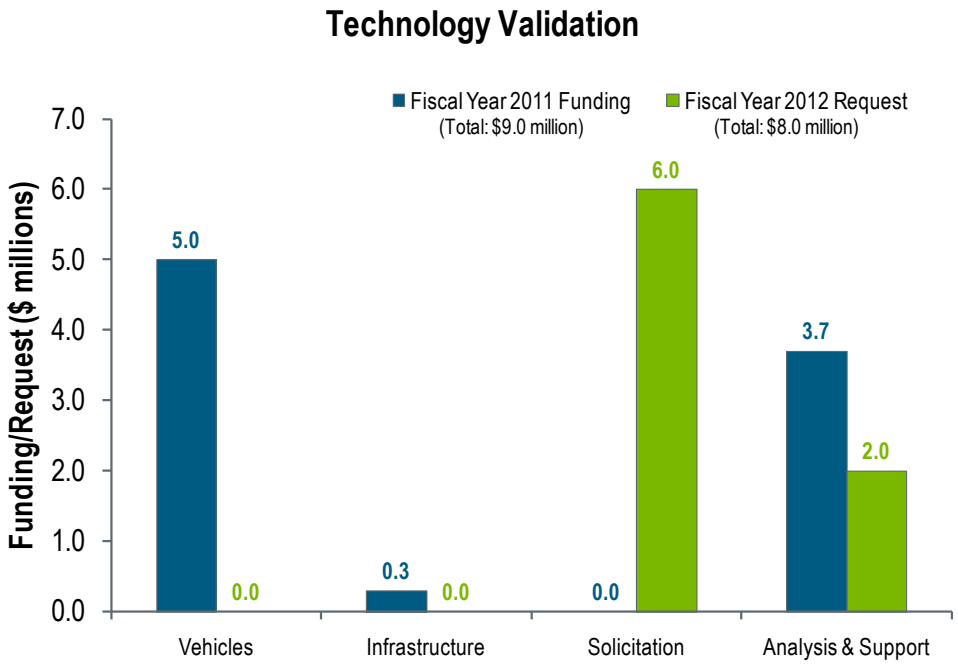
2011 — Technology Validation
Summary of Annual Merit Review of the Technology Validation Sub-Program

Summary of Reviewer Comments on the Technology Validation Sub-Program:

Overall, the reviewers were very complimentary of the projects in the Technology Validation sub-program. They observed that the data collection and analysis of both the Learning Demonstration projects and the transit bus activity were well managed and had a very good approach. One key recommendation was that the Learning Demonstration should continue in some form. They also recommended that future work should focus on effectively disseminating the information from the Learning Demonstration to key automotive decision-makers.

Technology Validation Funding by Technology:

The funding portfolio for Technology Validation will enable the sub-program to continue to collect and analyze data from fuel cells operating in both transportation and stationary applications. Data from fuel cell buses, forklifts, and backup power systems will be evaluated. In addition, analysis of new hydrogen refueling stations in California may be included in the data collection activities. The fiscal year (FY) 2011 appropriation was $9 million. Because the Learning Demonstration ended in FY 2011, there will be a funding opportunity announcement in FY 2012, and these new projects will be the main emphasis of the sub-program. The FY 2012 request of $8 million is subject to Congressional appropriations.



Majority of Reviewer Comments and Recommendations:

The reviewer scores for the six Technology Validation sub-program projects reviewed had a maximum of 3.9, a minimum of 2.4, and an average of 3.5.

A key strength identified by reviewers in all of the Technology Validation projects was that there has been excellent participation from collaborators, which was critically important to the success of the projects. In addition, all of the

projects supported the major goals of the U.S. Department of Energy Hydrogen and Fuel Cells Program and provided valuable information to the participants.

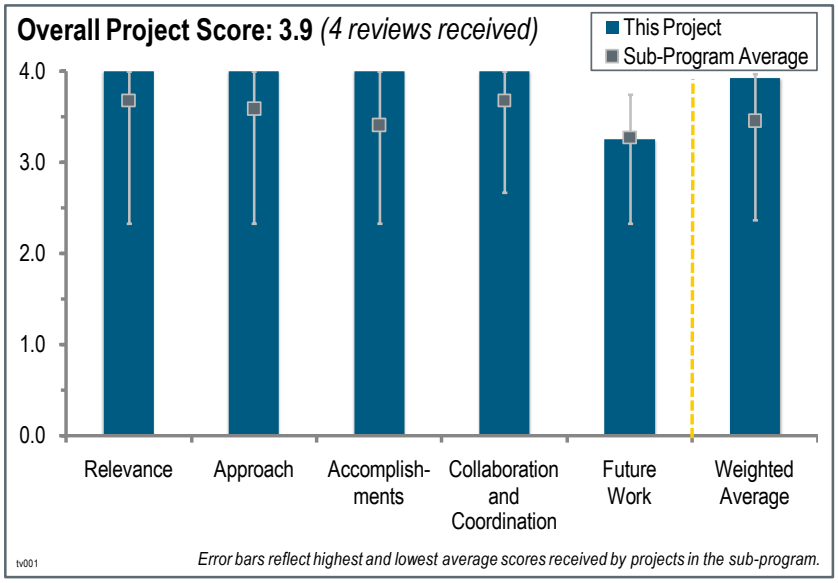
There were only a few minor weaknesses observed by the reviewers, including: an economic analysis is needed for the Integrated Energy Station project; the Hawaii Hydrogen Power Park had too many delays; and the Florida Hydrogen Initiative was difficult to evaluate due to the diversity of its tasks. Key recommendations included: the Integrated Energy Station should use the H2A model or equivalent to determine the cost of heat, electricity, and hydrogen produced; and the data analysis project should include material handling equipment.

Project # TV-001: Controlled Hydrogen Fleet and Infrastructure Analysis

Keith Wipke; National Renewable Energy Laboratory

Brief Summary of Project:

This project will provide facilities and staff for securing and analyzing industry sensitive data. . The results will be used to: (1) evaluate current status and progress toward targets; (2) provide feedback on current technical challenges and research and development opportunities in the U.S. Department of Energy's (DOE) Hydrogen and Fuel Cells Program; (3) provide analytical results to originating companies on their own data (detailed data products); and (4) collaborate with industry partners on new and more detailed analyses. Progress on the project is published or presented to the public and stakeholders (composite data products).



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **4.0** for its relevance to DOE objectives.

- The project provides a valuable service to the Technology Validation sub-program by collecting and documenting vehicle and fueling infrastructure performance data, which is very relevant to DOE goals and objectives.
- The project has been one of the best projects funded by the Program, and has helped DOE achieve its technical targets.
- Fuel cell electric vehicle (FCEV) technology validation under real-world conditions is a key factor for timely introduction of FCEVs into the marketplace.
- The project is an excellent data source.

Question 2: Approach to performing the work

This project was rated **4.0** for its approach.

- The approach has been proven and also improved over the course of the project. The process of providing specific, proprietary information to participants and general, nonproprietary information in the public domain is effective and useful.
- The researchers have met all of the difficulties in the project with professionalism, and have cooperated with industry.
- The approach pulls together and analyzes key operational data from company prototype FCEVs.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **4.0** for its accomplishments and progress.

- The project is moving toward completion, but still continues to deliver an impressive amount of critical information documented in appropriate reports and presentations.
- The project is above outstanding, with the project's Composite Data Reports providing excellent analysis.
- A wealth of important operational information has been acquired.
- The data is useful for users requiring actual data on FCEVs and hydrogen station real-world operation.

Question 4: Collaboration and coordination with other institutions

This project was rated **4.0** for its collaboration and coordination.

- This project has built a strong supporter base. Many collaborators continue to provide useful input to this project.
- The project has produced excellent work. The project collaborations are concluding now.
- Close collaboration has been a required key element for the success of this project.

Question 5: Proposed future work

This project was rated **3.3** for its proposed future work.

- The project is expected to continue to make excellent progress. The plan is to finish the project on time, leaving a lasting legacy.
- The project is nearly finished, and future work should focus on effectively disseminating information to key automotive decision-makers.
- It is hoped that DOE will be able to continue funding technology validation projects at the National Renewable Energy Laboratory (NREL).

Project strengths:

- The project demonstrated a solid approach, a strong team, and excellent participation from collaborators.
- NREL researchers maintained everyday quality control on the project. Researchers worked well with industry.
- The researchers demonstrated a highly effective data collection and analysis process.

Project weaknesses:

[There were no weaknesses listed by reviewers.]

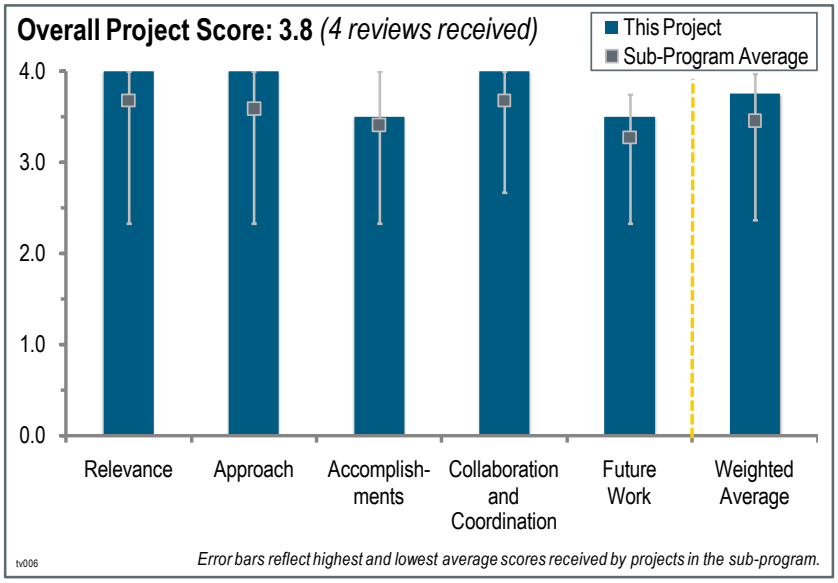
Recommendations for additions/deletions to project scope:

- The project should continue in some form. Future years will be critically important as fuel cell vehicles approach commercialization. Reliable and accurate data will be required for continued technology development. More information on the reasons vehicles are retired from the database would be helpful. Also, more information on the power drop-off at 350 bar would be appreciated.
- Analysis of material handling equipment should be added to the NREL technology validation portfolio.

Project # TV-006: Validation of an Integrated Hydrogen Energy Station

Ed Heydorn; Air Products

Brief Summary of Project:



The overall objective of this project is to determine the economic and technical viability of a hydrogen energy station designed to coproduce power and hydrogen. The project will utilize a technology development roadmap to provide deliverables and go/no-go decision points. The concept for this project was FuelCell Energy's molten carbonate fuel cell, plus Air Products' hydrogen purification system. Design, fabrication, and shop testing of the demonstration units are complete. Demonstration operation began in 2010 on renewable feedstock at the Orange County Sanitation District in California. The shop validation test was completed in March 2010, and the project is currently in a phase that includes operation, testing, data collection, and deployment.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **4.0** for its relevance to U.S. Department of Energy (DOE) objectives.

- The project has shown to have good potential for being an early and transition market for hydrogen production. The application of combined heat, hydrogen, and power (CHHP) systems has the greatest utilization of natural gas resources to provide a low greenhouse gas and criteria pollution footprint for the services required by many building types. The development of an infrastructure for hydrogen generation stations is a key element of the program.
- The project fully conforms to DOE objectives to validate a cogeneration technology. It is a good match for California's local leadership in hydrogen energy.
- The project is an excellent source of renewable hydrogen.

Question 2: Approach to performing the work

This project was rated **4.0** for its approach.

- While the system approach is great, the concern is whether pressure swing adsorption systems are the optimal cleanup solution. Because hydrogen purification is the most energy intensive part of hydrogen coproduction, it would be useful to determine the right technology to be developed.
- Natural gas and biogas are the input fuel to a molten carbonate fuel cell that produces both electricity and hydrogen. This is an excellent renewable energy approach for hydrogen production.
- This project represents a valuable approach to electric power and hydrogen coproduction from the same integrated system. The project is aimed to proceed all the way from feasibility to large-scale demonstrations. Input can be natural gas or biofuels, i.e., renewable fuel sources. Real-world operation and potential problems are being evaluated at a prototype site (Orange County Sanitation District facility).

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.5** for its accomplishments and progress.

- The system has moved to be commissioned in California. The system is first of a kind, and its commissioning on natural gas appears to be a success.
- A fully operational hydrogen energy station has been established.
- The project has moved steadily toward its targets and is apparently on schedule. Both shop and field validations of concept and equipment are largely completed. Product and power output specifications have apparently been met; however, no quantitative details are presented.
- The development of process economics is a major objective of this project, but no results were provided. Apparently this is to be completed during the operations stage after DOE involvement. (In response to a question, the presenter suggested preliminary hydrogen delivery costs were similar to gasoline.)

Question 4: Collaboration and coordination with other institutions

This project was rated **4.0** for its collaboration and coordination.

- It would be good for the project to show technology economics, as this is a first-of-a-kind system. However, it would also be good to show how the technology is expected to proceed down the cost curve. To determine if the molten carbonate fuel cell is the best choice and if the solid oxide fuel cell (SOFC) CHHP is on a different cost curve, it may be beneficial for Air Products to provide analysis for the project.
- The project is an excellent combination of industry, state government, and university collaborations.
- The project has excellent partnerships with industry, utilities, state and local governments, and universities. Most partners are in California, which has a serious interest in hydrogen development. Partners have provided funding in addition to DOE funding, leveraging more than 100% of federal dollars.

Question 5: Proposed future work

This project was rated **3.5** for its proposed future work.

- The project is expected to demonstrate operation on digester gas and operate on digester gas for the duration of the demonstration. Future upgrade of the technology to DFC1500 and DFC3000 is interesting. However, it would be of interest to show how the technology of CHHP would also work with SOFC systems. It may be worthwhile looking at the system that Bloom used for Alaska (see Bloom's Annual Merit Review presentation from 2008).
- Future activities target the needs and desires of the state of California.
- This project is very near the end of the DOE-supported portion. While the remaining work seems logical, it is not clear if there are enough resources to complete everything listed by the project with non-DOE funding. It is important to complete the process economics.

Project strengths:

- The researchers have an excellent concept, approach, and execution.
- The researchers have an excellent, mostly California-based team with very strong industrial experience with the Air Products and FuelCell Energy partnership.
- The project has an excellent source and location.

Project weaknesses:

- This reviewer believes that there are no weaknesses at this time.
- There needs to be transparent economic analysis.

Recommendations for additions/deletions to project scope:

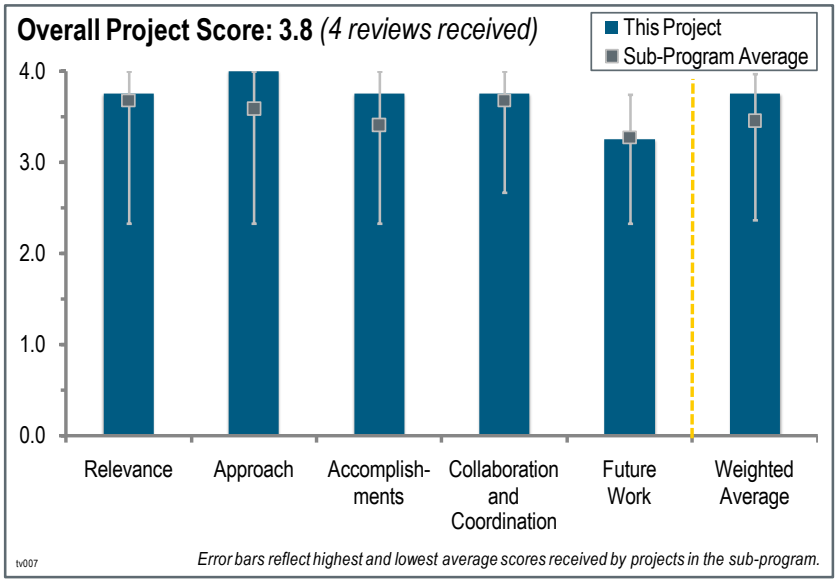
- This project could use the H2A model or equivalent to determine the cost of electricity, heat, and hydrogen.

Project # TV-007: California Hydrogen Infrastructure Project

Ed Heydorn; Air Products

Brief Summary of Project:

The objectives of this project are to: (1) demonstrate a cost-effective infrastructure model in California for possible nationwide implementation; (2) design, construct, and operate five hydrogen fueling stations; (3) collect and report infrastructure data; (4) document permitting requirements and experiences; (5) validate expected performance, cost, reliability, maintenance, and environmental impacts; and (6) implement a variety of new technologies with the objective of lowering the costs of delivered hydrogen.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.8** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project is absolutely relevant to developing a hydrogen economy. When historians review how the nation transitioned, failed to transition, or declined to transition to a fuel cell and hydrogen economy, they will recognize that in 2011 fuel cell technology was advanced enough to succeed and that America's infrastructure development met the challenge of the transition. Alternatively, historians will note that America stumbled because they could not deliver a needed product to the customer. The University of California, Irvine's (UCI's) station is thus one of several crucial programs necessary to demonstrate and advance what should be America's next energy technology.
- This project is the most relevant development for support of vehicle rollout in 2015. Automakers agree that station development is their top priority, as witnessed at the infrastructure workshop in Washington, D.C., earlier this year.
- The project fully conforms to the DOE Hydrogen and Fuel Cell Program's Technology Validation objectives to understand virtually all of the aspects of hydrogen refueling stations.

Question 2: Approach to performing the work

This project was rated **4.0** for its approach.

- Given California's tight budget, UCI has been outstanding in recognizing and meeting all requirements.
- Air Products is working on a wide variety of stations—pipeline; liquid delivery; on-site production of combined heat, hydrogen, and power; and tube trailer delivery.
- The project covers virtually the full scope of refueling stations, including original equipment manufacturer (OEM) vehicle needs, site selection, permitting, operations, and data taking. Additionally, the project is incorporating other technical innovations, including pipeline supply of hydrogen. Four stations have been built, and each is slightly different. The project also provides practical operating experience to DOE. While the project is based in California, it should be applicable nationally and internationally.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.8** for its accomplishments and progress.

- The researchers have done outstanding work. While funding, building, and using a hydrogen station is a bit more difficult than it seems, UCI met and continues to meet all requirements to advance the future of hydrogen.
- Air Products is making rapid progress on all of its station developments.
- There is considerable progress in all areas. Apparently, one planned station (Long Beach Mobile in California) is not complete. Filling stations, so far, have performed well. With the exception of one station (Torrance Pipeline in California), no economics were presented, and the presenter was not able to answer questions about preliminary economics.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.8** for its collaboration and coordination.

- The research represents outstanding collaborative work with private and public sector activities.
- Air Products could benefit in expanding its collaborations.
- The project has excellent collaborations among a wide range of industry, automobile OEM, local government, and university partners. The major participation of UCI is very good; it will provide training of the next generation of experts for the hydrogen economy.

Question 5: Proposed future work

This project was rated **3.3** for its proposed future work.

- The researchers have done solid work on both the discussion of the project and future needs.
- Air Products is going from a building phase to a monitoring phase. This is great progress that engages Air Products' and UCIs' analysts. However, it also puts its builders on the sideline. Although the remaining time on the project is small, the planned work is good and hopefully can be completed by the end of 2011. The principal investigator (PI) should focus strongly on promised economic analyses.

Project strengths:

- The project has a good station in a good location and meets a need.
- The project includes excellent organizations in a broad, comprehensive partnership.

Project weaknesses:

- There are no project weaknesses noted by this reviewer.
- There should have been a project PI present, if possible.

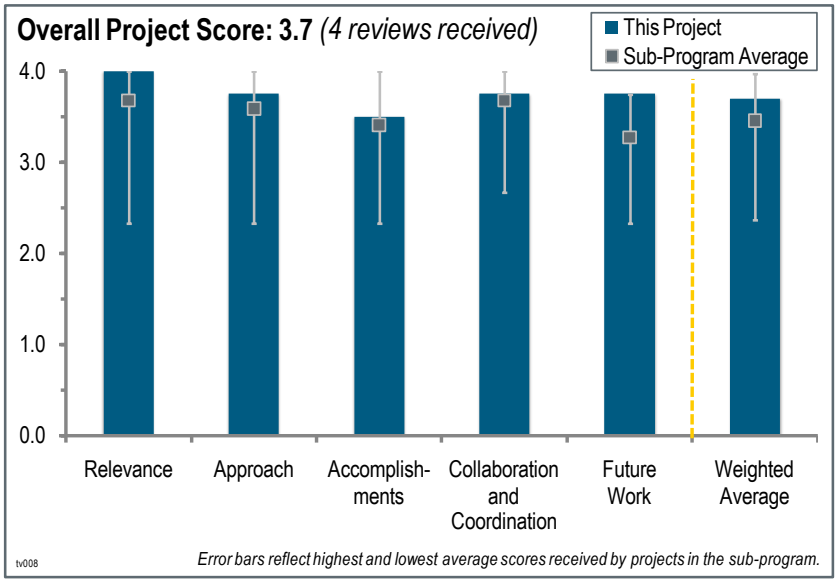
Recommendations for additions/deletions to project scope:

- The team should keep up the good work, and show cost data in future presentations.

Project # TV-008: Technology Validation: Fuel Cell Bus Evaluations

Leslie Eudy; National Renewable Energy Laboratory

Brief Summary of Project:



The overall objective of this project is to validate fuel cell technologies in transit applications. Objectives are to: (1) analyze fuel cell bus (FCB) performance and costs compared to conventional technologies to measure progress toward commercialization; (2) provide "lessons learned" on implementing fuel cell systems in transit operations to address barriers to market acceptance; and (3) harmonize data collection efforts with other FCB demonstrations worldwide in coordination with the Federal Transit Administration (FTA), an operating administration within the U.S. Department of Transportation (DOT), and other U.S. and international partners. Objectives for 2011 are to: (1) complete analysis and report results on first-generation FCBs; (2) document fuel cell hours; (3) continue data collection and analysis for next-generation FCBs at Burbank, SunLine, and AC Transit in California; and (4) conduct crosscutting analysis of the status of FCBs at all sites.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **4.0** for its relevance to U.S. Department of Energy (DOE) objectives.

- This ongoing project is an excellent source of valuable information to DOE and continues to be relevant to both DOE and DOT. DOE's goals are being well served with this project.
- The project is continuing work on an area that is vital to the commercialization of fuel cells. FCB programs continue to be an important base building block for a hydrogen economy.
- The project is directly oriented toward the DOE objective to obtain and analyze real FCB operating data.
- Buses are a great platform on which to test fuel cells and introduce hydrogen and fuel cells to the public.

Question 2: Approach to performing the work

This project was rated **3.8** for its approach.

- This approach has worked well for many years since the beginning of this project. The principal investigator (PI) has an excellent track record for approaching transit companies and working well with them. The data collected is helping DOE to overcome fuel cell barriers.
- This reviewer has no negative comments whatsoever; the planning and performance of work was complete and effective.
- Obtaining and analyzing real operating data from a number of FCB projects is exactly what is needed to objectively compare the data with conventional diesel buses. Obtaining complete data is very important to a proper analysis; cooperation between operators and the National Renewable Energy Laboratory (NREL) seems to be good.
- The project presents good data analysis.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.5** for its accomplishments and progress.

- The data collected and analyzed is methodic, logical, and useful to DOE's hydrogen program and others in the transit business. The end result is to help DOE determine if the technical targets are being reached and if the validation goals are being achieved. Without this project, there would not be an evaluation process.
- The presenters did outstanding work answering all pertinent questions.
- A lot of useful operating data was obtained, analyzed, and nicely presented. It seems to allow a good comparison between hybrid FCBs and diesel. The hydrogen results so far, even with improved fuel cells, seem a bit disappointing relative to diesel. Only one project showed greater than two times improvement in fuel economy. Operating costs were rather high, and downtime was marginally higher for FCBs. These deficiencies may ultimately vanish as research and development improves fuel cell technology in the future.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.8** for its collaboration and coordination.

- Excellent work was performed with all of the large transit agencies. The ongoing work is evident in the quality of interaction, and the project is being well served by the collaboration.
- Presenters did a good job of reviewing and presenting the work of other organizations in support of the goals. Presenters also did a good job on presenting what has been accomplished and providing responses to questions about the specifics of the participating organizations. The presentation discussed very thoroughly all of the organizations participating; however, it would have been outstanding if an organization had been included that was otherwise unexpected.
- The collaborations are clearly excellent. This is critically important for the success of the project.

Question 5: Proposed future work

This project was rated **3.8** for its proposed future work.

- The final reports will be essential for future decision-makers to determine the value of hydrogen fuel cells in buses.
- Not only has NREL clearly done a good job on building on the past work of other activities, but clearly NREL's current work can be used as a foundation of future work to advance the acceptance and use of fuel cell technology.
- Research work should continue as planned.

Project strengths:

- This PI has done an excellent job.
- The presentation on longer-term FTA operating requirements did a good job on meeting real-world requirements.
- The researchers were able to obtain and objectively analyze real operating data. Good feedback was provided to fuel cell and hybrid battery manufacturers.

Project weaknesses:

- There were no project weaknesses noted by this reviewer. NREL had room for creativity that may not have been fully realized.
- Possible negative impressions may be premature due to the current limits of fuel cell technology.

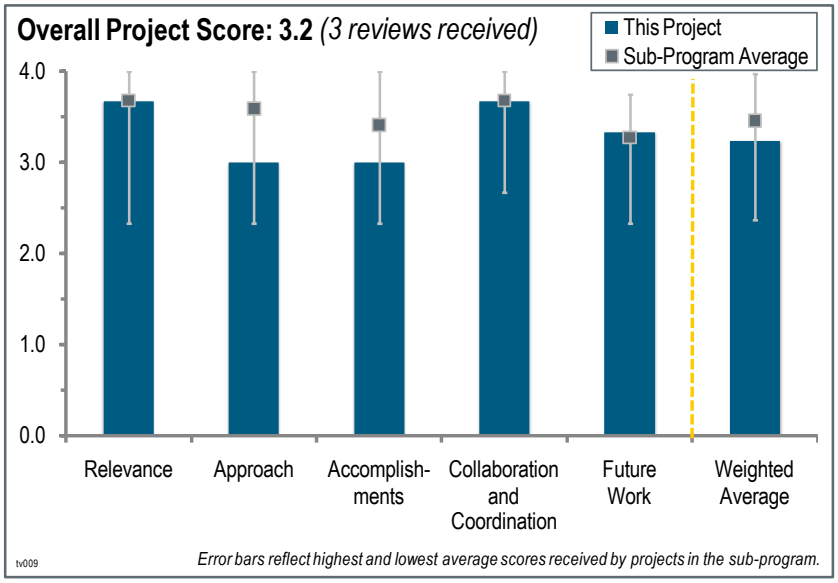
Recommendations for additions/deletions to project scope:

[Reviewers did not have any recommendations.]

Project # TV-009: Hawaii Hydrogen Power Park

Richard Rocheleau; Hawaii Natural Energy Institute

Brief Summary of Project:



The Power Park project scope was expanded in 2011 to support collaboration between the U.S. Department of Energy (DOE) and the U.S. Department of Defense that includes installations of higher-capacity hydrogen infrastructure at the Puna geothermal facility on the island of Hawaii and the Office of Naval Research (ONR)/General Motors (GM) fuel cell electric vehicle (FCEV) demonstration project at the Marine Corps Base Hawaii on Oahu. The objectives of this project are to: (1) support the operations of Hawaii Volcanoes National Park's (HAVO's) hydrogen plug-in hybrid electric vehicle shuttle buses until January 2013; (2) install fueling infrastructure at HAVO; (3) conduct engineering and economic analysis of HAVO bus operations on different routes, grades, elevations, and climatic conditions; (4) validate fuel cell system performance in harsh environments including high sulfur dioxide; (5) attract new partners and applications for Big Island hydrogen infrastructure including backup power applications; and (6) support the GM Equinox FCEV demonstration project at the Marine Corps Base Hawaii in partnership with ONR.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.7** for its relevance to DOE objectives.

- This project has many of the elements important to the DOE Hydrogen and Fuel Cells Program—automobiles, buses, and refueling infrastructure. It is definitely a relevant project.
- The project has one of the lowest-cost renewable hydrogen options (geothermal), plus mobile refuelers and a connection to the GM Equinox FCEV demonstration project.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- The approach is complex and difficult because it is so broad, with many validation demonstrations included in the project as well as many and varied participants. Given the complexity of the project, the approach seems to be working reasonably well.
- The approach appears to meet the challenges of management and coordination.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.0** for its accomplishments and progress.

- Project progress to date has been good; especially given that the project had to be restructured to accommodate new participants.

- There are good accomplishments to date, but the project has been hampered by delayed deliveries of buses and legal issues with the U.S. Park Service.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.7** for its collaboration and coordination.

- This project has an amazing number of partners, including federal and state agencies, vehicle suppliers, and national laboratories.
- There are good collaborations on the technical side as well as diverse funding sources.

Question 5: Proposed future work

This project was rated **3.3** for its proposed future work.

- Future plans seem reasonable with efforts focused on continuing to enable the various project partners.

Project strengths:

- There are many contributing partners to the project.
- The project has a good, experienced team and good funding sources.

Project weaknesses:

- There have been many delays to this project.

Recommendations for additions/deletions to project scope:

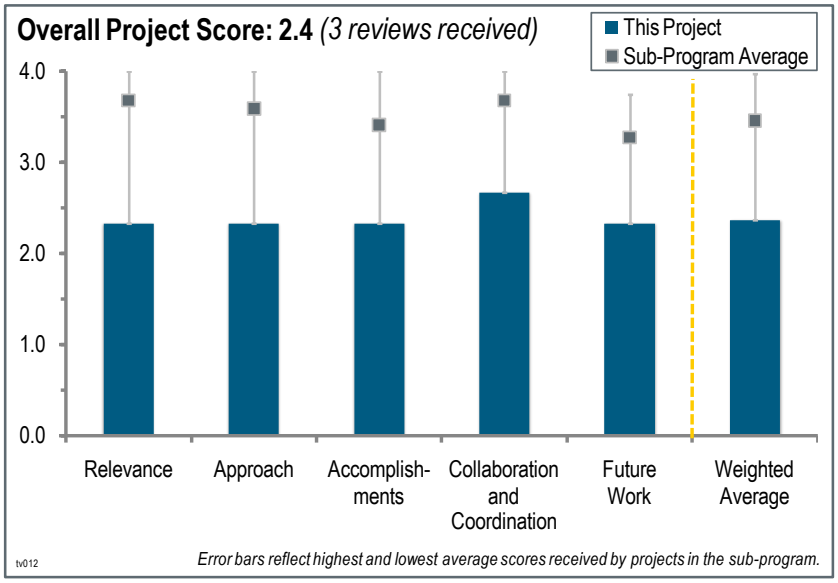
- The project may have to be extended in order for all of the various demonstrations to have sufficient time for operation and data collection. The lessons learned from this project will be very important.
- This reviewer has no recommendations at this time. It is a good project.

Project # TV-012: Florida Hydrogen Initiative

David Block; University of Central Florida

Brief Summary of Project:

This project seeks to develop the U.S. Department of Energy's (DOE's) and Florida's hydrogen and fuel cell infrastructure by: (1) creating partnerships for applied demonstration projects; (2) sponsoring research, development, and demonstrations in hydrogen and fuel cell technology; (3) facilitating technology transfers to create, build, and strengthen high-growth, high-technology companies; (4) developing industry support for applications; and (5) developing unique university-level education programs.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **2.3** for its relevance to DOE objectives.

- The subprojects included in this project appear to generally support the goals and objectives of the DOE Hydrogen and Fuel Cells Program. However, the selection of the subprojects seems to be "once removed" from the Program and as a result may lack programmatic guidance and integration.
- This project is a real mixture of disparate projects; some are relevant, some are not.

Question 2: Approach to performing the work

This project was rated **2.3** for its approach.

- The research approach involves the solicitation of proposed subprojects; however, only proposals from the faculty of the project institution were solicited. This approach may have adversely impacted the quality and relevance of the subprojects. This approach also appears to have replaced the traditional role of DOE regarding national program development and integration.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **2.3** for its accomplishments and progress.

- Progress on this project has been slowed due to project restructuring and a change in principal investigators. At present, the project appears to be back on track with all of the funding committed and all of the subprojects underway.
- There has been much progress from a year ago.
- This project is a "mixed bag" among the nine subprojects.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.7** for its collaboration and coordination.

- The collaborations are good, with each subproject required to have an industrial partner.
- There have been increased collaborations during the last 12 months.

Question 5: Proposed future work

This project was rated **2.3** for its proposed future work.

- Future plans involving continued monitoring of the subprojects are still underway.

Project strengths:

- The project has industrial partners.
- The biowaste aspect of the hydrogen project has great potential, but it is unclear whether the technology is viable.

Project weaknesses:

- The project had to be completely restructured due to numerous setbacks.
- The diversity of tasks makes it difficult to evaluate all of the tasks.

Recommendations for additions/deletions to project scope:

[Reviewers did not have any recommendations.]

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