers clearly understood.
- Project is sharply focused on a number technical barriers: 1) adoption of model building codes, 2) identifying the critical gaps, 3) establishing an R&D Roadmap for Hydrogen Safety and identifying key areas where future R&D is needed, 4) develop contact with US and worldwide C&S.
- Global and local participation most important.
- Sharing with the US and international is important.
- Safety priorities should be revised to encourage new research and solicitations.
- Spend less on standard development and "educating" code officials.
- Approach does not seem to address 2nd goal, but addressed somewhat in Key Milestones.

Question 3: Technical accomplishments and progress toward project and DOE goals

This presentation was rated **3.29** based on accomplishments.

- Key milestones are being met.
- Excellent in light of budget constraints.
- Still too early to properly judge. However, an important milestone has been met regarding identifying key people to assist this effort.
- Progress is being hindered by the "earmarks" which can be clearly seen in the funding profile.
- Budget cuts have slowed progress.
- Safety panel progressing well, but research has been delayed.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.57** for technology transfer and collaboration.

- Without question the effort interfaces with all the C&S efforts underway.
- Has involved industry, C&S officials, universities, as well as research industries.
- Also international involvement.
- Although activity has just begun, the project has had a number of collaborations between International Code Council (ICC) and National Fire Protection Association (NFPA).
- Good involvements.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.29** for proposed future work.

- Well thought out plan.
- There were not enough specifics regarding what the actual research would entail.
- It would be preferable to have future research more clearly defined.
- Long-term goals are reasonable.
- Restoration of budget cuts is critical. Identification of gaps in current C&S also critical.

Strengths and weaknesses

Strengths
- Very focused project with clear goals.
- Important and critical area for growth of hydrogen initiatives and economy.
- Safety panel activities.
- The role of DOE in framing (and facilitating) codes and standards is vital to the National effort.

Weaknesses
- Funds were taken out of the budget in key areas.
- A little more detail regarding actual safety projects would have been beneficial.
- Presentation is very stationary/building oriented.
- Long-term process.
- Very little safety research other than at National Labs and University of Miami.

Specific recommendations and additions or deletions to the work scope

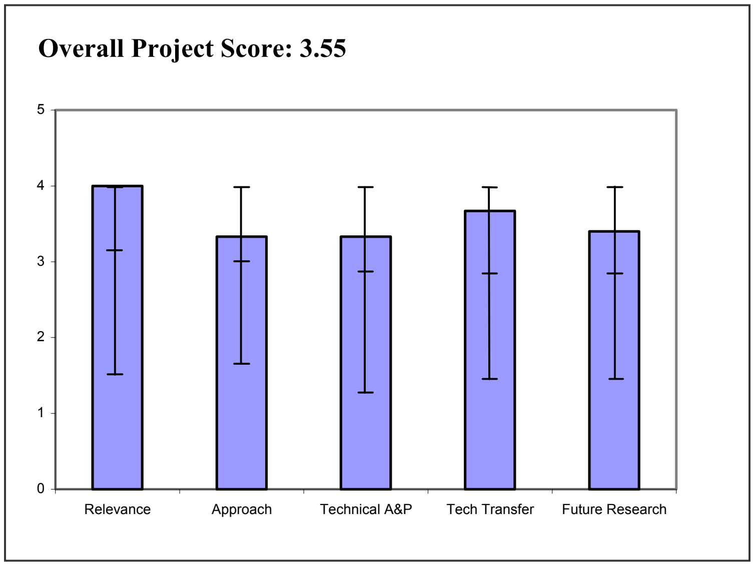
- A more balanced approach regarding the demonstration projects and safety would be recommended.
- Ensure international inclusion.

- Support bonafide safety research and analysis as a high priority rather than using funding for codes and standards, organizations, and code officials training.

Project # SCS-2: Hydrogen Codes and Standards
Ohi, Jim; National Renewable Energy Laboratory

Brief Summary of Project

In this project, the National Renewable Energy Laboratory (NREL) will work on hydrogen codes and standards to expedite hydrogen infrastructure development, coordinate such development activities for the Hydrogen Program, and incorporate hydrogen safety considerations into existing and proposed national and international codes and standards. This will be accomplished by bringing together experts to address key issues, coordinating a collaborative National effort between government and industry, and by serving as the central point of contact for up-to-date information on codes and standards activities.



Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Project is an absolute necessity.
- Codes and standards work is critical to the ability to sell, own and operate hydrogen powered vehicles and to install the supporting infrastructures.
- Necessary for coordination of all activities in this area.
- Critical area for continued growth.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Well-designed and thought out plan.
- Barriers understood.
- Difficult to evaluate this work along the prescribed criteria since much of the work is in coordination and negotiations among the various code setting bodies and among international organizations.
- Some of the work is reported to be research-based, but there is not enough information about this work to be able to evaluate it.
- Gather international input if available.
- Good practice to incorporate training/continuing education.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.33** based on accomplishments.

- Accomplishments on target.

- There seems to be slow progress; but, again, this may not be unexpected given the nature of much of the work.
- There appears to have been progress with the ICC work and with the establishment of templates, but much of the other work seems to be laying the ground work for future accomplishments.
- Conducting related R&D would be an important part of the effort, but it appears to be a small part and mostly consists of developing roadmaps and one referenced separation distance study.
- Good plan to integrate (template) all areas toward central focus for code adoptions.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.67** for technology transfer and collaboration.

- Collaboration is of the highest degree involving considerable number of organizations.
- Collaborations and interfaces are part and parcel of this task; and are mandatory for success.
- Team appears to be doing a good job.
- Collaboration with all involved parties, including international: 1) not easy, 2) necessary, 3) good work/organization.
- Positive intent to combined approach with multiple stakeholders.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.40** for proposed future work.

- Well planned outline for needed work to effectively reduce barriers.
- Expect promising outcome in the future especially in technical support for developing new hydrogen standards.
- Timetable/ not sure that crash testing will be done in 2007.
- C&S time table: push R&D and delay C&S setting until data is available.
- Need to discuss FY 05 draft standard for H_2 sensors/detectors.

Strengths and weaknesses

Strengths
- A vital part of the overall National hydrogen effort.
- Important area for future growth.

Weaknesses
- Remember to focus on getting right people, not just right industry sectors for workshops.
- Development will be "long-term."

Specific recommendations and additions or deletions to the work scope

- Would like to see clear definition between portion of budget that is directed towards interfaces with code setting bodies, international agencies, etc. and that part of the budget that is used specifically for R&D.

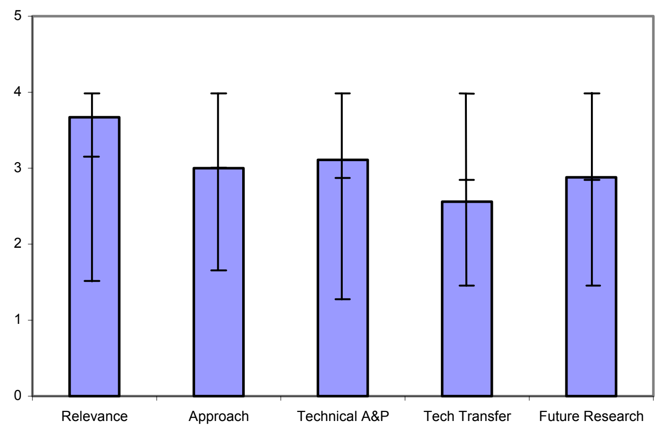
Project # SCS-3: Electrochemical Sensors for PEMFC Vehicles

Martin, Jim; Lawrence Livermore National Laboratory

Brief Summary of Project

Lawrence Livermore National Laboratory (LLNL) is developing solid-state electrochemical sensors for safety and fuel monitoring applications. The safety sensor will utilize new electrode materials and well-known oxygen conducting ceramics. The fuel sensor will utilize novel proton conducting ceramics in a traditional sensor concept.

Overall Project Score: 3.04



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.67** for its relevance to DOE objectives.

- Safety/fuel sensor work of utmost importance.
- Work on hydrogen sensors clearly supports the Hydrogen Fuel Initiative because the technology needs to be developed to support potential applications.
- While the research is important if sensors are needed, it is also relevant to note that support for the research should not be interpreted as agreement among the auto companies that sensors are required.
- Sensor technology needs to be developed in case it is needed for application in automotive use.
- Relevance to DOE overall objectives not well described.
- H_2 sensor technology is not yet perfected, and this work is very valuable.
- Key part of program.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- The many barriers and technical problems are identified.
- Good that PI is keeping in mind an awareness of the need for eventual commercialization of this technology.
- Clearly lower operating temperatures and operating voltages are needed in order for the sensor to be commercially practical.
- Need to establish whether this can be done in the commercialization phase or if additional research is needed.
- Natural gas is not typically found in a garage.
- Fuel sensor work is good.
- Safety sensor work: OEMs will engineer consumer-phase vehicles that don't require H_2 leak sensors.
- Good approach which evaluates different sensor technologies.
- Application could be broader and/or redirected.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.11** based on accomplishments.

- Considerable lab work done.
- Good progress.
- Need to evaluate sensor drift. Need to quantify sensor start-up time with response time. High temperature sensors generally take longer for start-up time then lower temperature sensors.
- Fuel sensor technology will be very valuable in the future to measure in-line H_2 quality.
- Lots of good data with one test configuration.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.56** for technology transfer and collaboration.

- Interaction with other institutions seems lacking except for 'discussion' with others (Auto, FC, etc.).
- Mentions papers written and presentations made as well as discussion with one fuel cell manufacturer and two auto makers.
- Collaborations not specifically described.
- Confirm/consider collaboration with industry and other sensor developments.
- Though a challenge, need to develop relations with partners/users; otherwise technology is guaranteed to sit unused on the shelf.
- Collaboration with potential manufacturer currently absent.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.88** for proposed future work.

- Proposed work is a fabrication method.
- Timeline/ milestones do show other efforts but not discussed.
- Not assessed as it appears the project is ending.
- Future research not described in much detail.
- Confirm sensors will operate in low (-50F) temperature external environments. As shown, the sensor requires about 440C for operation which may not be practical.
- Sensitivity to hydrocarbon typically formed in a garage, e.g. gasoline, diesel, paint thinner, etc., needs to be confirmed or included in the program. Natural gas not typically formed.
- Confirm operating temperatures of 440C will not present an ignition source for a large H_2 release.
- Confirming sensor life is a function of time and not a function of mass of H_2 absorbed. For example, a large release of say 1-2 parts of H_2 does not consume the sensor life.
- If on-board fuel processing decision is no-go, verify need for H_2 sensors.
- Some fundamental questions still need to be explored in order to stimulate interest in commercialization.

Strengths and weaknesses

Strengths

- Excellent work.
- Methodical plan of work.
- A comprehensive investigation of sensor technologies available and future possibilities.
- Good sensitivity, linear response.

Weaknesses
- Cost and durability?
- Investigation of sensor drift.
- The need to heat electrode will inherently raise reliability questions and start-up time questions.

Specific recommendations and additions or deletions to the work scope

- Reiterate that sensor research is valuable in case individual auto makers determine that sensors are needed in their products, but care needs to be exercised not to imply that, while the R&D is valued, on-board sensors ought to be maintained.
- Consider the issue that for many of the separation technologies and many of the off-gasses produced, e.g. $CO/CO_2/O_2$, may present additional hazards.
- Future work may need to confirm cost effective availability and application reliability of these other sensors under required environmental exposures.
- If funding/timing is available, fuel sensor development is a valuable effort to pursue further for in-line hydrogen quality sensing.
- Use different test set up that introduces cold H_2-air mixtures to heated electrodes.
- Explore signal response reduction at H_2 concentration >4%. Explanation of O_2 limitation is not convincing.

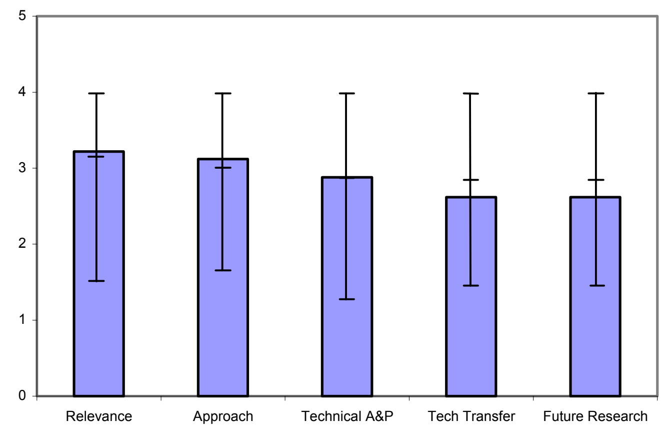
Project # SCS-P1: Interfacial Stability of Thin Film H_2 Sensors

Pitts, Roland; National Renewable Energy Laboratory

Brief Summary of Project

The National Renewable Energy Laboratory (NREL) is currently working to develop and make technology available that would produce safe, reliable, sensitive, fast, lightweight, and inexpensive hydrogen sensors. To do this, NREL will look at the factors affecting the stability and performance of thin film sensors, such as suspect contaminant gases, temperature variations, and humidity impacts, in practical environments and find solutions for extending the lifetime and functionality of thin film hydrogen sensors.

Overall Project Score: 2.89



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.22** for its relevance to DOE objectives.

- H_2 sensor work critical to program.
- Work on the hydrogen sensors clearly supports the Hydrogen Fuel Initiative because the technology needs to be developed to support potential applications.
- While the research is important if sensors are needed, it is also relevant to note that support for the research should not be interpreted as agreement among the auto companies that sensors are required.
- Sensor technology needs to be developed in case it is needed for application in automotive use.
- Difficult to understand relationship to overall DOE objectives.
- This project is very relevant, but falls short on a few goals such as lifetime and response time.
- Having reliable, inexpensive sensors is a critical need. However, there may be other approaches and sensor concepts to accomplish that need.

Question 2: Approach to performing the research and development

This project was rated **3.12** on its approach.

- Barriers properly identified, approach to solutions clear and straight forward.
- Approach seems sound, but it appears that the project has taken a rather long time to get to its present status.
- Approach appears to be well designed.
- More work could be done regarding integration in other research.
- Safety fully addressed.
- Difficulty in establishing lower temperature limit.
- Concept is ideally suited for use with distributed fiber optic based signals and control systems.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.88** based on accomplishments.

- Effectiveness, etc. -- good progress.
- Cost needs to be addressed.
- PI seems to have a reasonable approach to sensors, but will need to assess whether the design can be affordably manufactured if intended for automotive applications.
- PI indicated that he is looking at stationary applications which may be more appropriate for the level of sophistication in the design.
- Good progress.
- This project started in 1994 - 10 years ago! I don't think much progress has been made relative to the time invested.
- The project has come close to meeting DOE goals; however, research has been ongoing for years and durability improvements, improvements in temperature range, and accuracy were not described.
- Slow process to objectives.
- Excellent sensitivity.
- Fast response.
- Need to find film materials that will not saturate at concentrations $<10\%$ H_2.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.62** for technology transfer and collaboration.

- For the work scope the participants are appropriate.
- Need pipeline collaborators to ensure applications of technology.
- Some collaboration were shown.
- Need private industry collaboration to accelerate production development and commercialization.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.62** for proposed future work.

- Well identified but no timeline.
- No reference in poster material to future plans; perhaps because research appears to be nearing its end.
- Need to get on with getting this project finished.
- Confirm/consider future work will include exposure to heavier chain hydrocarbons e.g., gasoline, diesel, paint thinner, etc. that might typically be found in a garage environment.
- Vehicles will be engineered to handle H_2 safely without leaks, or they won't happen.
- A more disciplined approach to meeting DOE goals (and/or surpassing) should be a part of the presentation.
- There is no clear end in sight.
- Good foundation to future commercialization.

Strengths and weaknesses

Strengths
- Innovative sensor technology.

- Many of the DOE goals met.
- Enthusiastic ownership.
- Conceptual design.
- Sensitivity.

Weaknesses
- The OEMs do not intend to engineer FC vehicles that will require H_2 sensors- no more so than do gasoline vehicles today. So focus on vehicle application is misguided.
- Timeframes needs to be more goal oriented for future work.
- Limit of range or linearity.
- Film saturation at relatively low H_2 concentrations.
- Sensor work seriously behind the power curve.

Specific recommendations and additions or deletions to the work scope

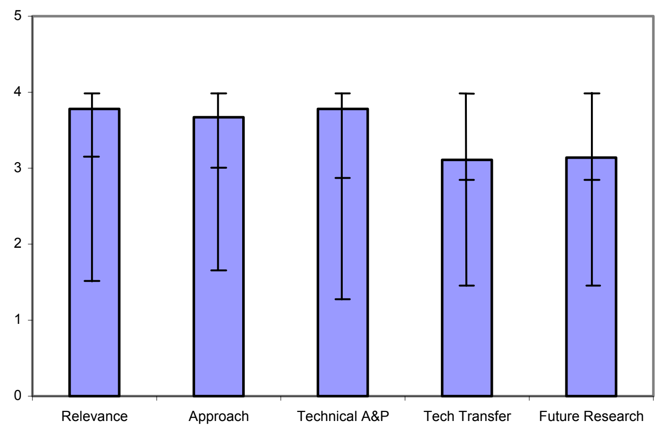
- Scope needs to be expanded to field-validate in real applications.
- Need to take the next step and include "array" concepts, total system awareness, feedback systems, etc.
- Reiterate that sensor research is valuable in case individual auto makers determine that sensors are needed in their products, but care needs to be exercised not to imply that, while the R&D is valued, on-board sensors ought to be maintained.
- Consider that for many of the separation technologies and many of the off-gasses produced, e.g. $CO/CO_2/O_2$ may present additional hazards.
- Future work may need to confirm cost effective availability and application reliability of the other sensors under required environmental exposures.
- Add focus on pipeline application.
- Indication of actual status for goals not yet met would be more helpful to judge the project.
- DOE targets need to have a target date.
- Explore feasibility of both a simpler, inexpensive onboard sensor for vehicle use, and another more elaborate design to provide H_2 concentrations for use in facility DCS intelligent signal processing.

Project # SCS-P2: Codes & Standards Analysis
Swain, Michael; University of Miami

Brief Summary of Project

The University of Miami is working on codes and standards to conduct a building safety analysis for the California Fuel Cell Partnership (CaFCP), including an assessment of safety issues related to garaged vehicles. They will develop a method to determine hydrogen sensor placement, and analyze safety issues for the writing of codes and standards. This will be accomplished by identifying concerns on hydrogen installations and designing, testing and verifying computer programs to accurately model hydrogen interactions.

Overall Project Score: 3.50



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.78** for its relevance to DOE objectives.

- The characterization of H_2 behavior, true ignition parameters and related aspects are crucial to the program.
- Data regarding hydrogen flammability will be key in the establishment of codes and standards.
- This study continues work done in the areas of hydrogen flammability characteristics.
- Title is misleading -- should be something about flammability limits.
- Excellent work needed at this time period to make realistic judgment calls on C&S relating to setback distances.
- Good foundation to an issue of concern for future commercialization.
- Good general objective, but not focused on any specific standard or application.

Question 2: Approach to performing the research and development

This project was rated **3.67** on its approach.

- The approach it is well understood.
- The PI uses a combination of sophisticated analytical and prediction tools and rather simple experimental methods to illustrate hydrogen flammability limits.
- The simple illustrative methodologies appear to be useful in demonstrating hydrogen properties to the code setting activities and to government and public bodies.
- Work was methodical and conclusive, and the results were clear.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.78** based on accomplishments.

- Accomplishments continue to be unprecedented.

- PI continues to develop data and illustrative information to support codes and standards.
- The project achieved its goals and targets.
- This work changes the historical assumptions on real world ignition energy of H_2 LFL conditions.
- The ignition sources that were evaluated were actual household appliances.
- Interesting test data, but no plan on how to use data or generalize it.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.11** for technology transfer and collaboration.

- Project very unique, so interaction would be limited.
- None listed or mentioned.
- Consider even more interactions and education with fire marshals.
- Transfer of information will or has been given to the key C&S organizations which deal with setback distances.
- No collaboration besides SNL.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.14** for proposed future work.

- Future work limited to reporting progress.
- No specific plans were noteworthy, but a continuation of current research would be valuable.
- Not applicable.
- Should move next to model more realistic release scenarios (smaller holes, higher P).
- The future work detailed was only regarding an upcoming presentation.
- Future work does not address other areas where real world LFL studies would be beneficial.
- Project appears complete.
- No plans on next step.
- No future research identified by PI.
- This work is most valuable to the overall effort.

Strengths and weaknesses

Strengths
- The work is laying out the groundwork to challenge the NFPA 70 (NEC) Group B class for H_2 (something done decades ago) in my opinion, which needs to be done.
- Good work and relevant.
- Good practical testing of light switches, garage door openers etc. -- this is an important education piece.
- Clearly documented, disciplined work which will assist in making setback distances based on material properties and not undue fears of H_2.
- Good video clips of flame blow off under some conditions, and flashback to release site under other conditions.

Weaknesses
- The funding level of this activity is much too low.
- Underwriter's Lab and others need to be part of this project.
- No plan to generalize data or apply it to other ignition sources and scenarios.
- No review of similar tests performed previously.

Specific recommendations and additions or deletions to the work scope

- Expand scope -- the criticality of imposing NFPA70 as non written on small H_2 systems will be a significant cost burden to implementing the "H_2 economy" and NFPA "group B" is technically flawed and has been for decades.
- The C&S title is too general as the scope was to evaluate LFL relating to setback distances.
- Should be maintained.
- Confirm (resources are provided) / consider (providing research) for integration of this work with LLNL/SNL/SRI's work on release rates, heat flux, etc. as well as risk (frequency of a release with associated consequences) to aid NFPA/ICC in determining appropriate cost effective, risk based, set-back distances.
- Future work needs to be concentrated not just in setback distances, but a suggestion would be enclosed facility LFL studies in order to realistically evaluate alarm levels/need for H_2 alarms and sensors in facilities which store H_2 vehicles, etc.
- Solicit input from technology validation projects on relevant ignition scenarios.

Hydrogen Education

Summary of Annual Merit Review Hydrogen Education Subprogram

Summary of Reviewer Comments on Hydrogen Education Subprogram:

Reviewers considered hydrogen education to be important to the President's Hydrogen Fuel Initiative and necessary for public acceptance of hydrogen use in daily activities. They noted that the education strategy, following a slow, multi-phased, and long-term approach, is appropriate. Reviewers also praised the hydrogen education plan for organization, understanding of barriers, coverage of target audiences, and effective coordination with key entities, particularly with state and university partners.

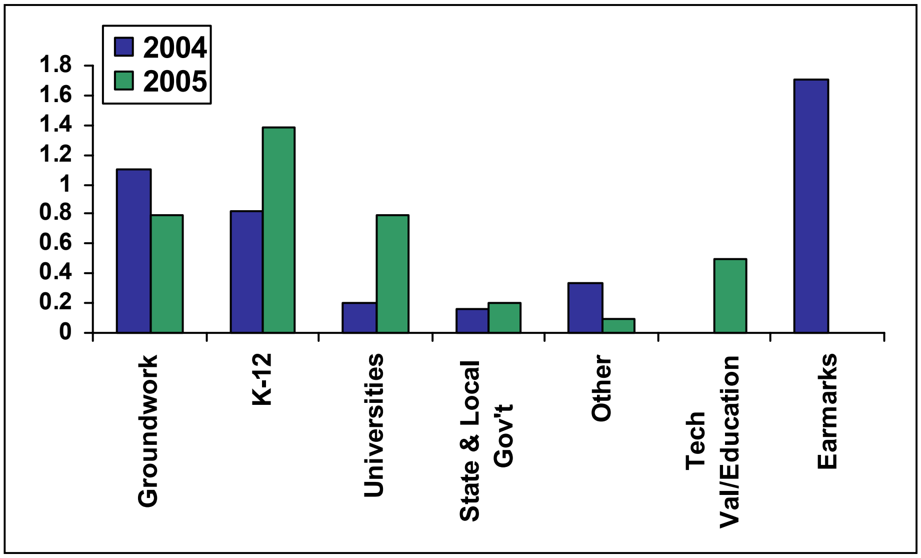
Reviewers commented on the need to coordinate education activities with technology validation projects to reach pertinent local audiences, although several commented that there is less need to focus on the general public until hydrogen fuel cell technology is closer to commercialization. It should be noted that there is coordination between the Education and Technology Validation Subprograms, although lack of funds due to Congressionally-directed projects affected this effort in FY2004.

It was also suggested that teachers participating in hydrogen education training sessions should be offered professional development credits, and that teachers representing multiple disciplines should be involved, rather than focusing on only science and math teachers. It should be noted that these points were considered in the development of the Hydrogen Education Solicitation prior to its release, and that both awards made for hydrogen curricula and teacher professional development address these issues.

There was also a request for more online learning opportunities. Several reviewers noted, however, that although the website and materials library are necessary activities, measuring their effectiveness may be difficult. The website and information center support education activities, such as workshops and training. Although their usage can provide helpful insight regarding education needs and interest, these tools are not intended to provide the primary measure of Education Subprogram effectiveness. Instead, a knowledge assessment/national survey initiated in FY2004 will measure key target audiences' understanding of the hydrogen economy. It will provide, not only information to help direct near-term education activities, but also a baseline from which the Education Subprogram can measure success over the long-term. Repeat surveys using the same methodology are planned for 2007 and 2010.

Hydrogen Education Funding:

The funding portfolio for hydrogen education addresses "groundwork" activities and development of general education materials to help lay the foundation for a long-term education campaign as called for in the President's National Energy Policy, as well as specific activities focused on several key target audiences that play a role in near-term transition activities to a hydrogen economy. The 2005 funding profile (subject to Congressional appropriation) supports projects awarded under two solicitations issued in 2004, education activities in coordination with technology validation projects, and a "phase 2" of state and local government education activities initiated in 2004.



Majority of Reviewer Comments and Recommendations:

The number of education projects included in the 2004 merit review is small, and includes only the baseline knowledge assessment, State Energy Program Special Projects, and Congressionally-directed projects. Efforts related to state and local government education were included in the Education Subprogram overview. In many ways, however, the Education Subprogram effort is just starting. New projects awarded through two competitive solicitations in 2004 have created a more robust education subprogram for review in 2005.

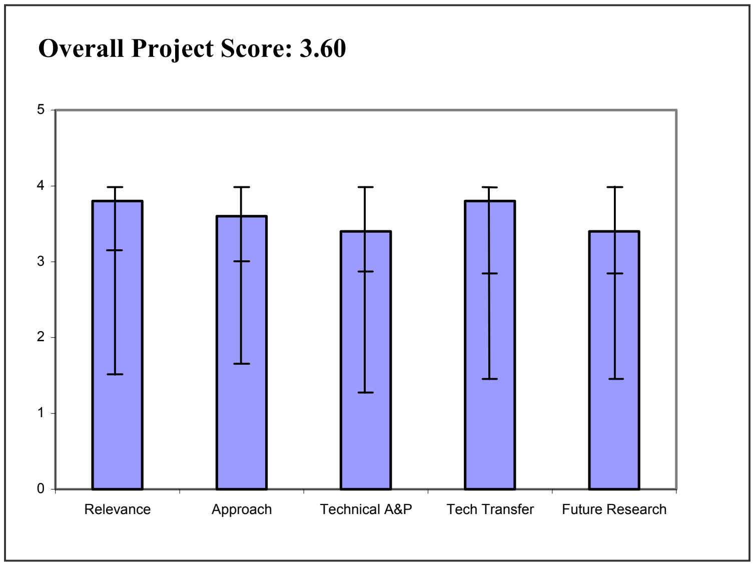
The reviewer scores for the education projects reviewed varied from as high as 3.92 to as low as 2.08. Many projects are new and had little progress to report, and reviewers commented on the need to focus Congressionally-directed projects on hydrogen and fuel cell technologies. Also, several projects awarded through the 2003 State Energy Program experienced significant funding delays that affected their performance. To the extent possible, DOE will act on reviewer recommendations to support the overall hydrogen education effort.

- **Baseline Knowledge Assessment:** Expand survey effort to include additional target audiences, including firefighters, local building code officials, and local community activist organizations in technology validation "test sites."
- **K-12 and University Projects –** Provide lessons learned and share results with other states interested in hydrogen education. Consider alternative funding mechanism to State Energy Program if funding delays persist.

Project # ED-1: Education Subprogram Overview
Cooper, Christy; DOE, Team Lead

Brief Summary of Presentation

The purpose of this Education Subprogram Overview is to describe subprogram goals/objectives, budgets, barriers/targets, approach, accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and puts into context the education strategy and projects that will be presented in this subprogram area during the Annual Merit Review.



Question 1: Relevance to overall DOE objectives

This presentation earned a score of **3.80** for its relevance to DOE objectives.

- Education plan essential.
- Education will be necessary for acceptance of hydrogen in the public's day to day activities.
- Covers all audiences/stakeholders.

Question 2: Approach to performing the research and development

This presentation was rated **3.60** on its approach.

- Barriers clearly understood.
- Although a website and library of materials are necessary activities, measuring their effectiveness may be difficult.
- Multi-phased, over a long-term.
- Good practice to show continuous improvement.
- Good appreciation of the need for a slow, long-term education program, and need to consider feedback.

Question 3: Technical accomplishments and progress toward project and DOE goals

This presentation was rated **3.40** based on accomplishments.

- Very comprehensive plan.
- Reaching a broad audience (through hotline, internet) a challenge.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.80** for technology transfer and collaboration.

- Interactions with many entities; well planned and coordinated.
- Continuous improvement displayed.
- Long-term approach to expand the audience.
- Networking to date appears effective.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.40** for proposed future work.

- Proposed plan very well laid out.
- More planning related as opposed to research.
- Too diffuse and scattered not consistent with "go slow approach."

Strengths and weaknesses

Strengths
- Outstanding organization, accomplishments, and goals.
- Coordinating with key organizations.
- Great work!
- Good outreach to state energy agencies and universities.

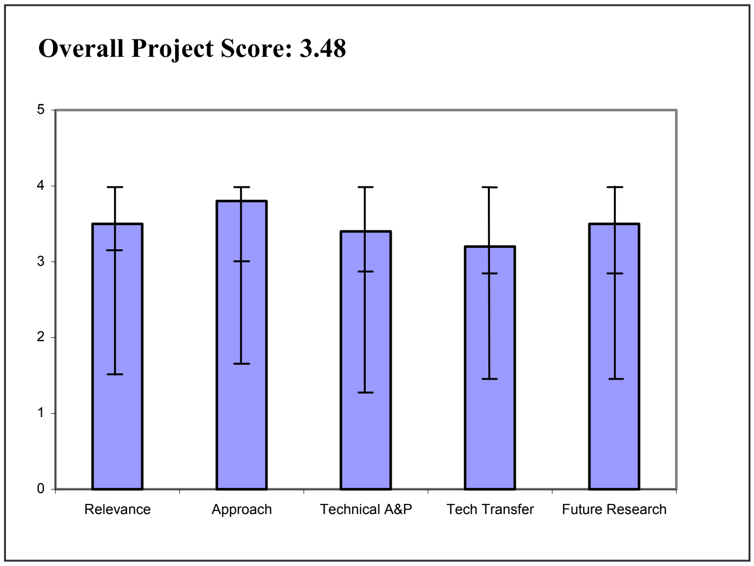
Weaknesses
- No coordination with Technology Validation Subprogram to reach pertinent local audience at project sites.

Specific recommendations and additions or deletions to the work scope

- Consider/confirm that any teacher attending the "train the teacher" sessions will receive a continuing education credit. (As a former teacher, this would raise my interest level.)
- Confirm scope of teacher involvement for all teaching fields, not limited to science and/or math.
- Title needs to be specific regarding scope.
- Develop more online learning possibilities.
- Share successful approaches among funded and future projects.
- Coordinate with Technology Validation Subprogram to identify most pertinent target audiences.
- Interact with professional engineering societies; ask them what would be helpful for their memberships.
- Cut back on education to general public, until we are closer to commercialization.

Project # ED-2: Baseline Knowledge Assessment

Truett, Tykey; Oak Ridge National Laboratory



Brief Summary of Project

Oak Ridge National Laboratory's (ORNL) project is to measure the current level of awareness and understanding of hydrogen and fuel cell technologies and the hydrogen economy in four target populations – general public, students and educators, state and local government agencies, potential large-scale users – and to establish a baseline for comparison of future evaluations of public awareness, knowledge, and opinion.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Important project.
- Project is critically relevant but very difficult to implement.
- Necessary to guide developments of education program - also will monitor effectiveness of education program.
- Very important work to assess current knowledge base.
- Capture of identified groups is a good practice for continued improvement.

Question 2: Approach to performing the research and development

This project was rated **3.80** on its approach.

- Very effective approach to obtain level of "awareness."
- 1000 adults + 1000 students + 100-150 educators + 100 S&L agencies + 50 large scale users = 2250-2300 total interviews?
- $270,000 investment for 2300 interviews?
- Confirm number of surveys planned will provide a statistically significant result for the overall population and minimize standard deviation and variance.
- Excellent approach - very well thought out.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.40** based on accomplishments.

- Commendable effort.
- Project still in initial stages - difficult to assess.
- 1000 people survey is a good start.
- Bureaucracy appears to slow progress.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.20** for technology transfer and collaboration.

- Limited "collaboration" other labs etc. but is nature of project.
- Too early in project to assess.
- In presentation, need to be more explicit with collaborations with other education organizations.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.50** for proposed future work.

- Very much in line to assess "progress" of getting the word out and evaluating public feedback in future.
- Survey will be done.
- Will 2007 survey be funded separately?
- Is there any value in using the internet as a vehicle for surveys?
- Baseline survey is necessary to measure progress of education program.

Strengths and weaknesses

Strengths
- Survey results/analysis will be very interesting.
- Look forward to analysis and project report next year.
- Good concept and organized.
- Good identification of targeted groups.
- Good survey sampling methods.
- Good analysis plans.

Weaknesses
- Assumed 50% success rates for calls seem high.
- Trying to reach too broad a population.
- Should focus on key users, regulators, and community activists.
- Telephone surveys can be negative as many people are on the do not call list.

Specific recommendations and additions or deletions to the work scope

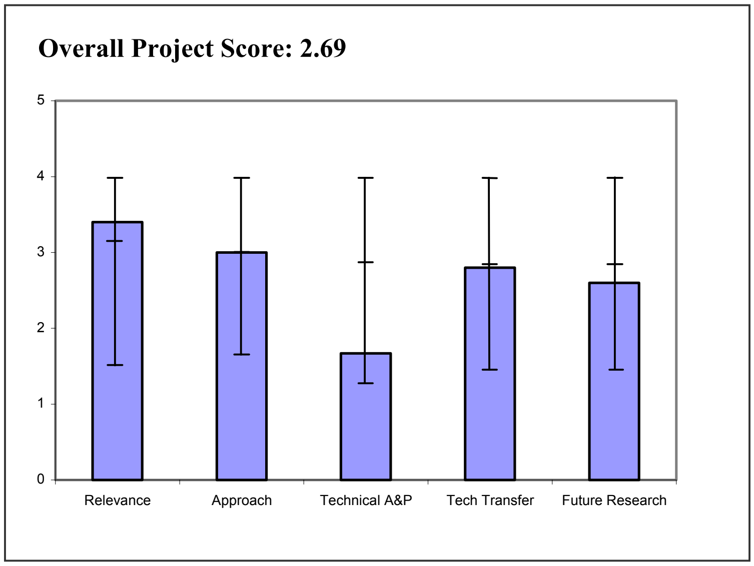
- Evaluate automated survey options for 2007 survey- might be more cost effective.
- A suggestion would be to go to schools, college campuses, earth day, fairs, etc. to do surveys.
- Survey firefighters and local building code officials.
- Survey local community activist organizations at future technology validation test sites.

Project # ED-P1: Demonstration of a PEM Fuel Cell with On-Site Generation of Hydrogen

Turner, Tim; North Carolina State University

<u>**Brief Summary of Project**</u>

This North Carolina State University (NCSU) project will support hydrogen education and outreach through a baseline demonstration of hydrogen fuel with zero emissions from source to point of use, supplemental and backup electrical power for operational purposes, and establishment of a core facility for hydrogen-related research at the university.



<u>**Question 1: Relevance to overall DOE objectives**</u>

This project earned a score of **3.40** for its relevance to DOE objectives.

- New project - not much data.
- Some barriers identified.
- Proposed project will enhance public awareness.
- SEP H_2 Education Project.

<u>**Question 2: Approach to performing the research and development**</u>

This project was rated **3.00** on its approach.

- Needs to think through education process - what level of kids (can't do all K-12, too expensive).
- Barriers clearly understood.
- Project will utilize PV electrolysis to produce H_2. Short term H_2 will produce electricity through FC but long term plans to use as transportation fuel.
- Safety plan not yet addressed.

<u>**Question 3: Technical accomplishments and progress toward project and DOE goals**</u>

This project was rated **1.67** based on accomplishments.

- New project.
- N/A, project not approved yet.
- Accomplishments and progress have been inhibited by funding process challenges. Too many layers to transfer the funding through. FY03 still not awarded to grant recipient. This is a problem.
- No accomplishments as work has not yet started - will not judge.
- Budget may be insufficient to meet objectives.
- Concept described may be difficult to reach target audience (K-12).

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.80** for technology transfer and collaboration.

- Not determined from posters.
- Collaboration proposed is appropriate.
- This is rated as a good plan. Once the project is implemented a real assessment can be done to determine the degree of success.
- Work is done through a university, but does not appear to be coordinated.
- Good fusion at site with multiple alternate fuels.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.60** for proposed future work.

- New project – not identified.
- Future pathway is clear.
- Again the project has not begun due to funding problems but, there is a plan to expand from PV to add wind electrolysis which is promising.
- Planning appears to be minimal at present.

Strengths and weaknesses

Strengths
- A good plan in place.
- Good ideas.

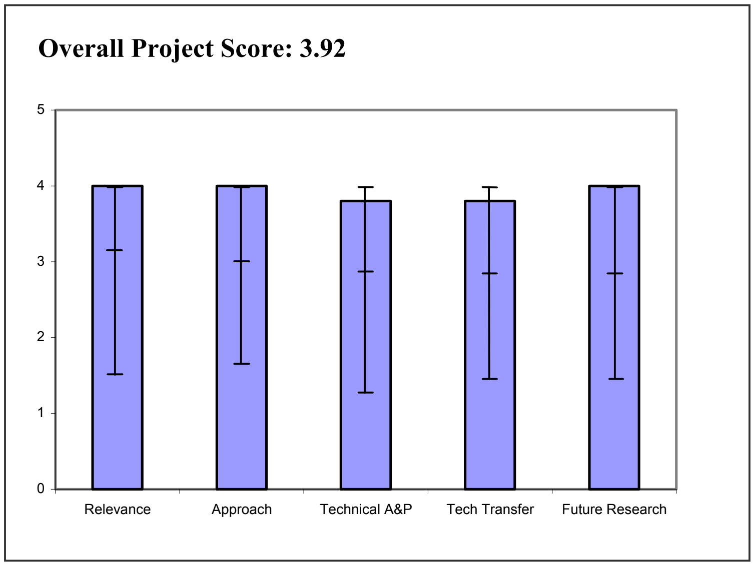
Weaknesses
- Although this is a new project, need to state clearly or think through aspects.
- All funding to project was not identified, although it was stated there was additional money.
- Safety plan needs to be better thought through and not left up to the state to administer.
- Funding process is a critical problem.
- Experience needed.
- Appearance of lack of planning (might be too early in the process).

Specific recommendations and additions or deletions to the work scope

- Identify funding issues and correct.
- Use different funding mechanism in the future.

Project # ED-P2: Washington State Fuel Cell Education and Demonstration Program

Vowles, Mira; Central Washington University



Brief Summary of Project

Central Washington University created a tool and process to educate K-12 students about hydrogen and fuel cells. It used a fuel cell curriculum and car kits, held hands-on workshops for 200 teachers, installed a PEM fuel cell at the university, offered additional fuel cell educational resources, and held four press conferences to increase public awareness. It will have educated 18,000 Washington students by 9/30/04 and measured impacts through pre- and post- quizzes.

Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Aggressive objectives - hope they achieve.
- Good idea for documentation of how well students learned.
- Very important education project.
- Project appears to be very successful.
- 200 teachers->18,000 students in 1 year.
- Very relevant - education initiative.

Question 2: Approach to performing the research and development

This project was rated **4.00** on its approach.

- Excellent combination of partners and participants…Army, industry, universities, etc.
- Barriers well understood and the means to overcome them clearly addressed.
- Project had great partners and cost share.
- Many of the project barriers had been identified in the planning stages so they were addressed, allowing for a very successful project.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.80** based on accomplishments.

- Accomplished all goals.
- Progress is well underway to achieve goals.
- Successful project in the 1st year and it appears it will continue for another year.
- Already "trained 200 trainers."
- Good practice to network through teachers.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.80** for technology transfer and collaboration.

- Very good partnerships.
- Very broad-based interactions with other entities.
- Good documentation process for teachers and students reached.
- Excellent use of negotiation skills to obtain FC kits and teacher access.
- Good practice to provide kits for hands-on experience.

Question 5: Approach to and relevance of proposed future research

This project was rated **4.00** for proposed future work.

- No further funding- project is essentially complete.
- Proposed future work sharply focused and should substantially "get the word out."
- Very good use of funds and partner collaboration.

Strengths and weaknesses

Strengths
- Well thought out project plan.
- Excellent collaboration with sponsors as well as teacher community.
- One of the most comprehensive H_2 training courses from K-12 & above.
- Share good and successful practices with other educational programs.
- Great job.

Weaknesses
- None provided.

Specific recommendations and additions or deletions to the work scope

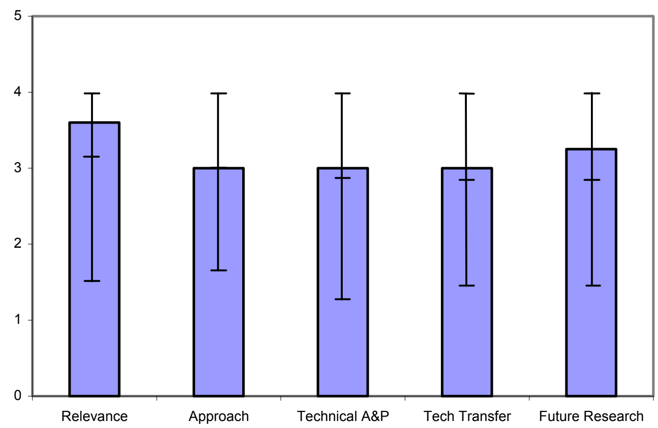
- Would be good to put "Lessons Learned" out for others who are considering similar K-12 projects.
- Keep up the good work!

Project # ED-P3: Development and Dissemination of PEM Fuel Cell Educational Modules
Peters, Andrew; University of North Dakota

Brief Summary of Project

The University of North Dakota (UND) education project involves the development and assessment of PEM fuel cell educational units for use in middle schools and junior high schools, implementation of energy-related courses in campus curricula and middle school teacher education, and support to the campus Chapter of the Society for Energy Alternatives and its efforts to develop a PEM fuel cell-powered vehicle for demonstrations, racing, and outreach with schools, the community, and governmental leaders.

Overall Project Score: 3.17



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.60** for its relevance to DOE objectives.

- New project.
- Good concept.
- Impressive plan "tasks 1-4."
- The project as described is very relevant.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Assessments to monitor progress - good.
- Need to focus more on safety of fuel cell car kit for students.
- Focused on critical areas for accomplishment.
- The teacher access appears to be fairly limited. 20 teachers.
- A secondary information dissemination plan might be helpful, i.e. make curriculum available to other teachers.
- Fuel cell race car is a good concept, but may be an unrealistic goal on a small budget.
- There are many safety systems built into a FC that have been tried out through certification tests.
- Race car implies that a vehicle is to go fast: without a certain amount of safety engineering. I would strongly recommend against such a endeavor unless a FCV manufacturer or FC technology company is involved. The budget and timing do not appear to account for this.
- Teacher training appears successful.
- Obtaining fuel cell has caused delays.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- New project.
- Availability of PEM FC car holding up project.
- There appears to be several issues that have caused delays in the progress of this project.
- Difficulty moving forward due to not being able to obtain fuel cell.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Did not identify fuel cell company - do not know how this will work.
- Work confined to UND participants.
- Very good cost share with UND.
- Innovative plan to reach across the state using the modified solar car.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- New project.
- Future work hidden in text. Needs to be brought forward to track.
- This is difficult to assess as this project is in its early stages.

Strengths and weaknesses

Strengths
- Good cost share for the project.
- Innovative plan to reach public in the state.
- Good plan for education program.

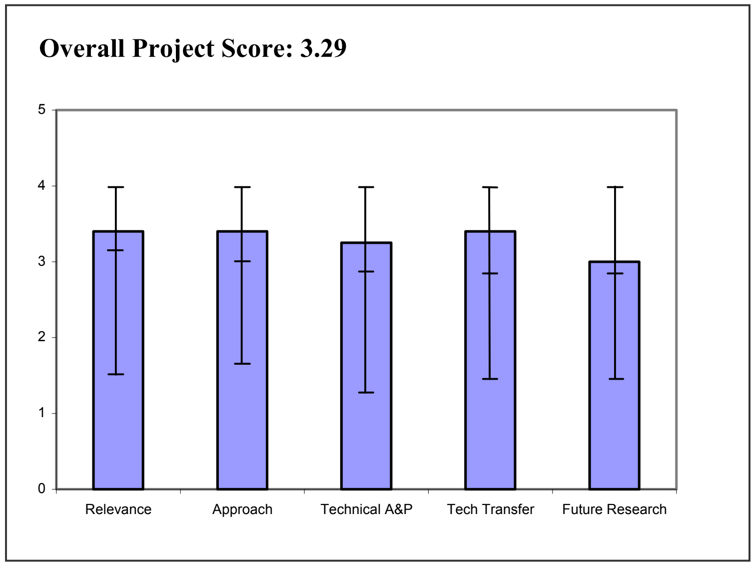
Weaknesses
- Future work hidden in text. Needs to be brought forward to track.
- Building a fuel cell race car plan not defined well enough.

Specific recommendations and additions or deletions to the work scope

- Recommended use of existing information from the DOE H_2 website basics i.e., how a fuel cell works. These can be easily used in this project.
- Develop more detailed safety proposal needed for a fuel cell vehicle race car.

Project # ED-P4: Lansing Community College Alternative Energy Center

Borger, Ruth; Lansing Community College



Brief Summary of Project

Lansing Community College (LCC) will increase awareness and knowledge, and prepare for the deployment of renewable energy technologies, including hydrogen fuel cells, by creating an integrated, educational, technical training program.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- New project - excellent speaker.
- Well thought through - takes advantage of other hardware.
- Very interesting project.
- The project activities are in support of alternate fuels which is great. There does not appear to be emphasis on H_2.

Question 2: Approach to performing the research and development

This project was rated **3.40** on its approach.

- Community college angle is a great idea.
- "Barriers" very well identified and solutions are clear and realistic.
- Approach is well thought out.
- Good approach - many different sources of funding. It is not obvious what the DOE is supporting. (about $1M).
- Good target audience - adults.
- Job retraining opportunities a best practice.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- New project.
- Project in early phase but the potential is enormous.
- The project is in early stages and cannot be adequately assessed.
- Project has not yet begun.
- Proximity of Cadillac plants a positive interaction.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.40** for technology transfer and collaboration.

- Good mix of partners and funding.
- Very broad interaction is proposed.
- A good plan for alternative energy been developed.
- Again it is too early in the project to do an adequate assessment.
- No detailed plan regarding technology transfer, etc.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Very effective plan proposed.
- The funding has not been received yet so it is difficult to assess future work.

Strengths and weaknesses

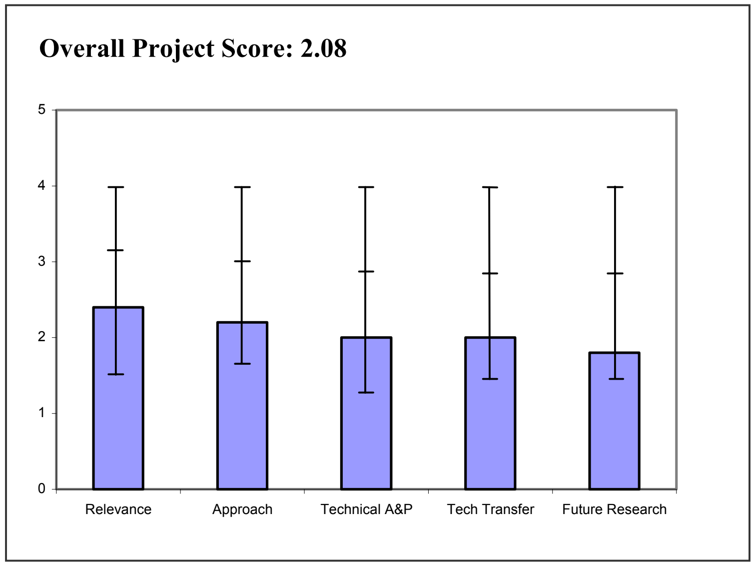
Strengths
- Great idea to use community college.
- Very professional.
- The enthusiasm is tremendous.
- Good alternative energy plan.
- Positive ownership of project.

Weaknesses
- May be taking on a lot of varied activities - be careful not to dilute focus.
- Not enough emphasis on H_2 and fuel cells.
- Presentation very vague - more detail required for plan and goals.

Specific recommendations and additions or deletions to the work scope

- Increase focus on H_2 and fuel cell activities.

Project # ED-P5: Shared Technology Transfer Project
Griffin, John; Nicholls State University



Brief Summary of Project

Nicholls State University (NSU) is to establish a collaborative process with domestic industries for the purpose of sharing Navy-developed technology. The purpose is to educate private business sectors to increase the awareness of these businesses to the vast amount of technologies that are available. The key objectives include cataloging NAVSEA-Carderock unclassified technologies, rating the level of readiness for each hydrogen program-related technology, developing and implementing an Educational Outreach program to increase awareness within hydrogen-related industries, identifying and matching hydrogen-related businesses that might benefit from the technologies, and launching an Educational Technology Showcase and website featuring the initial set of technologies that have been identified as being hydrogen related.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.40** for its relevance to DOE objectives.

- Hard to understand concepts.
- Objective not clear.
- Seems generalistic.
- The relevance to the DOE HFCIT Multi Year Plan could not be determined.
- Directly supports NAVSEA- Carderock. NAVSEA- Carderock was not defined.
- Presenter not available.

Question 2: Approach to performing the research and development

This project was rated **2.20** on its approach.

- Did not get idea of "how."
- "NAVSEA- Carderock" What is it?
- What is intended relationship (specific) to DOE program?
- Approach was interesting but not relevant to DOE HFCIT MYRD&D plan and objectives.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.00** based on accomplishments.

- Start date unknown?
- Very generic charts.

- Not relevant to President's H_2 Fuel Initiative.
- Catalog template looks like a valuable tool.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- No explanation.
- Very limited as discussed in the text.
- Who is "FHPL?"
- Ref: "Relationship of Programs" How do they contribute?
- Some interesting partners: HARC could possibly provide some opportunity of identifying some relevant projects/technologies.
- No detailed plan regarding technology transfer, etc.

Question 5: Approach to and relevance of proposed future research

This project was rated **1.80** for proposed future work.

- No explanation.
- Future work not identified.
- Not applicable as it is a new project.

Strengths and weaknesses

Strengths
- Good structure of project.

Weaknesses
- Difficult to obtain details without presentation.
- More detail required regarding technology transfer and collaboration.
- Not relevant to President's Hydrogen Fuel Initiative.
- Source of funding not clear.
- Referenced DOE barriers and targets but project does not identify its "own."
- Project timeline is one year?
- What is the advantage of using turbines to produce liquid hydrogen?
- Budget information was incomplete.
- No safety issues identified.
- No one available to explain the poster!

Specific recommendations and additions or deletions to the work scope

- Can't recommend additions/deletions as scope is not defined/unclear.

APPENDIX A: DOE HYDROGEN PROGRAM FY 2004 MERIT REVIEW AND PEER REVIEWER ATTENDEES LIST

Name	Organization	Email
Aaron, Tim	Praxair	tim_aaron@praxair.com
Abraham, Judi	Conference Management Associates	Confserv@aol.com
Aceves, Salvador	Los Alamos National Laboratory	saceves@llnl.gov
Adjemian, Kev	Atofina Chemicals	kev.adjemian@atofina.com
Adzic, Radoslav	Brookhaven National Laboratory	adzic@bnl.gov
Agrawal, Rakesh	Air Products & Chemicals, Inc.	agrawar@airproducts.com
Ahluwalia, Rajesh	Argonne National Laboratory	walia@anl.gov
Ahmed, Shabbir	Argonne National Laboratory	ahmed@cmt.anl.gov
Ajayi, Oyelayo	Argonne National Laboratory	ajayi@anl.gov
Alam, Mohammad	University of South Alabama ECE Department	malam@usouthal.edu
Allison, Steve	Oak Ridge National Laboratory	allisonsw@ornl.gov
Alyanakian, Peter	Department of Energy	peter.alyanakian@ee.doe.gov
Anderson, Arlene	Department of Energy	arlene.anderson@ee.doe.gov
Anderson, Michele	Office of Naval Research	andersom@onr.navy.mil
Anderson, Raymond	INEEL	anderp@inel.gov
Ando, Masaki	Toyota Motor Corp. Fuel Cell System Div.	masaki@ando.tec.toyota.co.jp
Anton, Donald	United Technologies Research Center	antondl@utrc.utc.com
Antonucci, Vincenzo	CNR-ITAE	antonucci@itae.cnr.it
Arif, Muhammad	National Institute of Standards & Technology	arif@nist.gov
Armstrong, Tim	Oak Ridge National Laboratory	armstrongt@ornl.gov
Aronsson, Robert	Apollo Energy Systems, Inc.	aholmes@electricauto.com
Atanasoski, Radoslav	3M	rtatanasoski@mmm.com
Atanassova, Paolina	Cabot Superior MicroPowders	paolina_atanassova@cabot-corp.com
Austgen, Dave	Shell Hydrogen	rona.bush@shell.com
Autrey, Tom	Pacific Northwest National Laboratory	tom.autrey@pnl.gov
Bailey, Carol	Sentech, Inc.	cbailey@sentech.org
Bailey, Sterling	Mechanology, LLC	sterling@mechanology.com
Bain, Addison	Consultant	addbain@juno.com
Baker, Wendy	Naval Research Lab	wbaker@ccs.nrl.navy.mil
Bakke, Paul	National Renewable Energy Laboratory	paul.bakke@go.doe.gov
Ban, Stephen	Argonne National Laboratory	sdban@anl.gov
Barnes, David	Vehicle Projects LLC	wendy.shumway@vehicleprojects.com
Barnhart, Steven	DaimlerChrysler Corporation	sab15@dcx.com
Baskaran, Suresh	Pacific Northwest National Laboratory	suresh.baskaran@pnl.gov
Bauer, Bernd	FuMA-Tech GmbH	bb@fumatech.de
Bauman, Jayson	E.I. du Pont de Nemours and Company, Inc.	jayson.bauman@usa.dupont.com
Bavarian, Farshad	ChevronTexaco	bavarf@chevrontexaco.com
Baxley, Phil	Shell Hydrogen	rona.bush@shell.com
Bayless, David	Ohio University	bayless@ohio.edu
Bechtold, Richard L.	QSS Group, Inc.	rbechtol@qssgroupinc.com
Beebe, Harold "Bud"	Sacramento Municipal Utility District (SMUD)	bbeebe@smud.org
Bellan, Josette	Jet Propulsion Laboratory	josette.bellan@jpl.nasa.gov
Bellows, Richard	Bellows Advanced Energy Systems	bellows_richard_j@sbcglobal.net
Benicewicz, Brian	Rensselaer Polytechnic Institute	benice@rpi.edu
Benjamin, Tom	Argonne National Laboratory	benjamin@cmt.anl.gov

Name	Organization	Email
Bennett, Doug	Air Products & Chemicals, Inc.	bennetdl@apci.com
Bensel, Krista	Air Products & Chemicals, Inc.	benselkl@airproducts.com
Berchtold, Kathryn	Los Alamos National Laboratory	berchtold@lanl.gov
Berkey, Edgar	Concurrent Technologies Corp	berkeye@ctc.com
Berlowitz, Paul	ExxonMobil Research and Engineering Co	paul.j.berlowitz@exxonmobil.com
Bierer, Lindsey	General Atomics	bierer@gat.com
Bingham, Dennis	INEEL	bingdn@inel.gov
Bischoff, Brian	Oak Ridge National Laboratory	bischoffbl@ornl.gov
Bjerrum, Niels J.	Technical University of Denmark	njb@kemi.dtu.dk
Blair, Larry	DOE	larry.blair@ee.doe.gov
Blake, Dan	National Renewable Energy Laboratory	dan_blake@nrel.gov
Blencoe, James	Oak Ridge National Laboratory	blencoejg@ornl.gov
Bless, Ed	H2 Solutions Inc.	ebless@h2solutions.com
Block, David	Florida Solar Energy Center	block@fsec.ucf.edu
Bloyd, Cary	Argonne National Laboratory	Bloyd@anl.gov
Boateng, Akwasi	USDA/ARS/ERRC	aboateng@errc.ars.usda.gov
Boehm, Robert	Center for Energy Research	boehm@me.unlv.edu
Bogicevic, Alexander	Ford Motor Co.	abogicev@ford.com
Bollepalli, Srinivas	Columbian Chemicals Company	Bsriniva@phelpsd.com
Bordeaux, Christopher	Department of Energy	christopher.bordeaux@ee.doe.gov
Borger, Ruth	Lansing Community College	borgerr@lcc.edu
Borup, Rod	Los Alamos National Laboratory	Borup@lanl.gov
Bourgeois, Richard	GE Global Research	bourgeoi@crd.ge.com
Bouwman, Peter	Naval Research Laboratory	bouwman@nrl.navy.mil
Bouza, Antonio	Department of Energy	antonio.bouza@ee.doe.gov
Bowen, David	Gas Technology Institute	dave.bowen@gastechnology.org
Boyd, Lynnae	National Renewable Energy Laboratory	lynnae_boyd@nrel.gov
Boyer, Jeffrey	Plug Power Inc.	jeff_boyer@plugpower.com
Bradshaw, Richard	Stirling Strategic Services, LLP	rbradshaw@dykema.com
Bresenham, Damon	Sycamore-DeKalb LLC	dbresenham@charter.net
Bromberg, Leslie	MIT	
Bromenshenk, Jerry	The University of Montana	jjbmail@selway.umt.edu
Brooks, Chris	Honda Research Institute	cbrooks@honda-ri.com
Brown, Ken	Safe Hydrogen, LLC	kbrown@safehydrogen.com
Brown, Lloyd	General Atomics	lloyd.brown@gat.com
Brown, Marilyn	Oak Ridge National Laboratory	brownma@ornl.gov
Bull, Stanley R.	National Renewable Energy Laboratory	stanley_bull@nrel.gov
Burton, Marvin	Reldan Metals,Inc	MarvinB@reldanmetals.com
Buttner, William	Illinois Institute of Technology	buttner@iit.edu
Cabasso, Israel	State University of New York, Poly. Res. Inst.	icabasso@syr.edu
Calundann, Gordon	PEMEAS GmbH	g.calundann@pemeas.com
Cameron, Christopher	Sandia National Laboratories	chris.cameron@ee.doe.gov
Campbell, Karen	Air Products & Chemicals, Inc.	campbekm@airproducts.com
Campbell, Stephen	Ballard Power Systems	stephen.campbell@ballard.com
Carbone, Allessandra	CNR-ITAE	carbone@itae.cnr.it
Carlin, Richard	Oak Ridge National Laboratory	carlinr@att.net
Carlson, Eric	TIAX LLC	carlson.e@tiaxllc.com
Carlson, Todd	Air Products & Chemicals, Inc.	carlsote@apci.com

Name	Organization	Email
Chalk, Steve	Department of Energy	steven.chalk@ee.doe.gov
Chandra, Dhanesh	University of Nevada, Reno	dchandra@unr.edu
Chao, Benjamin	Texaco Ovonic Hydrogen Systems	benchao@ovonic.com
Chellappa, Anand	MesoFuel, Inc.	rhonda.lujan@mesofuel.com
Chen, Christopher	Air Products & Chemicals, Inc.	chencm@airproducts.com
Chen, Lei	United Technologies Research Center	chenl1@utrc.utc.com
Chen, Philip	ATMI	pchen@atmi.com
Chen, Ping	National University of SIngapore	phychenp@nus.edu.sg
Chernicoff, William	US DOT	chernicoff@volpe.dot.gov
Chesley, Fred	Startech Environmental Corp.	fchesley@startech.net
Chew, James	TJ Technologies	jchew@tjtechnologies.com
Chianelli, Russell	UTEP	Chianell@utep.edu
Chin, Artie	Rohm and Haas Co.	achin@rohmhaas.com
Chintawar, Prashant	Nuvera Fuel Cells, Inc.	pchintawar@nuvera.com
Choi, Saemin	Visteon	schoi5@visteon.com
Chornet, Esteban	Sentech, Inc.	lreese@sentech.org
Chu, Deryn	US Army Research Laboratory	dchu@arl.army.mil
Chu, Wilson	Johnson Matthey Fuel Cells	chuw@jmusa.com
Clark, Thomas	UTC Fuel Cells	Paula.Herrington@UTCFuelCells.com
Clausen, Max	Pacific Northwest National Laboratory	max.clausen@pnl.gov
Cleary, Bill	Argonne National Laboratory	bill.cleary@ee.doe.gov
Cohen, Steven	Teledyne Energy Systems Inc	steve.cohen@teledynees.com
Coker, Eric	Sandia National Laboratories	encoker@sandia.gov
Collier, Kirk	Collier Technologies, Inc.	gsander@bestemissions.com
Cooper, Alan	Air Products & Chemicals, Inc.	cooperac@airproducts.com
Cooper, Christy	Department of Energy	christy.cooper@ee.doe.gov
Cornelius, Chris	Sandia National Laboratories	cjcorne@sandia.gov
Corrigan, Dennis	Ovonic Fuel Cell Company	dcorrigan@ovonic.com
Cortright, Randy	Virent Energy Systems	randy_cortright@virent.com
Coughlin, Bryan	University of Massachusetts, Amherst	coughlin@mail.pse.umass.edu
Cready, Erin	Sentech, Inc.	ecready@sentech.org
Cropley, Cecelia	Giner, Inc.	ccropley@ginerinc.com
Cross, James	Nuvera Fuel Cells Inc.	cross.j@nuvera.com
Curry-Nkansah, Maria	BP America Inc.	curry-me@bp.com
DaCosta, David	HERA USA Inc	dacosta@ergenics.com
Dai, Hongli	DuPont CR&D	hongli.dai@usa.dupont.com
Damle, Ashok	Research Triangle Institute	adamle@rti.org
Danz, Roxanne	Department of Energy	roxanne.danz@ee.doe.gov
Davis, Audrey	Naval Surface Warfare Center	davisam@nswccd.navy.mil
Davis, Christopher	UTC Fuel Cells	Paula.Herrington@UTCFuelCells.com
Davis, Patrick	Department of Energy	patrick.davis@ee.doe.gov
Davis, Thomas	University of South Carolina	tom.davis@sc.edu
Day, Danny	Eprida	danny.day@eprida.com
De Castro, Emory	E-TEK div, De Nora N.A., Inc.	emory.decastro.etek@denora.com
Debe, Mark	3M	mkdebe1@mmm.com
DeCuollo, Gerald	Sarnoff Corporation	gdecuollo@sarnoff.com
Dedrick, Daniel	Sandia National Laboratories	dededri@sandia.gov
Defelice, Scott	Oxford Performance Materials	sdefelice@oxfordpm.com

Name	Organization	Email
Dempsey, Roxanne	US DOE, SRO	roxanne.dempsey@ee.doe.gov
Deng, Xunming	University of Toledo	dengx@physics.utoledo.edu
DesMarteau, Darryl	Clemson University	fluorin@clemson.edu
Devlin, Pete	Department of Energy	peter.devlin@ee.doe.gov
Di Blasi, Alessandra	CNR-ITAE	diblasi@itae.cnr.it
DiMeo, Frank	ATMI	fdimeo@atmi.com
Diver, Richard	Sandia National Laboratories	rbdiver@sandia.gov
Dmowski, Wojtek	University of Tennessee	
Dressen, Sharon	ATK Thiokol, Inc.	sharon.dressen@atk.com
Dubois, Ray	Colonial Metals Inc.	rdubois@colonialmetals.com
Duffy, Michael	Battelle Memorial Institute	duffym@battelle.org
Edlund, Dave	IdaTech	nwalleen@idatech.com
Edwards, Christopher	Stanford University	cfe@stanford.edu
Eisman, Glenn	Plug Power Inc.	donna_ranallI@plugpower.com
Elam, Carolyn	National Renewable Energy Laboratory	carolyn_elam@nrel.gov
Epping, Kathi	Department of Energy	Kathi.Epping@ee.doe.gov
Ernst, William	Plug Power Inc.	donna_ranalli@plugpower.com
Every, Hayley	Case Western Reserve University	hae@po.cwru.edu
Fable, Scott	TIAX LLC	fable.scott@tiaxllc.com
Fan, Chinbay	Gas Technology Institute	qfan@gastechnology.org
Fang, Zak	University of Utah	zfang@mines.utah.edu
Farley, Adrian	QSS Group, Inc.	adrian.farley@ee.doe.gov
Faur-Ghenciu, Anca	Johnson Matthey Fuel Cells	ghencia@jmusa.com
Feinberg, Edward	ELFeinberg	feinbel@verizon.net
Fenske, George	Argonne National Laboratory	gfenske@anl.gov
Fiegenschuh, Karl	Ford Motor Co.	kfiegens@ford.com
Filiou, Constantina	European Commission	constantina.filiou@jrc.nl
Fischer, Christopher	Pacific Northwest National Laboratory	christopher.fischer@pnl.gov
Flasch, Tom	BP	tjflasch@att.net
Fletcher, James	UNF	jfletcher@unt.edu
Foure, Michel	Atofina Chemicals	michel.foure@atofina.com
Freeman, Scott	DaimlerChrysler Corporation	sjf@daimlerchrysler.com
Frikken, Donald	Becht Engineering Company	frikkend@fidmail.com
Gaboury, Scott	Atofina Chemicals	scott.gaboury@atofina.com
Gabrielov, Alexei	Shell Chemicals	alexei.gabrielov@shell.com
Gadre, Sarang	University of South Carolina	sarang@sc.edu
Garbak, John	Department of Energy	john.garbak@ee.doe.gov
Gardner, Dale	National Renewable Energy Laboratory	dale_gardner@nrel.gov
Garland, Nancy	Department of Energy	nancy.garland@ee.doe.gov
Garrett, Bobi	National Renewable Energy Laboratory	bobi_garrett@nrel.gov
Garzon, Fernando	Los Alamos National Laboratory	garzon@lanl.gov
Gee, Mark	Honeywell Engines, Systems & Services	mark.gee@honeywell.com
Geyer, Bernadette	US Fuel Cell Council	bernie@usfcc.com
Ghirardi, Maria	National Renewable Energy Laboratory	maria_ghirardi@nrel.gov
Ghosh, Shubhro	United Technologies Research Center	ghoshs@utrc.utc.com
Glass, Robert	Lawrence Livermore National Laboratory	glass3@llnl.gov
Goldbach, James	Atofina Chemicals	james.goldbach@atofina.com
Goswami, Yogi	University of Florida	solarjrl@mae.ufl.edu

Name	Organization	Email
Grassilli, Leo	Department of Navy	Grassilli@FuelCells.com
Green, Johney	Oak Ridge National Laboratory	greenjbjr@ornl.gov
Greene, David	Oak Ridge National Laboratory	dlgreene@ornl.gov
Gromis, Adam	California Fuel Cell Partnership	agromis@cafcp.org
Gronich, Sigmund	Department of Energy	sigmund.gronich@ee.doe.gov
Gross, Karl	Sandia National Laboratories	kjgross@sandia.gov
Grot, Stephen	Ion Power, Inc.	staci.mitchell@ion-power.com
Guo, CJ	Air Liquide America	cj.guo@airliquide.com
Gurau, Bogdan	Cabot Superior MicroPowders	bogdan_gurau@cabot-corp.com
Guro, David	Air Products & Chemicals, Inc.	gurode@airproducts.com
Haack, David	Porvair Fuel Cell Technology	dhaack@pamus.com
Haberman, David	IF, LLC	ifdhllc@aol.com
Hachisu, Eiichi	Nedo	hachisueii@nedo.go.jp
Hagans, Patrick	UTC Fuel Cells	Patrick.Hagans@UTCFuelCells.com
Ham, Linda	National Renewable Energy Laboratory	linda_ham@nrel.gov
Hamrock, Steve	3M	sjhamrock@mmm.com
Hansel, James	Air Products & Chemicals, Inc.	hanseljg@airproducts.com
Hardesty, Donald	Sandia National Laboratories	mestead@sandia.gov
Hardis, Jonathan	National Institute of Standards & Technology	jonathan.hardis@nist.gov
Harrison, Jeffrey	InnovaTek	jeff@tekkie.com
Hartvigsen, Joseph	Ceramatec, Inc.	jjh@ceramatec.com
Haug, Andrew	UTC Fuel Cells	andrew.haug@utcfuelcells.com
He, Ting	Honda Research Institute	the@honda-ri.com
Heben, Michael	National Renewable Energy Laboratory	mikeh@nrel.gov
Hedges, Jeff	ChevronTexaco	hedgeja@chevrontexaco.com
Hefley, Bob	Hyradix, Inc	lance.anderson@hyradix.com
Heinzel, John	Naval Surface Warfare Center	HeinzelJM@nswccd.navy.mil
Henderson, David	Department of Energy	david.henderson@hq.doe.gov
Herring, Andy	Colorado School of Mines	aherring@mines.edu
Herring, Steve	INEEL	sth@inel.gov
Hickner, Michael	Sandia National Laboratories	mahickn@sandia.gov
Hicks, Mike	3M	mike-hicks@mmm.com
Hirano, Shinichi	Ford Motor Company	shirano7@ford.com
Ho, Donna	Department of Energy	donna.ho@ee.doe.gov
Ho, Winston	The Ohio State University	ho@che.eng.ohio-state.edu
Hobbs, Ray	Arizona Public Service	raymond.hobbs@aps.com
Hock, Susan	National Renewable Energy Laboratory	susan_hock@nrel.gov
Hoffman, Donald	Naval Surface Warfare Center	hoffmandj@nswccd.navy.mil
Hsu, Michael	ZTEK Co	mhsu@ztekcorporation.com
Ibrahim, Samir	Teledyne Energy Systems Inc	samir.ibrahim@teledynees.com
IEIRI, Yuji	Engineering Advancement Association of Japan	tdd332@enaa.or.jp
Iguchi, Masaru	Honda R&D Co., Ltd.	masaru_iguchi@n.t.rd.honda.co.jp
Ikematsu, Masaki	Nippon Oil Corporation	masaki.ikematsu@eneos.co.jp
Ingersoll, David	Sandia National Laboratories	dingers@sandia.gov
Inui, Masahiro	IAE	inui@iae.or.jp
Irvin, Jennifer	US Navy	jennifer.irvin@navy.mil
Irving, Patricia	InnovaTek	irving@tekkie.com

Name	Organization	Email
Ishihara, Toshikazu	Sanyo North America Corp.	tishihara@sna.sanyo.com
Ivy, Johanna	National Renewable Energy Laboratory	johanna_Ivy@nrel.gov
Jacobson, David	National Institute of Standards and Technology	david.jacobson@nist.gov
Jalil, Nashat	DaimlerChrysler	nkj@dcx.com
James, Brian	Directed Technologies Inc.	Brian_James@DirectedTechnologies.com
Jensen, Craig	University of Hawaii	jensen@gold.chem.hawaii.edu
Jersey, Gilbert	ExxonMobil Research and Engineering Co	gilbert.r.jersey@exxonmobil.com
Johnson, William	W. L. Gore & Associates	wjohnson@wlgore.com
Jones, Russ	Pacific Northwest National Laboratory	rh.jones@pnl.gov
Jorgensen, Scott	General Motors R & D	scott.w.jorgensen@gm.com
Karlsson, Anette	University of Delaware	karlsson@me.edel.edu
Kartha, Sivan	Tellus Institute	skartha@tellus.org
Kato, Takehiko	Interlink Corporation	katotsr@aol.com
Kauffman, Matt	Department of Energy	matthew.kauffman@ee.doe.gov
Kaufman, Joseph	ConocoPhillips	joseph.w.kaufman@conocophillips.com
Kaya, Maurice	State of Hawaii, DBEDT	mkaya@dbedt.hawaii.gov
Keenan, Gregory	Air Products & Chemicals, Inc.	keenangr@airproducts.com
Kegerreis, James	ExxonMobil Research and Engineering Co	james.e.kegerreis@exxonmobil.com
Keller, Jay	Sandia National Laboratories	dmagost@sandia.gov
Kelly, John	Sandia National Laboratories	jekelly@sandia.gov
Kelly, Michael	Millennium Cell Inc	kelly@millenniumcell.com
Kerr, John	Lawrence Berkeley National Laboratory	jbkerr@lbl.gov
Kervitsky, George	Sentech, Inc.	gkervits@sentech.org
Khaleel, Mohammad	Battelle Memorial Institute	moe.khaleel@pnl.gov
Killmeyer, Rich	NETL	richard.killmeyer@netl.doe.gov
King, David	Pacific Northwest National Laboratory	david.king@pnl.gov
King, Mike	Princeton Research	mike@princetonresearch.com
Kinoshita, Katsuhiko	Penn State University	kxk46@psu.edu
Kinzey, Bruce	Pacific Northwest National Laboratory	Bruce.Kinzey@pnl.gov
Kisilis, Eleanora	United Technologies Research Center	KisiliED@utrc.utc.com
Klebanoff, Lennie	Sandia National Laboratories	lekleba@sandia.gov
Knight, Brian	UTRC	knightba@utrc.utc.com
Ko, Jui	Quantum Technologies	jko@qtww.com
Koch, Steve	Freudenberg NOK General Partnership	syk@fngp.com
Koehler, Joachim	Umicore	joachim.koehler@eu.umicore.com
Kopasz, John	Argonne National Laboratory	Kopasz@cmt.anl.gov
Kordesch, Prof. Dr. Karl	Apollo Energy Systems, Inc.	aholmes@electricauto.com
Kountz, Dennis	DuPont Fuel Cells	denniskountz@att.net
Krause, Curtis	ChevronTexaco	CKrause@ChevronTexaco.com
Krause, Theodore	Argonne National Laboratory	krause@cmt.anl.gov
Krongold, Marty	Air Liquide America	marty.krongold@airliquide.com
Kroposki, Ben	National Renewable Energy Laboratory	ben_kroposki@nrel.gov
Kumar, Ravi	GE Global Research	kumarr@research.ge.com
Kumar, Romesh	Argonne National Laboratory	kumar@cmt.anl.gov
Kung, Harriet	Department of Energy	harriet.kung@science.doe.gov
Lara-Curzio, Edgar	Oak Ridge National Laboratory	laracurzioe@ornl.gov
Larche, Brooke	USARDECOM/TARDEC/NAC	larcheb@tacom.army.mil

Name	Organization	Email
Lasher, Stephen	TIAX LLC	lasher.stephen@tiaxllc.com
Lau, Francis	Gas Technology Institute	francis.lau@gastechnology.org
LaVen, Arne	IdaTech	nwalleen@idatech.com
Lee, James	Oak Ridge National Laboratory	Leejw@ornl.gov
Lee, Sheldon H.D.	Argonne National Laboratory	lee@cmt.anl.gov
Lee, Tom	CSMi	tlee@csmi.com
Lewandowski, Allan	National Renewable Energy Laboratory	allan_lewandowski@nrel.gov
Li, Wen	Toyota Technical Center, U.S.A., Inc.	wli@ttc-usa.com
Li, Yi-Qun	Intematix Corporation	yqli@intematix.com
Lightner, Valri	Department of Energy	valri.lightner@ee.doe.gov
Linkous, Clovis	Florida Solar Energy Center	calink@fsec.ucf.edu
Lipiecki, Frank	Rohm and Haas Co.	flipiecki@rohmhaas.com
Lipp, Ludwig	Fuel Cell Energy	llipp@fce.com
Liss, William	Gas Technology Institute	william.liss@gastechnology.org
Liu, Chung		chung.liu@honeywell
Liu, Helen	Catalytica Energy Systems, Inc.	hliu@catalyticaenergy.com
Liu, Hongtan	University of Miami	hliu@miami.edu
Liu, Jie	Duke University	j.liu@duke.edu
Liu, Yafeng	Catalytica Energy Systems, Inc.	yliu@catalyticaenergy.com
Lott, Melissa	QSS Group, Inc.	mlott@qssgroupinc.com
Low, John	UOP LLC.	John.Low@uop.com
Luo, Weifang Luo	Sandia National Laboratories	wluo@sandia.gov
Lutz, Andy	Sandia National Laboratories	aelutz@sandia.gov
Luzader, Rex	Millennium Cell Inc	dwyer@millenniumcell.com
Lvov, Serguei	Penn State University	lvov@psu.edu
Lynch, David	Startech Environmental	dlynch@startech.net
MacQueen, Brent	SRI International	brent.macqueen@sri.com
Madden, Thomas	United Technologies Research Center	maddenth@utrc.utc.com
Maeland, Arnulf	Institute for Energy Technology	arnulf@juno.com
Magee, Steve	Honeywell	steven.magee@honeywell.com
Majzoub, Eric	Sandia National Laboratories	ehmajzo@sandia.gov
Maloney, Thomas	Proton Energy Systems	tmaloney@protonenergy.com
Maness, Marcina	Sandia National Laboratories	mmaness@sandia.gov
Maness, Pin-Ching	National Renewable Energy Laboratory	pinching_maness@nrel.gov
Manheim, Amy	Department of Energy	amy.manheim@ee.doe.gov
Mann, Margaret	National Renewable Energy Laboratory	margaret_mann@nrel.gov
Manning, Michael	Praxair	mike_manning@praxair.com
Marianowski, Len	Gas Technology Institute	len.marianowski@gastechnology.org
Markel, Tony	National Renewable Energy Laboratory	Tony_Markel@nrel.gov
Maroni, Victor	Argonne National Laboratory	maroni@cmt.anl.gov
Martin, Michael	EMTEC	dely@emtec.org
Martin, Peter	Lawrence Livermore National Laboratory	martin89@llnl.gov
Martin Bermejo, Joaquin	European Commission	joaqui.martin@cec.eu.int
Masten, David	General Motors	david.masten@gm.com
Maxey, Curt	Oak Ridge National Laboratory	maxeylc@ornl.gov
Mays, Jimmy	University of Tennessee	jimmymays@utk.edu
McCarthy, David	Air Products & Chemicals, Inc.	mccartdj@airproducts.com

Name	Organization	Email
McClaine, Andrew	Safe Hydrogen, LLC	awmcclaine@safehydrogen.com
McDonald, Joseph	Environmental Protection Agency	mcdonald.joseph@epa.gov
McFarland, Eric	University of California	
McGrath, Jim	VA Tech	jmcgrath@vt.edu
McIntyre, Timothy	Oak Ridge National Laboratory	mcintyretj@ornl.gov
McKay, Chris	Northern Power Systems	cmckay@northernpower.com
McKenzie, Stewart	Columbian Chemicals Company	smckenzie@phelpsdodge.com
McQueen, Shawna	Energetics Inc.	smcqueen@energetics.com
Melis, Tasios	UC Berkeley	melis@nature.berkeley.edu
Meyers, Jeremy	UTC Fuel Cells	jeremy.meyers@utcfuelcells.com
Miller, Eric	University of Hawaii, HNEI	ericm@hawaii.edu
Miller, Michael	Southwest Research Institute	michael.miller@swri.org
Miller, Robert	Air Products & Chemicals, Inc.	millerrn@airproducts.com
Milliken, JoAnn	Department of Energy	JoAnn.Milliken@ee.doe.gov
Millman, William	DOE	william.millman@science.doe.gov
Mills, Kevin	USARDECOM/TARDEC/NAC	millsk@tacom.army.mil
Mintz, Marianne	Argonne National Laboratory	mmmintz@msn.com
Mitchell, William	Nuvera Fuel Cells Inc.	mitchell.w@nuvera.com
Mitlitsky, Fred	Fred Mitlitsky Technical Consulting	mitlitsky@yahoo.com
Moen, Chris	Sandia National Laboratories	cmoen@sandia.gov
Moore, Graham	ChevronTexaco Technolgy Ventures	Graham.Moore@Chevrontexaco.com
Moore, Richard	Department of Energy	
More, Karren	Oak Ridge National Laboratory	morekl1@ornl.gov
Morimoto, Yu	Toyota Motor Corp. Central R&D Labs	morimoto@mosk.tytlabs.co.jp
Morrison, Blake	Kinectrics	blake.morrison@kinectrics.com
Motyka, Theodore	Savannah River National Laboratory	ted.motyka@srs.gov
Muhs, Jeff	Oak Ridge National Laboratory	muhsjd@ornl.gov
Mullapudi, Sailesh	Johnson Matthey Fuel Cells	
Muradov, Nazim	Florida Solar Energy Center	muradov@fsec.ucf.edu
Murata, Kenji	The Institute of Applied Energy	murata@iae.or.jp
Murphy, KP	QSS Group, Inc.	kpmurphy@qssgroupinc.com
Murphy, Tim	INEEL	murphytc@inel.gov
Myers, Deborah	Argonne National Laboratory	MYERS@CMT.ANL.GOV
Nair, Bindu	Foster Miller	bnair@foster-miller.com
Nakamura, Kenji	Toyota Technical Center USA, Inc.	nakamura@ttc-usa.com
Namazian, Mehdi	Altex Technologies	mehdi@altextech.com
Narayanan, S.R.	Jet Propulsion Laboratory	s.r.narayanan@jpl.nasa.gov
Nelson, Bruce	Zoot Properties, LLC	bnelson@zootweb.com
Nenoff, Tina	Sandia National Laboratories	tmnenof@sandia.gov
Newell, Kenneth	Quantum Technologies	knewell@qtww.com
Nicole, Jacques	Catalytica Energy Systems, Inc.	jnicole@catalyticaenergy.com
Niehues, Michael	DaimlerChrysler	michael.niehues@daimlerchrysler.com
Nomura, Tadashi	Honda Research Institute USA	tnomura@honda-ri.com
Ogden, Joan	UC Davis	jmogden@udavis.edu
Ohi, Jim	National Renewable Energy Laboratory	jim_ohi@nrel.gov
Olson, Gregory	HRL Laboratories, LLC	glolson@HRL.com
Omstead, Thomas	Intematix Corporation	tomstead@comcast.net
Ortega, Jeff	Millennium Cell Inc	jortega@millenniumcell.com

Name	Organization	Email
Page, Richard	Southwest Research Institute	richard.page@swri.org
Papasavva, Stella	General Motors	stella.papasavva@gm.com
Parks, George	ConocoPhillips	george.d.parks@conocophillips.com
Paster, Mark	Department of Energy	mark.paster@ee.doe.gov
Paur, Richard	US Army Research Office	Richard.Paur@US.Army.mil
Pawel, Steve	Oak Ridge National Laboratory	pawelsj@ornl.gov
Payne, Cameron	HydrogenCorp.	campayne@swbell.net
Payzant, Andrew	ORNL/UT-Battelle	payzanta@ornl.gov
Pederson, Larry	Pacific Northwest National Laboratory	larry.pederson@pnl.gov
Peng, Ying	InnovaTek	ying@tekkie.com
Perfect, Scott	Los Alamos National Laboratory	perfect1@llnl.gov
Perkins, Chris	University of Colorado	Christopher.perkins@colorado.edu
Perret, Robert	UNLV Research Foundation	ntsllc@rperret.com
Perrin, Jerome	Air Liquide America	jerome-m.perrin@airliquide.com
Peters, Andrew	University of North Dakota	petersaj@gra.midco.net
Peters, Robert	UAB	tbrazzle@uab.edu
Petrovic, John	Los Alamos National Laboratory	john.petrovic@ee.doe.gov
Pez, Guido	Air Products & Chemicals, Inc.	pezgp@airproducts.com
Phillippi, Harold	ExxonMobil Research and Engineering Co	harold.l.phillippi@exxonmobile.com
Piccione, Patrick	Atofina Chemicals	patrick.piccione@atofina.com
Pierre, Joseph	Siemens Westing House	josepth_pierre@siemens.com
Pile, Donald L.	Sandia National Laboratories	DLPile@sandia.gov
Pitts, John	National Renewable Energy Laboratory	roland_pitts@nrel.gov
Pivovar, Bryan	Los Alamos National Laboratory	pivovar@lanl.gov
Pless, Jason	Sandia National Laboratories	jdpless@sandia.gov
Podolski, Walt	Argonne National Laboratory	podolski@cmt.anl.gov
Pope, James	SMC/RNP	JIM.POPE@RC.PATRICK.AF.MIL
Popov, Branko	University of South Carolina	popov@engr.sc.edu
Porter, Stephen	Proton Energy Systems	sporter@protonenergy.com
Privette, Robert	Umicore	rmpagain@yahoo.com
Pua, Lee	Heatric	lee.pua@heatric.com
Quah, C.G. Michael	NextEnergy	michaelq@nextenergy.org
Rachlin, Aaron	Praxair	Aaron_Rachlin@Praxair.com
Raghupathi, Raghu	Concurrent Technologies Corp	raghupathi@adelphia.net
Raiford, Kim	DuPont Fuel Cells	kimberly.g.raiford@usa.dupont.com
Raissi, Ali	Florida Solar Energy Center	ali@fsec.ucf.edu
Raman, Venki	Air Products & Chemicals, Inc.	ramansv@apci.com
Rannels, Kristen	Sentech, Inc.	mchornet@interlinx.qc.ca
Read, Carole	Department of Energy	carole.read@ee.doe.gov
Regan, Robert	DTE Energy	reganr@dteenergy.com
Reinkingh, Jessica	Johnson Matthey Fuel Cells	reinky@jhusa.com
Renock, Devon	T/J Technologies	drenock@tjtechnologies.com
Replogle, William	Sandia National Laboratories	wcreplo@sandia.gov
Richardson, James	University of Houston	jtr@uh.edu
Riddell, Jeff	Luxfer Gas Cylinder	jeff.riddell@luxfer.net
Rieke, Peter	Pacific Northwest National Laboratory	peter.rieke@pnl.gov
Rijsdijk, Vincent	Royal Netherlands Embassy	vincent@nost.org
Ringer, Matthew	National Renewable Energy Laboratory	matthew_ringer@nrel.gov

Name	Organization	Email
Ritter, Ann	GE Global Research	ritter@research.ge.com
Robbins, John	ExxonMobil Research and Engineering Co	john.l.robbins@exxonmobil.com
Robertson, Arthur	Engelhard Corporation	Bruce.Robertson@engelhard.com
Robinett III, Rush	Sandia National Laboratories	nenicol@sandia.gov
Rocheleau, Richard	Hawaii Natural Energy Institute	rochelea@hawaii.edu
Roelofs, Mark	DuPont Fuel Cells	mark.g.roelfs@usa.dupont.com
Rogers, Jerry	General Motors R & D	jerry.rogers@gm.com
Romney, Greg	Cabot Superior MicroPowders	greg_romney@cabot-corp.com
Rose, Robert	Breakthrough Technologies Institute	brose@fuelcells.org
Ross, Philip	Lawrence Berkeley National Laboratory	pnross@lbl.gov
Roy, Surajit	QuestAir Technologies Inc.	roy@questairinc.com
Rubinstein, Leon	Shell Hydrogen	rona.bush@shell.com
Ruiz, Antonio	Department of Energy	antonio.ruiz@ee.doe.gov
Ryan, Charles	NCMS	chuckr@ncms.org
Sachtler, Adriaan	UOP LLC.	Adriaan.Sachtler@UOP.com
Sandelli, Gregory	Hydrogen Source, LLC	greg.sandelli@hydrogensource.com
Sandrock, Gary	SunaTech, Inc.	sandrock@warwick.net
Sankar, S. G.	Advanced Materials Corporation	sankar@advanced-material.com
Sarno, David	University of Pennsylvania	dsarno@sas.upenn.edu
Sasaki, Kotaro	Brookhaven National Laboratory	ksasaki@bnl.gov
Satyapal, Sunita	Department of Energy	sunita.satyapal@ee.doe.gov
Schade, Chris	Hoeganaes Corp.	cschade@hoegcorp.com
Schell, Andreas	DaimlerChrysler	as675@dcx.com
Schlasner, Steven	ConocoPhillios	steven.m.schlasner@conocophillips.com
Schmetz, Edward	Department of Energy	Edward.Schmetz@hq.doe.gov
Schneider, Jesse	DaimlerChrysler	Jesse.Schneider@DaimlerChrysler.com
Schneider, Mark	Delaware County Electric Cooperative, Inc.	mark.schneider@dce.coop
Schull, Terence	Naval Research Laboraotory	enb@cbmse.nrl.navy.mil
Schultz, Ken	General Atomics	ken.schultz@gat.com
Schwartz, Joseph	Praxair	joseph_schwartz@praxair.com
Schwartz, Viviane	Oak Ridge National Laboratory	schwartzv@ornl.gov
Seaba, James	ConocoPhillips	jim.p.seaba@conocophillips.com
Seawell, Nicole	CSMi	nseawell@csmi.com
Seibert, Michael	National Renewable Energy Laboratory	mike_seibert@nrel.gov
Shaw, Montgomery	University of Connecticut	Shawmt@mail.ims.uconn.edu
Shen, Jian Ping	Cabot Superior MicroPowders	jian-ping_shen@cabot-corp.com
Shen, John	Department of Energy	john.shen@hq.doe.gov
Shinkle, Robert	EMTEC	dely@emtec.org
Shore, Lawrence	Engelhard Corporation	larry.shore@engelhard.com
Short, Walter	National Renewable Energy Laboratory	Walter_Short@nrel.gov
Simonson, John M.	Oak Ridge National Laboratory	simonsonjm@ornl.gov
Sims, Ron	National Renewable Energy Laboratory	ronisims@comcast.net
Sink, Carl	Department of Energy	carl.sink@nuclear.energy.gov
Skolnik, Edward	Energetics Inc.	eskolnik@energetics.com
Slattery, Darlene	Florida Solar Energy Center	dkslatt@fsec.ucf.edu
Smith, Barton	Oak Ridge National Laboratory	smithdb@ornl.gov
Smith, Brad	Shell Hydrogen	rona.bush@shell.com
Smith, William	Infinity Fuel Cell and Hydrogen, LLC	wsmith@infinityfuel.com

Name	Organization	Email
Spangler, Lee	Montana State University	jhendricks@montana.edu
Sridharan, Srikesh	Sentech, Inc.	ssridharan@sentech.org
Staudt, Rhonda	Plug Power Inc.	rhonda_staudt@plugpower.com
Stefanakos, Elias	University of South Florida	stefanak@eng.usf.edu
Stephenson, Rhoads	MVFRI	rodys@earthlink.net
Stevens, James	ChevronTexaco	James.Stevens@chevrontexaco.com
Stevens, Walter	Department of Energy	walter.stevens@science.doe.gov
Stone, Harry	Battelle Memorial Institute	stoneh@battelle.org
Stroh, Ken	Los Alamos National Laboratory	stroh@lanl.gov
Sullivan, Andrew	UAB	asullivan@uab.edu
Surdoval, Wayne	Department of Energy	wayne.surdoval@netl.doe.gov
Sutton, Robert	Argonne National Laboratory	sutton@cmt.anl.gov
Sverdrup, George	National Renewable Energy Laboratory	george_sverdrup@nrel.gov
Svet, Frank	EMTEC	delyemtec.org
Swain, Michael	University of Miami	mswain@miami.edu
Swartz, Scott	NexTech Materials, Ltd.	swartz@nextechmaterials.com
Swider-Lyons, Karen	Naval Research Laboratory	karen.lyons@nrl.navy.mil
Tamhankar, Satish	The BOC Group	satish.tamhankar@boc.com
Tasaki, Ken	MC Research & Innovation Center	ken_tasaki@m-chem.com
Taylor, Amy	Department of Energy	amy.taylor@nuclear.energy.gov
TeGrotenhuis, Ward	Pacific Northwest National Laboratory	ward.tegrotenhuis@pnl.gov
Teliska, Maggie	Naval Research Lab	mteliska@gwu.edu
Tessier, Pascal	Air Liquide America	pascal.tessier@airliquide.com
Tewari, Surendra	Cleveland State University	S.Tewari@csuohio.edu
Theiss, Tim	Oak Ridge National Laboratory	theisstj@ornl.gov
Thomas, George	Sandia National Laboratories	george.thomas@sbcglobal.net
Thomas, Larry	Air Products & Chemicals, Inc.	thomaslb@airproducts.com
Thompson, Levi	University of Michigan	ltt@umich.edu
Thompson, Michael R.	Pacific Northwest National Laboratory	michael.thompson@pnl.gov
Thorn, David	Los Alamos National Laboratory	dthorn@lanl.gov
Timbol, Greg	Materials Design	gtimbol@materialsdesign.com
Toops, Todd	Oak Ridge National Laboratory	toopstj@ornl.gov
Tortorelli, Peter	Oak Ridge National Laboratory	tortorellipf@ornl.gov
Tosca, Michael	UTC Fuel Cells	mike.tosca@utcfuelcells
Townsend, Susan	GE Global Research	townsends@research.ge.com
Toy, Lora	Research Triangle Institute	ltoy@rti.org
Tran, Doanh	DaimlerChrysler	dtt4@dcx.com
Triebold, Wayne	Toray	WTriebold@TorayCompAm.com
Truett, Tykey	Oak Ridge National Laboratory	TruettLF@ornl.gov
Truly, Richard	National Renewable Energy Laboratory	karen_stiveson@nrel.gov
Tullmann, Sigmar	Safe Hydrogen, LLC	shtullmann@safehydrogen.com
Tumas, William	Los Alamos National Laboratory	tumas@lanl.gov
Turner, John	National Renewable Energy Laboratory	john_turner@nrel.gov
Turner, Tim	NC State Univ/Solar Center	tim_turner@ncsu.edu
Udovic, Terrence	National Institute of Standards & Technology	udovic@nist.gov
Uehara, Jun	Nippon Oil USA	j.uehara@nocusa.com
Uihlein, James	BP	uihlejp@bp.com
Ukena, Amy	Air Products & Chemicals, Inc.	ukenaam@airproducts.com

Name	Organization	Email
Uribe, Francisco	Los Alamos National Laboratory	uribe@lanl.gov
Vajo, John	HRL Laboratories, LLC	jjvajo@HRL.com
Van Honacker, Hugues	European Commission	hugues.van-honacker@cec.eu.int
Vanderborgh, Nicholas	Argonne National Laboratory	n.vanderborgh@comcast.net
VanOoteqhem, Suellen		svanoo@intergate.com
Velev, Omourtag	AeroVironment, Inc	velev@aerovironment.com
Venkataraman, Venkat	NETL	Venkat.Venkataraman@netl.doe.gov
Virden, Jud	Pacific NW National Laboratory	jud.virden@pnl.gov
Voecks, Gerald	Self	gvoecks@aol.com
Vogel, John	Plug Power Inc.	donna_ranalli@plugpower.com
Wadell, Aaron	Global Photonic Energy Corp.	awadell@globalphotonic.com
Wagner, Fred	Energetics Inc.	fwagner@energetics.com
Wagner, Frederick T.	General Motors Fuel Cell Activities	frederick.t.wagner@gm.com
Wahal, Sanjay	RTI	swahal@rti.org
Wait, Mark	Air Products & Chemicals, Inc.	waitmf@airproducts.com
Waki, Keiko	Tokyo Institute of Technology	wen@es.titech.ac.jp
Wang, Chunsheng	Tennessee Technological University	cswang@tntech.edu
Wang, Cong-Huo	Sarnoff Corporation	cwang@sarnoff.com
Wang, Paul	Concurrent Technologies Corp	wangp@ctcgsc.org
Wang, Yong	PNNL	yongwang@pnl.gov
Wang, Yu	Farasis Energy, Inc.	ywang@farasis.com
Wang Ph.D., James	Sandia National Laboratories	jcwang@sandia.gov
Wariishi, Yoshinori	Honda R&D Co., Ltd.	yoshinori_wariishi@n.t.rd.honda.co.jp
Weber, Adam	Lawrence Berkeley National Laboratory	aweber@uclink.berkeley.edu
Weeks, Brian	Gas Technology Institute	brian.weeks@gastechnology.org
Wegrzyn, James	Brookhaven National Laboratory	jimtheweg@bnl.gov
Weiner, Steven	Pacific Northwest National Laboratory	sc.weiner@pnl.gov
Weisberg, Andrew	Lawrence Livermore National Laboratory	weisberg1@llnl.gov
Weiss, Robert	University of Connecticut	rweiss@mail.ims.uconn.edu
Welk, Margaret	Sandia National Laboratories	mewelk@sandia.gov
Wendt, Kraig	INEEL	
Wheeler, Doug	DJW Technology	douglas.wheeler@utcfuelcells.com
White, Ralph	University of SC	white@engr.sc.edu
Whyatt, Greg	Pacific Northwest National Laboratory	greg.whyatt@pnl.gov
Williams, Mark	NETL	mark.williams@netl.doe.gov
Wilshire, Scott	Plug Power Inc.	scott_wilshire@plugpower.com
Wimmer, Robert	Toyota Motor North America	robert_wimmer@tma.toyota.com
Wipke, Keith	National Renewable Energy Laboratory	keith_wipke@nrel.gov
Wixom, Mike	T/J Technologies	mwixom@tjtechnologies.com
Wolverton, Christopher	Ford Motor Co.	cwolvert@ford.com
Woods, Byrad	Utah State University	byard.wood@usu.edu
Woods, Richard	Intelligent Energy	root.woods@intelligent-energy.com
Woudenberg, Rich	University of Massachusetts, Amherst	woody@mail.pse.umass.edu
Wu, Ying	Millennium Cell Inc	wu@millenniumcell.com
Wysocki, Robert "Bob"	Shell Hydrogen	rona.bush@shell.com
Wysor, Tad	Environmental Protection Agency	wysor.tad@epa.gov
Xu, John	Rutgers University	johnxu@rci.rutgers.edu
Yamamoto, Yasuhiro	Toyota Motor Corp. Mfg NA	yyamamot@tmmna.com

Name	Organization	Email
Yasuda, Masashi	Sanyo Electric	m_yasuda@rd.sanyo.co.jp
Yee, David	Catalytica Energy Systems, Inc.	DYee@CatalyticaEnergy.com
Yoshida, Phyllis	Department of Energy	Phyllis.Yoshida@ee.doe.gov
Yushin, Gleb	Drexel University	jf63@drexel.edu
Zalesky, Rick	ChevronTexaco Technolgy Ventures	rickzalesky@chevrontexaco.com
Zalosh, Robert	WPI	bzalosh@wpi.edu
Zamansky, Vladimir	GE Global Research	zamansky@research.ge.com
Zawodzinsski, Thomas	Case Western Reserve University	rrw3@case.edu
Zelenay, Piotr	Los Alamos National Laboratory	zelenay@lanl.gov
Zidan, Ragaiy	Savannah River National Laboratory	ragaiy.zidan@srs.gov
Zimmer, Stephen	DaimlerChrysler Corporation	sez@daimlerchrysler.com
Zoia, Giorgio	BP America Inc.	zoiagl@bp.com
Ferrada, Juan	Oak Ridge National Laboratory	ferradajj@ornl.gov

APPENDIX B: HYDROGEN PROGRAM FY 2004 MERIT REVIEW AND PEER REVIEWER AND PARTICIPANT FEEDBACK

These notes summarize the comments received at the various reviewer feedback sessions, as well as those provided on questionnaire forms filled out by many participants. The comments received were generally focused on the basic meeting process; however, where relevant, notes specific to a particular session will be designated and called out.

Overall

- Kickoff talks for the various technology areas could be used to provide more extensive details to reviewers and attendees.
- The quality of the papers has improved significantly, but they are technically less interesting. The inclusion of obligatory slides may be the cause.
- With regard to the PIs having to submit their presentations one month in advance, a PI mentioned that it helped to improve his communication of the key points, as opposed to focusing on experiments right up to the presentation time.
- Some of the projects had just started, and the new presentations seemed forced. They did not have enough material to talk about. Presenters seemed to be trying to fill in time. Problems with the projects were unknown, and technical accomplishments were absent.
- Reconsider having (not having) projects that have just started going through the review process. It is not appropriate to rate these projects on accomplishments and progress when they have started only weeks ago. These projects could either be presented as info only or as posters.
- Standardize the name of this meeting -- it was sometimes called "Program Review" or "Annual Merit Review" or "Peer Review." Pick one and stick with it.

Presentation Content

- Each presentation should present the concept for the work early in the presentation.
- Presenters should provide a brief background and perspective to put their program within the larger framework of the overall DOE program.
- On a percentage basis, the content was not all that great. It would have been helpful if “future plans” were discussed early in the presentation.
- In the future, would suggest having each PI not only present targets and objectives, but also their specific performance to those targets and interim goals. Unfortunately in almost every presentation targets and goals were only mentioned at the beginning and then no discussion on how the research was making progress on achieving them. Each PI should be able to self-evaluate their projects towards targets and be willing to share the evaluation.
- Some presenters did not explain what has been and what will be carried out -- what was being done and why was not clear. Details about the data point was not provided. For example, if a data point was 500 hrs…and 400 hrs was achieved why was the test stopped…. explain the reasons for that.
- PI’s seem to focus on the things they have done and not the accomplishments. With the short time allotted presentations need to be better focused.

- Presentations need to tie accomplishments to funding. It is difficult to assess a project and its accomplishments when there is nothing to indicate at what point in the year funding may have been received. It is very important to include the phases of the projects and the time-phased availability of funding.
- Large variation in the quality of presentations. Some were excellent presenters, others were not. Is it possible for TDMs to choose who will present?

Obligatory Slides

- Hard structure/format on required slides was a good addition this year. One reviewer recommended that the hard structure be dedicated to one or two slides. Assuming that one required slide is used to present the information that slide could be divided in 3 and use 1/3 for budget, 1/3 for Safety, and 1/3 for other content.
- There was general consensus that the number of obligatory slides be reduced so that the PIs can focus on more important details.
- "Collaboration" could be more consistent - some just make a list - need to show benefit/goal of collaboration presented.
- People seem to waste time reading all info on budget straight from the slides. Provide slide for info but they should only address the slide to add info. We know how to read.
- There was a lot of overhead, non-technical information in the slides and it was distractive. The reviewers would have preferred technical data rather than so much boiler plate information. Boiler plate information (e.g. safety) took a big chunk of time from the technical information in the presentation.
- One solution to it might be to include this information in the last few slides in the oral presentation (or as back-up slides) or just in the hard copies of the presentation.
- The reviewers took too much time discussing the required safety slide.
- Safety slides were not that useful - there should be another way to address this important topic.
- Safety pages ended up being "pro forma" not really value added or differentiating. Perhaps it would be better for DOE program managers to make this part of their site visits/progress reviews and capture/share safety management best practices. Could "score" research teams on safety and have them report that score at annual review to keep as a clear priority!
- It was pointed out that the benefit of their inclusion, which spanned the spectrum of safety concerns, but also that some of the PIs glossed over the material
- Concern about safety incidents, among the DOE funded projects is a serious matter for the Safety TDM and Safety Panel. Presentation content in the area of safety should not be eliminated.

Oral Presentations

- Readability:
  - A lot of information was compressed in the presentation slides. It was difficult to read even from the front.

- Suggest a PI "format" guidance instruction such as: "Be able to be read by audience" (font size), no busy diagrams (these can be seen in report).
- Provide guidelines to presenters regarding font size. Too many slides were too small to read from the middle of the room. Enforce the font size requirement.

- It would be better if each speaker had a clip-on mic. That way the speaker is not restricted to a specific location. With the podium mics, as speakers looked toward the screen, their voice would fade.

Poster Presentations

- Poster session was much better in terms of space compared to last year's poster session.
- Poster sessions allowed for in-depth discussion/dialogue, very valuable.
- The posters were effective in providing access to some of the work and were located very effectively for people to see them, especially during breaks.
- Having the poster presentations at separate, scheduled sessions, rather than all available simultaneously, was good.
- Provide chairs for the poster session presenters - 3.5 hours is a long time to stand!
- The information in the posters were cramped -- too much information on the posters.
- Don't like posters and talks at same time. Poster schedule as presented was confusing.

Timing

- Need to consider if it is preferable to leave early if the session ended early, or to stay on schedule by making each presentation start at the designated time.
- Some of the speakers were not sticking to their allotted times and this was an issue for the reviewers. It was difficult to attend more than one session. By the time they go to the other session from one session, they either would have to wait for the next presentation to begin or come in somewhere in the middle of the presentation.
- The time allocated for each presentation should be based on the project funding level.
- Presentations were a bit frustrating because presenters didn't have time to go into important details. However, there really isn't time to be able to be able to go into greater depth for either the reviewers or the presenters.
- Do not allow a 30-page presentation for a 20 minute time slot. It is very ineffective to flash a slide of data for 30 seconds and talk so fast that the audience had no time to absorb information.
- Allocate twenty minutes for presentation and 5-10 minutes questions.
- The timing clock worked well.
- Just like last year (Berkeley meeting), the timer machine should have audible, beeping mechanisms to get the speaker's attention.

Logistics

- With regards to meeting logistics, with the number of reviewers using laptops to conduct reviews in real time there is a need for access to electricity supply, powerstrips, etc.

Ultimately this is a hotel selection issue as not all hotels are sufficiently equipped to provide such services. The Philadelphia Marriott did not.

- There is strong consensus that a hotel that offers amenities like a Kinkos and a Starbucks Coffee is a significant plus for the meeting.
- It is preferable to have the meals in the hotel because that would ensure that everyone goes out to lunch and gets back in time. This also allows people to sit down and talk to each other.
- In the hard copy, there should be two slides in one page rather than four in one page.
- Classroom style seating arrangement is preferred for the presentation area.
- It would be nice to get the receipts when you check in. It was emailed to the people who had registered, but a hard copy of the receipt is sometimes preferred.
- It was difficult to understand the program (agenda in packet). The copies supplied were practically unreadable - too tiny a font. Please make bigger! It was very hard to read!!

Peer Review Process

- Need better coordination of review assignments and earlier publication of review assignments. Additional papers were assigned without warning.
- Also would have been nice to know that reviewers would be required to purchase a hard copy of the presentations if they didn't want a bunch of loose papers.
- It was pointed out that there is insufficient time to really evaluate the projects. Reviewers stated that they need more one-on-one opportunity to meet with the presenters. The Tech Teams review projects over a much longer period of time and one of the Tech Team members questioned whether more time is needed to allow for one-on-one time, or if more people should be invited to the Tech Team reviews.
- Many reviewers liked the fact that the presentations were posted to the SENTECH website during the week before the review. Preference would be to have them posted a week before if possible. Consider providing more information for reviewers on websites. One person reported problems downloading from the site.
- Require a 2-4 page project abstract and make that available before the meeting for the reviewers.
- Reviewing posters during the oral sessions presented a serious problem for the reviewers and more than a few reviewers missed some of those assignments. Future review meetings should not have concurrent poster and oral review sessions.
- Reviewers need one-on-one time with presenters – logistics for this could be a problem, however, a session for just reviewers and presenters should be considered.
- The opportunity for more reviewer interactions with poster presenters was positive.
- In the past, the reviewers sat in front and asked questions. This time, in some sessions, the reviewers were dispersed throughout the audience and did not ask questions. This was very informal and more like a symposium than a Program Review. The formality of a Review should be retained. The reviewers should be more pro-active. The question period was not used by the reviewers to gather information. In some sessions, virtually no questions were asked and no sense of a formal review was given. More active question time, prompted by the session chairs if necessary, would be useful.
- Reviewers preferred that presentations be available to them in advance.

Next Year Recommendations

- How will the new "Centers" be incorporated into the review process next year? Will Center directors will present an overview, and the projects will be presented in poster format?
- On the issue of improvements for next year, there was a suggestion that separate gatherings be organized for the different topical areas, i.e. storage reviewers and PIs gather separately for reception or posters to provide an opportunity for one-on-one conversations.
- It was suggested that the next meeting should be kept just as this one. It has worked well until now. It would be better if the fossil and nuclear programs were not mixed with the current session. They should be run in parallel sessions and attendees might have to forego one presentation for another.
- Consider splitting into smaller sub-groups for review. This may lead to more discussion of the goals of the projects. Conversely it is good to get a big picture.

Storage

- Presentations should include a mass breakdown of storage system components – it was felt that this might be premature for some projects – but might be appropriate for other projects.

Technology Validation

- It would be helpful to have technology assessment reports as projects near completion (a lessons learned-type document).
- One project doesn't really fit with the rest of the Tech Val projects, and it is difficult to evaluate with the current review sheets.
- It is difficult for people who are involved in Tech Val projects to identify all the issues and give a really good review.
- Projects that were specifically designed for an application seemed to be more valuable than projects that simply focused on the technology.
- Projects that collected data and information and considered its applicability to future work, in addition to validating technology, were very valuable. These points are important to articulate - PIs should remember to consider the objectives of the HFCIT MYRD&D Plan.

What was the most useful part of the meeting?

- Seeing portfolio of programs in one place, meeting face to face with program managers.
- Getting an overview of the "bandwidth" of activities.
- Exposure to projects - both complementary plus competitive projects. At the same time the allocated time for presentations is not sufficient! A good start to the review process in a systems integrated program.
- Seeing the whole program.

- Progress to date.
- The ability to see all projects grouped by theme is good for better understanding of where the focus of the research community is. Networking with others in the hydrogen & fuel cell community.
- This was my first time and as such - it was enlightening. Now I understand what happens and can manage my way around better.
- Opportunity to get updated information from competition, competitive landscape and potential partners.
- The PI's presentation guidance (document/format/scope) plus peer review plan.
- Gaining fact-based knowledge of technical progress across all areas of PEM fuel cells.
- Presentations included all of the necessary elements for review - budget, goal, approach, collaborations, accomplishments, plus future directions.
- Obtaining an overview of the individual projects and the timelines for each.
- Review of the entire program in one place at one time.
- To get a complete overview of activities in this area.

Miscellaneous comments and suggestions:

- A general comment was made that the DOE team should be very proud of the program and its activities and accomplishments.
- With the multi-year program plan (even though a draft), Peer Review Plan, and direction/guidance for the PIs has resulted in a very well managed program. "We all can read from the same page." Vast improvement over the reviews of years ago. My hat is off to the DOE Hydrogen Team!
- I had low expectations for the event and am leaving with much value - It was a worthwhile expense of time and money. The networking is the most valuable aspect. I actually enjoyed the poster sessions [from a poster session presenter].
- This is a great overview of the program!! It is very challenging as a project review.
- My purpose for being here -- interested in alternative energy and its status. DOE - you are doing an excellent job in managing the effort - very well structured and thought-out. Your effort will no doubt move us to an alternate energy source - stick with it! And let all know about what you are doing - continue to promote public interest. DOE, thank you!
- Provides a good cross section of projects and interest. This is a good group of highly motivated and talented researchers. Kudos also to the DOE team.
- The whole event was well coordinated and professionally conducted - provided an excellent forum for technical interactions with PIs and discussions with DOE staff.

April 16, 2004

DOE Hydrogen Program
2004 Annual Program Review
Project Evaluation Form

Session: Mon ☐ Tue ☐ Wed ☐ Thu ☐ a.m. ☐ p.m. ☐ Tuesday Reception ☐

Reviewer: ______________________

Title of Project: ______________________

Presenter Name: ______________________

Project No. ☐

Using the following criteria, rate the work presented in the context of the program objectives and provide **specific, concise** comments to support your evaluation. -- Write/print **clearly** please. --

1. **Relevance** to overall DOE objectives – the degree to which the project supports the President's Hydrogen Fuel Initiative and the goals and objectives of the HFCIT Multi-Year RD&D plan.

4-Outstanding. The project is critical to realization of the President's Hydrogen Fuel Initiative and fully supports the RD&D plan objectives		Specific Comments:
3-Good. Most aspects of the project align with the President's hydrogen vision the RD&D plan objectives.		
2-Fair. The project partially supports the President's hydrogen vision the RD&D plan objectives.		
1.-Poor. The project provides little support to the President's hydrogen vision the RD&D plan objectives.		

2. **Approach** to performing the R&D – the degree to which technical barriers are addressed, the project is well-designed, technically feasible, and integrated with other research.

4-Outstanding. The project is sharply focused on one or more key technical barriers to development of the hydrogen or fuel cell technologies. Difficult for the approach to be improved significantly.		Specific Comments:
3-Good. The approach is generally well thought out and effective but could be improved in a few areas. Most aspects of the project will contribute to progress in overcoming the barriers.		
2-Fair. Some aspects of the project may lead to progress in overcoming some barriers, but the approach has significant weaknesses.		
1.-Poor. The approach is not responsive to project objectives and unlikely to make significant contributions to overcoming the barriers.		

3. **Technical Accomplishments and Progress** toward overall project and DOE goals – the degree to which research progress is measured against performance indicators and to which the project elicits improved performance (effectiveness, efficiency, cost, and benefits).

4-Outstanding. The project has made excellent progress toward objectives and overcoming one or more key technical barriers. Progress to date suggests that the barrier(s) will be overcome.		Specific Comments:
3-Good. The project has shown significant progress toward against its objectives and to overcoming one or more technical barriers.		
2-Fair. The project has shown modest progress in overcoming barriers, and the rate of progress has been slow.		
1.-Poor. The project has demonstrated little or no progress towards its objectives or any barriers.		

Project No.

4. **Technology Transfer/Collaborations** with industry/universities/other laboratories – the degree to which the project interacts, interfaces, or coordinates with other institutions and projects.

4-Outstanding. Close coordination with other institutions is in place and approporiate; partners are full participants.		Specific Comments:
3-Good. Some coordination exists; full and needed coordination could be accomplished fairly easily.		
2-Fair. A little coordination exists; full and needed coordinatiion would take significant time and effort to initiate.		
1.-Poor. Most all of the work is done at the sponsoring organization with little outside interaction.		

5. **Proposed Future Research** approach and relevance – the degree to which the project has effectively planned its future, considered contingencies, built in optional paths or off ramps, etc.

4-Outstanding. The future work plan clearly builds on past progress and is sharply focused on one or more key technical barriers in a timely manner.		Specific Comments:
3-Good. Future work plans build on past progress and generally address removing or diminishing barriers in a reasonable period.		
2-Fair. The future work plan may lead to improvements, but should be better focused on removing/diminishing key barriers in a reasonable timeframe.		
1.-Poor. Future work plans have little relevance or benefit toward eliminating barriers or advancing the program.		

Strengths

Weaknesses

Recommendations for Additions/Deletions to Project Scope