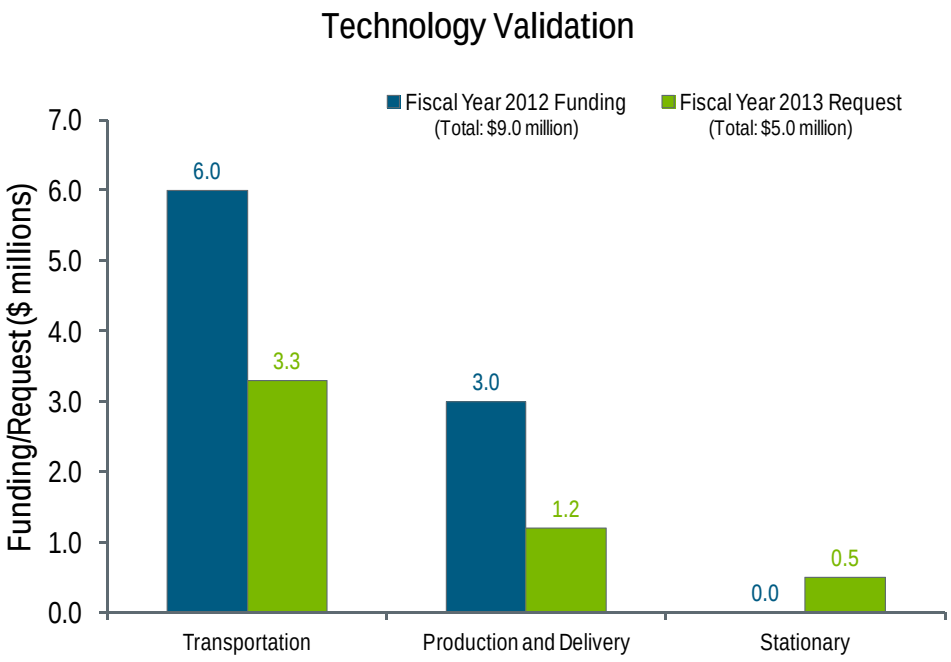
2012 — Technology Validation
Summary of Annual Merit Review of the Technology Validation Sub-Program

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

In general, the reviewers believed the sub-program area was adequately covered. Important issues were identified and progress was clearly presented. Projects included in the sub-program were effectively summarized, and highlights presented. Plans were identified for addressing issues and challenges. The Technology Validation sub-program is in transition. Important elements of the sub-program's future portfolio will be determined in large measure by awards resulting from current Funding Opportunity Announcements (FOAs). The FOAs focus on light duty fuel cell electric vehicle validation and hydrogen refueling station performance. The reviewers believed the sub-program to be focused and managed fairly well, noting the transition in management. However, overall the sub-program is effective in addressing U.S. Department of Energy's (DOE's) Hydrogen and Fuel Cells Program's (the Program's) needs. A reviewer notes that some activities were not in good alignment with the sub-program's goals.

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 transportation and stationary applications, as well as hydrogen production and delivery technologies. Data from fuel cell buses, forklifts, and backup power systems will continue to be evaluated. In addition, analysis of new hydrogen refueling stations in California and the Northeast will be included in the data collection activities. The fiscal year (FY) 2012 appropriation was $9 million. The Learning Demonstration ended early in FY 2012, and in late FY 2012, new project awards were announced for collecting hydrogen refueling station data and validating advanced refueling components, which include a high-pressure electrolyzer and increased-capacity hydrogen storage for stations. Also in late FY 2012, a fuel cell vehicle data collection funding opportunity closed. Selections are anticipated in early FY 2013, but the projects will also be funded using FY 2012 funding. These new projects will be the main emphasis of the sub-program. The FY 2013 request of $5 million is subject to congressional appropriations.



Majority of Reviewer Comments and Recommendations:

The reviewer scores for the four Technology Validation sub-program projects that were reviewed had a maximum of 3.8, a minimum of 2.3, and an average of 3.1. A key strength identified by reviewers in all of the Technology Validation projects was the excellent participation from collaborators, which has been critically important to the success of the projects. In addition, the projects supported the major goals of the Program and provided valuable information to the participants.

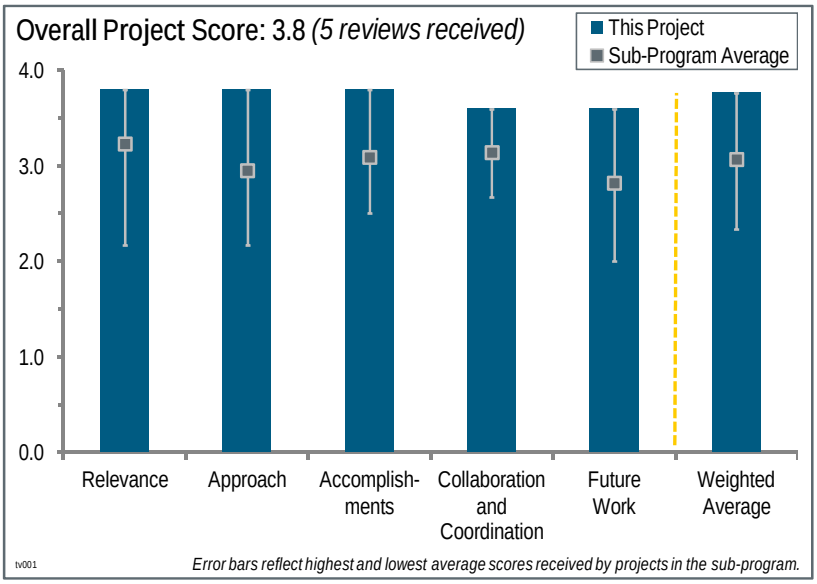
Reviewers observed that the National Renewable Energy Laboratory's approach for collecting, securing, and analyzing data is well-established and has been expanding to other applications such as material handling equipment and backup power. Reviewers recommended the continuation and expansion of the Controlled Hydrogen Fleet and Infrastructure Analysis activity because of its vital importance for informing decision-makers for public and private investments in hydrogen and fuel cells for transportation. Continued tracking of technology status is important for capturing the next generation of vehicles as they become commercial. The importance of fuel cell buses was broadly acknowledged. The principal investigator for the fuel cell bus evaluations was applauded for her excellent collaborations with transit agencies, developers, and others. It was recommended that fuel cell buses be compared to other hybrid buses; that warranty repair costs be included in the repair costs; and that more be done to compare buses of similar age, size, and service conditions. The merits of grid support in frequency and response to wind in the Wind to Hydrogen project were highlighted, but the technology validation project needs to focus on technology validation goals and have a more open process for bringing in equipment to validate. The Florida Hydrogen Initiative was difficult for reviewers to evaluate due to the diversity of its tasks; however, a few tasks received positive remarks and it was observed that the effort provided a meaningful educational experience for many.

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

Keith Wipke; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) validate hydrogen (H_2) fuel cell vehicles and infrastructure in real-world settings and (2) identify the current status and evolution of the technology. The National Renewable Energy Laboratory (NREL) provides the facility and staff for securing and analyzing industry-sensitive data, performs analysis using detailed data in its Hydrogen Secure Data Center, and publishes and presents composite data products to the public and stakeholders.



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

This project was rated **3.8** for its relevance to DOE objectives.

- This project is a major technology validation activity that provides important metrics on programmatic progress. It is definitely relevant to the DOE Hydrogen and Fuel Cells Program (the Program).
- This project is fully relevant to DOE objectives because it collects and disseminates real-world operating data.
- This is probably the most important DOE project related to large-scale H_2 and fuel cell electric vehicle (FCEV) deployments that offer the best opportunity for widespread use of H_2 and fuel cells in the economy.
- The data collection over the years is great and the improvements demonstrated are commendable. It is unclear where this type of data collection goes from here—additional testing and data collection will be absolutely necessary in the next few years for acceptance of the technology.
- The Program has devoted substantial resources to fuel cell vehicle and H_2 infrastructure technology validation projects. NREL's collection, analysis, and reporting of performance data associated with those projects has made a vital contribution to understanding the status of technology development relative to DOE's goals. NREL's data products have been continually refined so as to increase their value for both government and industry decision makers. The detailed, objective results of NREL's work are easily understood by those responsible for decisions on public and private investment in technology research, development, and commercialization. Over the past few years, this work has likely been the most significant contributor to unbiased, supportable, statistically valid conclusions about progress toward programmatic targets—vehicle range, stack durability, mean time between failure, fueling rates, and many other metrics.

Question 2: Approach to performing the work

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

- The approach is solid and clearly demonstrates that extensive data collection is and will continue to be necessary to move this technology into the mainstream.
- This project featured a very well organized and excellent data presentation, with results widely used by others in the hydrogen and fuel cell community.
- The project approach is very good; the project team collected and analyzed numerous data provided by operating partners for vehicles, filling stations, and performance. The project, correctly, does not make strong judgments on the performance of fuel cell vehicles, but rather objectively presents the results. Important components of this project are the communications to DOE, stakeholders, and the public.

- The approach has evolved over several years and is based on what works best. It is totally dependent of self-reporting by the program participants. Over time, participants have grown to trust the NREL team and to value the conclusions and findings of the project.
- Over time, Keith Wipke and his team have steadily focused and refined this project's approach to data collection, analysis, and reporting. The result is an outstanding and constantly expanding collection of Composite Data Products (CDPs) and Detailed Data Products (DDPs). With ongoing feedback from data providers and users, NREL developed a logical approach that has resulted in routine periodic production of high-quality, informative CDPs, DDPs, and progress reports. These reports provide outstanding documentation for industry, government, and the public. While the project being reported on is near completion, the approach employed by NREL's team for this work is serving as a model for fuel cell and H_2 projects other than those focused on on-road vehicles; these include projects for fuel-cell-powered material handling equipment and stationary fuel cells.

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

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

- Progress continues to be steady and constant over the nine years that the project has continued. This year was no exception, with significant accomplishments.
- The hard data collected over 10 years was clearly needed and demonstrated value in continuously monitoring developments and improvements.
- A large and useful quantity of data has been obtained over the nearly 10-year life of this project. Many presentations and publications have been made. However, some of the slides presented in this DOE Hydrogen and Fuel Cells Program Annual Merit Review presentation may be a bit esoteric to the non-expert. It is generally, but not always, clear how close the real-world performance results are to the DOE performance targets. There is good leverage into forklifts and other emerging fuel cell markets.
- This project provides the best, most objective, and most independent indicators of progress toward DOE's targets and goals for the key metrics associated with fuel cell light-duty vehicles and related H_2 infrastructure. The development and publication of 99 CDPs is an exceptional accomplishment. The highlights of selected accomplishments during the past year (the final year of the project), included in the presentation, are quite impressive. Taken together, they provide an appreciation for the merits of both NREL's data project (reported on here) and the progress of fuel cell vehicle and H_2 infrastructure technologies. The final data analysis and report on the vehicle learning demonstration has been published. Publication of the final report has been complemented by papers, webinars, and other initiatives.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.6** for its collaboration and coordination.

- Needless to say, collaborations are outstanding and absolutely necessary because the value and worth of the project is totally dependent on accurate, current input from project partners.
- Collaborations seem quite fine with Daimler, General Motors, and Air Products. No indication was given why Ford Motor Company/BP and Chevron/Hyundai-Kia dropped out in 2009. The project continuation needs more partners.
- Collaborations are extensive—it is too bad that several partners dropped out two years ago. It was surprising that some of the high-throughput stations shut down "early." If the project was to be renewed, it is essential that such stations "stay the course."
- NREL's data collection and analysis team has earned the trust of all organizations that have participated in the vehicle learning demonstration program. Industry confidence in NREL has grown continuously since its data project commenced in 2003. Contributing factors include ongoing communications, opportunities for input and feedback to the process, and NREL's system for protection of sensitive and proprietary information (the Hydrogen Secure Data Center). NREL's team has also maintained excellent communications with many organizations sponsoring related activities and/or having a stake in the outcome of DOE's program, such as the California Fuel Cell Partnership and the Fuel Cell and Hydrogen Energy Association.

Question 5: Proposed future work

This project was rated **3.6** for its proposed future work.

- There are good plans for the completion of the project, which is scheduled for the end of this fiscal year.
- Such a real-world project must continue as fuel cell vehicles continue their advancement toward commercial reality.
- It is very important to keep this team involved with the next technical validation projects to keep continuity in data evaluation.
- This question is not applicable because the project is ending.
- This NREL data project was undertaken in conjunction with, and in support of, the major DOE fuel cell vehicle learning demonstration activity. Activity associated with the learning demonstration program has been completed; NREL's work on this project is winding down and will be completed this year. DOE is currently planning new vehicle and H_2 infrastructure evaluation projects. NREL's team is supporting DOE in launching these initiatives. DOE is also utilizing NREL's data handling and analysis capability for the benefit of technology validation activities related to other fuel cell applications.

Project strengths:

- This project features strong analysis connections to the developmental industry and demonstration efforts.
- This project has an excellent team of experts and an excellent track record of digesting and presenting results of FCEV testing.
- This project's strengths include its strong project team, proven analysis methodology, and extensive participation of project partners that provide basic data on vehicle and infrastructure performance.
- The experience and expertise of NREL's team, including Keith Wipke, NREL's team leader, is a strength. Other areas of strength include industry's confidence and trust in NREL's team and approach to the project, and the continuous improvement and enhancement of project products, particularly CDPs and DDPs. The project provides a significant contribution to the merits of the vehicle learning demonstration (technology validation) program for a relatively small expenditure of the total program resources.
- One strength is this project's many years of statistical data analysis and data collection—it is too bad this will be ending, because additional data is required to demonstrate improvements in technology.

Project weaknesses:

- It would be even more effective if more partners participated.
- This is not really a weakness, but more information on the specific benefits that the project partners have derived from the project results would be helpful. Perhaps case studies could be an option.
- One weakness is the "premature" shut down of refilling stations and other partners no longer involved—it raises the question of how to get commitments for the longer term.
- Two reviewers could not identify any weaknesses.

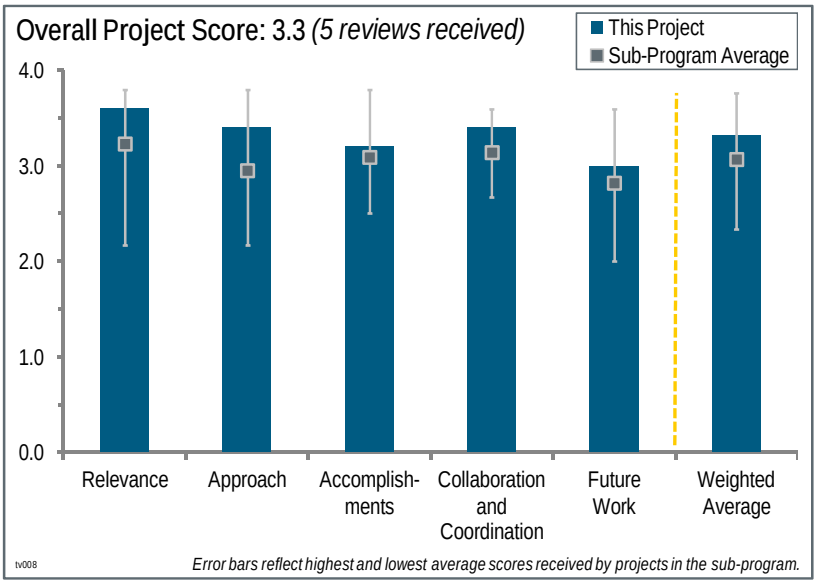
Recommendations for additions/deletions to project scope:

- This project is too important and useful to end—it needs to be continued in some form.
- The project is near its contractual end. Continuation and expansion are recommended, if funding becomes available.
- The project being reported on is nearly complete; its final report has been published. DOE is urged to maintain and utilize the data analysis expertise existing at NREL, which has been built as a result of this project. It seems this is being done in the context of other validation initiatives and projected future activities.
- The database and technical analysis team should be maintained through the next generation of FCEV deployments. If possible, someone should keep track of the FCEVs with the longest-running fuel cell stacks.

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. The specific objectives for 2012 are to: (1) document more than 10,000 fuel cell hours and double the fuel economy compared to baseline technology (diesel and natural gas buses); (2) continue data collection and analysis for second-generation fuel cell buses at Burbank, SunLine, and AC Transit; (3) collaborate with the U.S. Department of Transportation (DOT) and the Federal Transit Administration (FTA) to collect data on sites for the National Fuel Cell Bus Program (NFCBP); and (4) conduct crosscutting analysis and comparison of fuel cell electric bus (FCEB) status at all sites.



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

This project was rated **3.6** for its relevance to DOE objectives.

- This project featured excellent relevance to DOE needs regarding gathering bus operating data for analysis and public summary.
- Next to passenger vehicles and forklift trucks, FCEBs are the best option for widespread fuel cell utilization and public visibility.
- Transit operations are an integral part of the DOE Hydrogen and Fuel Cells Program (the Program); thus, the project that monitors FCEB performance and cost compared to conventional technologies is a relevant component of the Technology Validation sub-program.
- While this data is necessary to collect, and demonstrations are critical for future implementation of the technology, it is unfortunate that there is no post-mortem analysis to understand why some of the buses failed so early. It is highly commendable that a bus reached >12,000 hours, but it would benefit the community to couple this with an explanation of why this was possible.
- The Program has devoted substantial resources to fuel cell vehicle and hydrogen (H_2) infrastructure technology validation projects. Buses have been an important target of opportunity for fuel cell development and demonstration. Significant funding, from both DOE and DOT, has been provided for FCEBs. The National Renewable Energy Laboratory's (NREL's) collection, analysis, and reporting of performance data associated with vehicle demonstration projects, including those focused on buses, has made a vital contribution to understanding the status of technology development relative to DOE's goals. NREL's data products have been continually refined, increasing their value for both government and industry decision makers. The detailed, objective results of NREL's work are easily understood by those responsible for decisions on public and private investment in technology research, development, and commercialization. Over the past few years, this work has been an important contributor to achieving unbiased and supportable conclusions about progress toward DOE and DOT targets—bus fuel economy, fuel cell bus utilization, durability, miles between roadcall, fueling rates, and other metrics.

Question 2: Approach to performing the work

This project was rated **3.4** for its approach.

- The approach is strongly based on the highly successful approach used in the Hydrogen Fleet and Infrastructure Analysis and is focused on self-reporting by participating transit agencies.
- This project features lots of data collection, but it lacks some understanding as to what factors affect lifetime, fuel economy, and performance. More information regarding "out-of-service" would have been appreciated.
- The approach involves looking at a broad spectrum of fuel cell, hybrid, and diesel buses for real operating environment comparisons. The data cover a variety of bus and fuel cell manufacturers, transit systems, and fuel sources. The data are analyzed on various bases relative to DOE targets. A key value of the project is the presentation and publication of the results.
- Since commencement of bus evaluations in 2003, the principal investigator (PI) and her team have steadily refined this project's data collection, analysis, and reporting activities. With ongoing feedback from data providers and users, NREL has developed a logical approach that results in routine periodic production of high-quality, informative reports. These reports provide outstanding documentation for industry, government, and the public. Since 2010, data has been collected on an increasing number of buses. The process uses data already collected by transit agencies. Data is collected on conventional diesel buses, as well as natural gas and diesel hybrids, for comparison purposes. The current second-generation fuel cell bus evaluation process is building on the experience gained during operation of first-generation buses from 2005 to 2010. Several steps could be taken to improve project results and benefits. These include: (l) acquiring additional data on the performance of advanced technology hybrid electric buses; (2) improving access to warranty costs; (3) and increasing the ability to compare buses with similar age, size, and service conditions. These issues are understood by the PI. They were not included in the project presentation, but they are alluded to in the reviewer-only slides. With regard to information on slide 14, it is recommended that more intensive investigation be done into the reasons for the unavailability of fuel cell buses. Particular focus should be on "bus maintenance," which accounts for more than 60% of bus unavailability for two transit agencies.

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

This project was rated **3.2** for its accomplishments and progress.

- This project has produced good results so far.
- This project made good progress on reporting the performance of first-generation buses—the project is moving on to second-generation buses, with significantly more buses included in the study. The project features significant publications and presentations that are important to the dissemination of project findings and conclusions.
- Much good data has been obtained from the bus operators, and it has been thoroughly and understandably analyzed. The analyzed results show improvements in fuel cell bus technology over many performance parameters: fuel economy, availability, repair frequency, lifetime, cost, etc. The overall results are very positive for the future of fuel cell buses. The slides are simple and easily understandable. Some qualitative parameters could be added; for example, drivers' personal comments. Many publications and presentations resulted from the analysis work.
- This project provides the best, most objective, and most independent indicators of progress toward DOE's targets and goals for metrics associated with FCEBs and related H_2 infrastructure. Ms. Eudy's presentation includes readily understandable graphs that enable reviewers to compare goals and bus performance for key metrics, including monthly service miles and fuel economy. Results are presented for each bus type and transit agency. Variability in factors influencing performance, such as duty cycles, is noted. For selected metrics, such as miles between roadcall, the improvement in second-generation fuel cell buses is cited. The presentation's highlights of selected accomplishments during the past year are impressive. Taken together, they provide an appreciation for the merits of both NREL's data project (reported on here) and the progress—for example, hours in service before repair or replacement—of fuel cells used in operational buses. An annual FCEB status report, with analysis comparing fuel cell and other bus results for all FCEB locations, is published. Publication of this report is complemented by papers on individual bus projects and presentations at selected conferences.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.4** for its collaboration and coordination.

- There are many very useful collaborations in this project.
- The project has good collaboration between partners, but communication could be improved a little.
- The project features good collaborations with project partners—the quality of project results is dependent on collaborations with transit operators.
- As indicated on slides 8 and 19, NREL's FCEB data project involves collaboration and routine communication with every transit agency in the United States that operates any type of fuel cell bus. NREL's evaluation team routinely coordinates with federal and other government organizations; transit agency management and operating personnel; bus manufacturers; fuel cell and related system providers; hybrid electric technology providers; and others that have a stake in FCEB research, development, and commercialization. NREL's bus data collection and analysis team has earned the trust of all organizations participating in the FCEB demonstration program. NREL's team also maintains excellent communications with many organizations sponsoring related activities, both in the United States and other countries.

Question 5: Proposed future work

This project was rated **3.0** for its proposed future work.

- There are good plans for expanding transit agency participation in the project—significantly more partners will be contributing to the program as more fuel cell buses are introduced into the national fleet.
- The proposed future work is good, and the project team should continue as planned. The team should expand into other (new) bus operations, if possible, as well as add other fleet vehicles—for example, forklifts, delivery vans, mine vehicles, and other types.
- This NREL data project was undertaken in conjunction with, and to support, FCEB demonstration projects supported by U.S. government agencies. New FCEBs are being funded with the support of NFCBP. Slide 20 of the presentation provides an excellent display of bus projects to be evaluated through 2013. Buses to be evaluated will be operated in all regions of the country. NREL's team intends to continue its dialogue with transit agencies and others regarding data collection at new sites.

Project strengths:

- The project features a good team, database, and analysis.
- This project has a strong team and good methodology based on a successful automotive project.
- This project has good analyses of real operating data as well as widespread dissemination of results, which are convincing.
- The project features a large mass of data, but its goals are unclear and recommendations to improve performance in buses are not part of the project.
- A strength of this project is the experience and expertise of NREL's team, including the PI. Funding support from FTA is also a strength. This averages about $250,000 per year. (This information should be included in the presentation.) Another strength is the active collaboration and interaction with manufacturers and users of advanced technology buses. The project has made a significant contribution to the merits of the FCEB demonstration program for a relatively small expenditure of total program resources.

Project weaknesses:

- The data collection is challenging and results are encouraging, but it is still unclear how the data is being used to lead to technological improvements.
- Achieving statistically valid performance comparisons among buses is inherently difficult, due to factors beyond NREL's control. Such factors include regional differences, transit agency procedures, the variety of bus types, multiple fuel cell bus design strategies, variability of duty cycles, and differing service profiles. Another weakness is the limitations on cost details provided by bus manufacturers and transit agencies.
- Two reviewers did not identify any weaknesses.

Recommendations for additions/deletions to project scope:

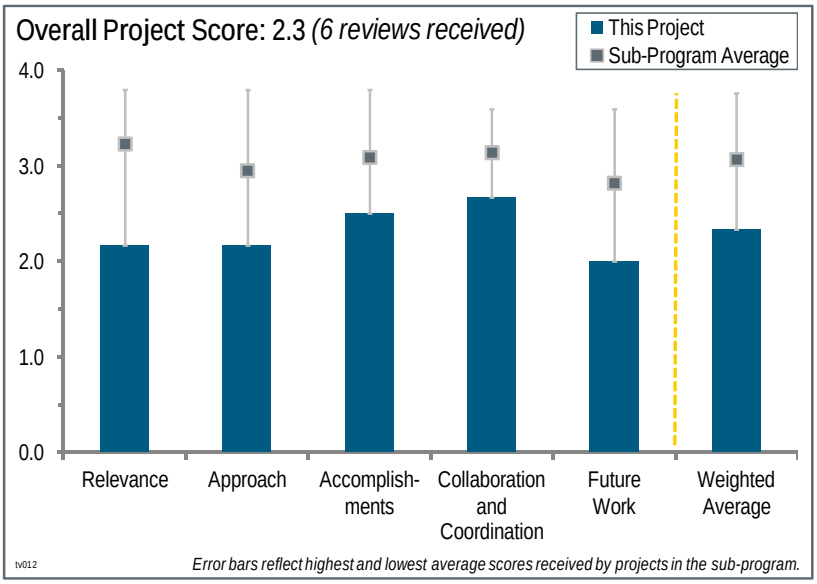
- The project team should continue and expand as much as possible.
- The project team should add a component to the project to encourage interpretation and recommendations for further improvements.
- The project might add a new category such as “Powertrain Availability.” Ideally the “availability” (or lack thereof) should only reflect fuel cell system failures. Fuel cell technology should not be penalized due to other bus failures, accidents, etc. Of course, the diesel and compressed natural gas buses should be treated the same, with availability only dependent on powertrain failures.
- DOE is urged to maintain and utilize the bus data analysis expertise available at NREL, which has been built as a result of this project. Ms. Eudy mentioned sharing of information with organizations in other countries. Continuing the initiative is encouraged because it could lead to comparisons of performance results for FCEBs around the world.

Project # TV-012: Florida Hydrogen Initiative (FHI)

David Block; University of Central Florida

Brief Summary of Project:

The objectives of this project are to: (1) develop hydrogen (H_2) and fuel cell infrastructure, (2) create partnerships, (3) sponsor fuel cell and H_2 research and development (R&D), (4) facilitate technology transfer, (5) develop industry support, and (6) develop unique education programs. Twelve individual projects were competitively selected; six have been completed to date, and nine were presented at the 2012 DOE Hydrogen and Fuel Cells Program (the Program) Annual Merit Review and Peer Evaluation meeting.



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

This project was rated **2.2** for its relevance to DOE objectives.

- Each of the individual projects in the overall umbrella project is relevant to a specific DOE objective.
- Technology validation is very important and this effort took a number of attempts across a number of areas. Unfortunately, this effort has not resulted in any significant technology validation. There are eight projects that make up this Florida Hydrogen Initiative (FHI), but few of them relate to the others, which diminishes the overall impact.
- Selection of projects outside of the normal Program Funding Opportunity Announcement (FOA)/Annual Operating Plan (AOP) process makes it difficult for DOE to ensure the strong relevance of the projects. In addition, the very long duration of time between project award and completion of individual projects makes this even harder.
- Some of the sub-projects underway as a part of this project appear to be relevant, while others do not bring any new, unique contributions to the Program. The sub-projects are not selected by the DOE programmatic procurement process; thus, they may or may not fit in the Program's portfolio.
- FHI manages individual, independent projects using DOE funds appropriated prior to fiscal year (FY) 2009. Some of the nine active projects contribute to achieving the Program's goals and objectives and include activities that can be linked to DOE's targets. The most relevant projects are "Development of a Low Cost, High Efficiency polymer electrolyte membrane (PEM) fuel cell System" – Florida State University (FSU)/Bing Energy, Inc.; "High Efficiency, Low Cost Electrocatalysts for Hydrogen Production and Fuel Cell Applications" – Florida Solar Energy Center (FSEC); "Chemochromatic Hydrogen Leak Detectors for Safety Monitoring" – FSEC; and "Advanced HiFoil Bipolar Plates" – EnerFuel, Inc. References to a DOE target were mentioned only twice in the presentation's 83 slides. During discussions at the poster session, leaders for two of the projects above demonstrated familiarity with DOE's targets applicable to their work.
- This is a project involving nine diverse and different tasks. With a couple of exceptions (e.g., "Portable Fuel Cell" and "Hydrogen Storage"), it is not very clear how they relate to DOE's quantitative targets and goals. With the exception of the "Hydrogen Technology Rest Area," this project does not generally fit in the category of technology validation. Eight projects seem like R&D, not technology validation, making it difficult to rate this project by the Technology Validation sub-program's standards and goals.

Question 2: Approach to performing the work

This project was rated **2.2** for its approach.

- Basically, this is a collection of unrelated projects. The individual projects all have reasonable approaches to achieving their particular objectives.
- The approach to selecting new sub-projects for this project seems to be reasonable. However, it is noted that all of the sub-project participants seem to be from the state of Florida. It is questionable if the best possible, most qualified staff are secured for each of the research areas. The sub-projects appear to be a mixed bag of unrelated activities. There is no common theme, focus, or technical thrust to the selection process for sub-projects.
- Again, having multiple projects within a project makes the approach difficult to assess. The management of this effort has changed multiple times, leading to a scatter-shot technical approach that bears no resemblance to an integrated plan. Enerfuel, FSU, the University of Central Florida, the University of South Florida (USF), Florida Institute of Technology, and Florida Atlantic University are all capable performers and represent a diverse set of partners. The renewable H_2 from renewable methanol was poorly conceived; it lacked a domestic source of supply and had to be ultimately cancelled. The lack of a coordinated approach to FHI fails to move the state forward in any real way toward an H_2 infrastructure or any significant validation of promising technologies.
- Across the nine active projects within FHI, the purposes are varied and the range of activities is very broad. When the projects are considered together, it is not possible to describe an overall approach with clarity. No attempt was made to do so in the poster presentation. The overall initiative has little, if any, relationship with technology validation. Across the nine projects, there are elements of basic research, applied R&D, training and education, technology transfer, and partnership development. For two projects, a description of the approach was well stated. For others, the approach was either not included or so general that it was not useful.
- This project has a bewildering array of distinctly different activities, most subcontracted by FSEC to others. Some seem to be interesting and possibly unique. Others seem similar to other foreign and U.S. activities. The principal investigator (PI) has not made clear presentations as to which approaches are really new and how they relate to others (other than virtually all are being performed in Florida).

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

This project was rated **2.5** for its accomplishments and progress.

- Progress appears to be adequate, with sub-projects being completed and new ones initiated.
- The accomplishments of the individual projects have been of a varied nature. Most of the projects have shown reasonable results, although none of them has produced outstanding results. There was one project that was quite interesting, and one project that was disappointing.
- Overall, decent progress has been made on the individual projects. Some have nearly completed demonstrations, and some have proven new technologies. Given that most of the projects are two years old or less, overall the accomplishments are respectable and generally (though not in all cases) address DOE goals.
- Good work has been accomplished by some of the nine projects within the Florida Hydrogen Initiative. In particular, DOE should examine closely the results of four of the sub-projects. A short conversation with the team leader for task 11, “Development of a Low Cost and High Efficiency 500 W Portable PEM fuel cell System” (slide 58), made it clear that some of the R&D has led to patent applications and commercial interest. Technical accomplishments are also reported for task 7 (slides 22 through 27), task 8 (slides 33 and 34), and task 14 (slide 80). Note: “Projects” are referred to as “Tasks” in the poster presentation.
- There are some interesting results, and significant quantities of data have been obtained that should be of value to the Program. It is not always made clear how much advancement has been made beyond national and international states of the art. From the funding summaries, it seems that all tasks have not been funded in FY 2011 and FY 2012. Half of the tasks have already been completed, and the remaining tasks are to be completed by the end of calendar 2012.
- “EV Charging Station Powered by a Fuel Cell” achieved moderate success (Enerfuel and Florida Atlantic). The mechanical and chemical durability of membrane electrode assemblies (MEAs) does not appear to be a noteworthy project with significant validation. The production of H_2 from biowaste poster did not justify assertions, including the projected cost/kilogram of the resultant H_2 and the efficiency of the bromine-hydrogen process. “Design and Development of Advanced H_2 Storage System” using novel materials did not have reproducible results. “Advanced HiFoil Bipolar Plates” (Enerfuel) appeared to achieve good results. “Low Cost

High Efficiency 500W Portable PEM Fuel Cell" achieved good results (>90% platinum [Pt] utilization using "Bucky paper"), but FSU/Bing ended up transitioning the technology to a Chinese supplier.

Question 4: Collaboration and coordination with other institutions

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

- Collaborations on the individual projects were found to be somewhat limited.
- There are significant collaborations, but virtually all are within Florida. If this is really a DOE-funded activity, there should be more national and international collaborations.
- There are collaborations within this project, but partners are paid participants and there appears to be little or no interaction between sub-projects. In fact, the sub-projects have little in common and thus little opportunity for collaboration.
- The PI engaged with a wide range of Florida-based universities and companies in the eight projects that were undertaken. There was very little coordination and collaboration among the institutions involved. They each had their own project, but they did not participate in review or coordinate with each other. Little technology transfer has occurred despite the large number of universities involved.
- FHI, managed by FSEC, funded proposals submitted in response to a request for proposal. To accomplish the work being done within the various projects, FSEC has partnered with multiple organizations in Florida, primarily universities. The manager of FHI maintains excellent knowledge regarding each of the nine active projects. Based on a discussion with him at the poster session, it is clear that he coordinates routinely with project leaders, and that he is quite familiar with project plans, content, progress, and results.

Question 5: Proposed future work

This project was rated **2.0** for its proposed future work.

- All projects will be ended by December 2012.
- This project is scheduled to end this year. The subjects should be moving to completion on that schedule.
- The future work is qualitatively reasonable, but it does not seem to be very well directed toward DOE targets and barriers. All tasks are shown as ending in the next seven months or are presently unfunded.
- Future work was not planned in a timely and logical manner. The poor performance of many of the projects and the need to ask for even another extension to December 31, 2012, do not show good schedule or risk management. There are no significant barriers that appear to have been eliminated as a result of these sub-projects. The Technology Validation sub-program has not been advanced as a result of this project.
- FHI is nearly complete. No DOE funding has been provided since FY 2008. Three of the nine active projects are reported as complete by FHI; the rest are scheduled to be finished by the end of calendar year 2012. The incremental additional work on the six projects still to be completed is not expected to contribute substantively to the achievement of DOE objectives. There are no plans to request more DOE funds or extend activities beyond this year.

Project strengths:

- Each individual project has relevance to DOE programmatic goals.
- The project contains some interesting approaches.
- Strengths include the two projects conducted by Enerfuel: "EV Charging Station Powered by a Fuel Cell" and "Advanced HiFoil Bipolar Plates." "Low Cost High Efficiency of PEM Fuel Cell System" achieved some interesting results in terms of Pt utilization using Bucky paper.
- One area of strength is the research capabilities of some project teams. In recent years, the management attention provided by FSEC was a strength. As a result, some beneficial results, and relevant additions to knowledge, have been achieved by FHI.
- The diversity of activities is an area of strength. The projects seem to be fairly well focused, although objectives are not in all cases aligned with (current) DOE goals. The Florida A&M/Bing Energy MEA structure looks interesting—the work should be followed up.

Project weaknesses:

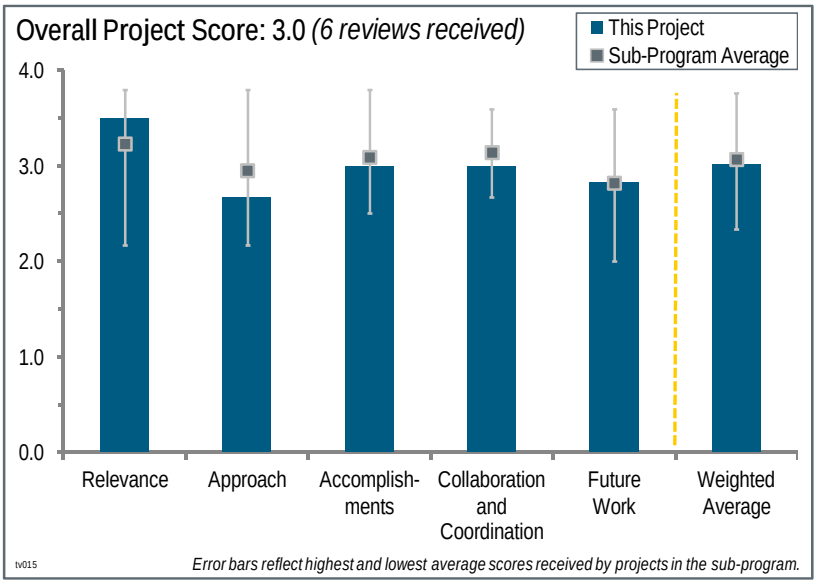
- The overall project is essentially an assembly of unrelated individual projects.
- There was no coordination of sub-projects and no selection of sub-projects on the basis of a single, common technical goal or objective. The project includes an inefficient process in terms of technical oversight and overhead costs (for FSEC), and it is of questionable benefit to the Program.
- The overall project represents a handful of discrete projects that have no relationship to one another. "Advanced Hydrogen Storage System" did not produce repeatable results. "Hydrogen from BioWaste" did not demonstrate results that were measurable. The project leadership team has undergone turnover, resulting in delays and starts and stops for many projects. There has been poor technology transfer despite the large number of universities involved. FSEC did not demonstrate enough initiative to quickly make adjustments and decisions related to the work plan when difficulties were encountered.
- FHI is a collection of individual, unconnected projects with widely varied activities and objectives. DOE resources have been divided among many relatively small projects, with no overarching focus. There is a lack of clear linkage among most project activities, DOE technology targets, and barriers to achieving the targets. There is minimal or no collaboration with industry for most projects.
- The project is not focused well toward DOE targets and objectives, and it is not very collaborative beyond the borders of Florida. All tasks can be led from Florida, but there should be some national and international collaboration to optimize the efficiency and value of the project.
- The overall approach of soliciting and funding projects apart from the normal DOE FOA/AOP process is poor. The H_2 leak detection tape sub-project seems not to hit the major objective of a sensor—an electronically monitorable response (voltage output). The requirement of visual inspection to see tape change color seems to greatly limit applications. The low-cost catalyst sub-project needs to show industry interest. It is not clear how the bipolar plate project is providing new materials, processes, or products.

Recommendations for additions/deletions to project scope:

- For the "EnerFuel HyTech Rest Area," DOE should ensure that operational data is collected from the demonstration. Regarding the academic program, someone should evaluate if this activity is replicable to other universities. The activity does not do DOE much good if it cannot be adopted other places. The H_2 storage project at USF did not appear to accomplish any goals—it should not be continued.
- Project activities should be completed this year as planned.
- Four reviewers had no recommendations, since the tasks are all ending in December 2012.

Project # TV-015: Wind to Hydrogen

Kevin Harrison; National Renewable Energy Laboratory



Brief Summary of Project:

The main objectives of this project are to: (1) perform characterization and performance testing on electrolysis systems developed from U.S. Department of Energy (DOE)-awarded projects; (2) test electrolyzer stack and system response with typical renewable power profiles; (3) develop and validate a system to characterize hydrogen (H_2) mass flow; (4) identify opportunities for system cost reduction and optimization as they pertain to electric utilities; (5) characterize, evaluate, and model integrated renewable energy systems (IRESs); (6) evaluate the reliability growth of IRESs; (7) characterize electrolyzer performance with variable stack power; and (8) design, build, and test shared power electronics and direct-coupled renewable-to-stack configurations.

Question 1: Relevance to overall DOE objectives

This project was rated **3.5** for its relevance to DOE objectives.

- This project is relevant to the goals and objectives of the DOE Hydrogen and Fuel Cells Program (the Program). H_2 production is an important component of the Program and electrolysis is being supported by the Hydrogen Production and Delivery sub-program.
- The project is quite relevant to DOE plans and objectives. It is especially useful to include testing of DOE-funded systems.
- H_2 storage of intermittent renewable energy could provide a much-needed boost to renewable energy deployments.
- Validation of electrolyzer systems is essential, but it is unclear how such manufacturers/systems are selected. Validations were only presented for Proton OnSite, and it was unclear if Proton OnSite is the only manufacturer. Responses to tests are only assessed by a single person, and it is unclear if there is a panel.
- Electrolyzers are “reverse fuel cells” and have a lot in common with regular fuel cells. They also can work in conjunction with fuel cells in a renewable microgrid. For that reason, it is critical to the fuel cell industry to prove itself in this new and potential huge market—Ancillary Grid Support Services. With many states adopting renewable portfolio standards, utilities are having to deal with renewables whether they initially wanted to or not. Electrolyzers have been mentioned in the context of renewable energy storage and grid support, but not to the same degree as batteries, nor has there been much, if any, technology validation from independent sources. This project provides evidence that electrolyzers can perform the grid frequency support mission. This effort ties in three parts of DOE: the Office of Electricity, the Fuel Cell Technologies Program (FCT Program), and the Wind Program. Integrated projects across multiple DOE programs can have a higher payoff.
- The relevance of this project can be considered from multiple perspectives: performance testing of electrolysis systems developed by other DOE projects, technology development and understanding, testing and characterization of electrolyzer system response to renewable power profiles, and evaluation and modeling of integrated renewable energy systems. Some technical targets for water electrolysis H_2 production are provided on slide 4 of the presentation. While statements on development needs are also included, the slides and oral presentation did not establish direct linkages between project activities and progress toward meeting the targets.

Question 2: Approach to performing the work

This project was rated **2.7** for its approach.

- The independent component testing of electrolyzer and fuel cell systems is highly valued.
- The approach focuses on testing and evaluation of electrolysis equipment. The real value of this project should be the benefits it contributes to the commercialization and implementation of this H_2 production technology. It is not clear how the approach supports the dissemination of results of the study and its potential impact on the H_2 production marketplace to obtain renewable, cost-competitive H_2.
- The project addresses many barriers to the use of electrolyzers in a microgrid. A significant amount of testing is included in this project, so as to leave little doubt that the results are indicative of actual performance. The only negative is that so many areas were addressed in the project approach. It might have been too much, especially because the project is only given $450,000 or so per year in resources. For instance, the H_2 pressure vessel mass flow measurements were not critical to the outcome of the project. It was pointed out by one of the reviewers that off-the-shelf H_2 gas measurement systems are available for purchase. On the other hand, it is a credit to the initiative of the co-principal investigators (PIs), who were willing to take on so much. Good partners were chosen for the effort. Having a utility (Xcel Energy) involved was critical, as were all of the domestic electrolyzer manufacturers.
- To someone not familiar with this project, the activities seem to go in too many directions and try to serve too many purposes. The approach stated in slide 5 supports this conclusion, as does the overall presentation. There is good work being accomplished, but the clarity of the project's primary purposes is somewhat lost in the maze of its varied activities. Besides evaluating and validating technological progress, the project has elements of a test facility, a user test facility, technology research and development, a diagnostics laboratory, technology modeling, and test procedure development.
- The approach seems sound, but it is limited and somewhat arbitrary—it is unclear how systems for testing/validation are chosen. It seemed that only companies willing to donate a system could participate, and it would be interesting to know about the others. It is unclear if all of the manufacturers are approached to participate.
- This project is investigating a number of useful controls and system improvements to achieve optimum integration of electrolyzers with inherently variable alternative energy systems (especially photovoltaic and wind power). Correctly, cost reduction is the main barrier addressed. Although this is an excellent engineering simulation, it is not always clear why the work needs to be largely experimental. It would seem that more of the work could be modeling, based on the previously known performance of electrolyzers, control components, and wind power. There is question as to whether it is always necessary to validate with an actual integrated system experiment.

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

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

- Great progress has been made—the PI seems to really understand the systems and is completely capable of conducting these assessments. More coordination among the manufacturers for arranging/scheduling validations for meaningful comparisons would have been appreciated.
- Progress on this project seems to be fairly slow. A lot of time and effort was devoted to building and qualifying a mass control system when readily available mass flow and controllers could have been used. It was not clear why this approach was taken.
- Great progress was achieved on all fronts. Having the data on electrolyzer performance in a renewable (simulated) microgrid, especially more than 6,000 hours, was a significant accomplishment. Industry benefitted as well, as exemplified by the PI telling of a situation with Proton OnSite in which "tightening some nuts" on the electrolyzer was the solution to a set of field failures that had the company puzzled as to its cause. The IRES demonstration does indeed fill in gaps where industry does not have the data. Opportunities to reduce system costs—based on real data—will be identified and shared with industry as a result of this effort. Excess costs were mitigated by testing electrolyzers that were bought under other DOE-funded projects.
- Some activities reported on in the presentation are impressive. Examples include the characterization of stack performance under varying current conditions, development of the prototype diagnostics laboratory now available at the National Renewable Energy Laboratory (NREL), mass flow measurements, and construction of

an integrated "complete system" for testing and evaluation. As a project that emphasizes technology development and testing, contributing to technology progress toward targets—or at least documenting progress—is important. However, no specific information was provided about how the work on this project has overcome barriers to achieving DOE's H_2 production goals and targets. Slide 2 states that the project started in 2003. In the oral presentation, however, the PI said it is a "new project" this year. In either case, quantitative information is needed on how the project is overcoming barriers.

- A reasonable number of accomplishments have been achieved, and real-world data have been generated. It was not always clear exactly what was done in the last fiscal year and what may have been done earlier. The measurement of H_2 production via a pressure technique is good and can be directly used in the final commercial products. There were many public presentations and publications. One or two examples of problem solving for vendors were cited. This is excellent, but it begs the question of whether commercial suppliers of fuel cells and other components should be expected to contribute financially to the laboratory effort. After all, the end commercial market will be theirs.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.0** for its collaboration and coordination.

- This project featured excellent collaborations and communications.
- There are collaborations with various governmental agencies, but for the most part collaborations seem to be superficial. More collaboration with actual hardware developers, working together in the hardware testing and evaluation activities, would strengthen the project.
- Validation projects should be "objective and independent" rather than focusing on single manufacturers, and they should not be derailed by additional responsibilities such as development. The validation aspects were diluted in some way because of other distractions.
- Each institution that is a part of this team (California Fuel Cell Partnership, California Department of Food and Agriculture, electrolyzer original equipment manufacturers [OEMs], and Xcel Energy) has benefitted from the knowledge gained from this effort. NREL in general does a superb job in collaborating, and the co-PIs in this project were no exception. More could have been done in terms of collaborating with the U.S. Department of Defense, which has funded a large amount of federal microgrid work to date. DOE will certainly benefit from the collaborative nature of this project, involving objectives from the DOE Wind Program, FCT Program, and Office of Electricity. Perhaps it will generate ideas for further projects in this area.
- Slide 19 indicates that the project staff has collaborations with a variety of organizations on a variety of topics related to electrolysis and H_2 production. Work with Xcel Energy and the California Department of Food and Agriculture was cited in the presentation. Slide 10 mentions a contract between two California government agencies, but it does not identify NREL's role. Information on funding for this project from sources other than DOE would be helpful.

Question 5: Proposed future work

This project was rated **2.8** for its proposed future work.

- The future path is unclear—it looks like the project is coming to a close.
- Future plans seem to be more of the same. Work in the future should focus on integration with private-sector hardware manufacturers bringing competitive hardware and electrolysis processes to the commercial marketplace through incremental product improvement.
- It appears that this project—or set of projects—has built upon previous milestones in a systematic and logical manner. It was difficult to make an assessment of the past 12 months of work because the key decision points had passed. The PI laid out a logical path forward for after this project is completed in October 2012.
- Future work plans, as presented on slide 20, include validation of electrolysis H_2 production systems, continuation of stack testing, continuation of work on mass flow, and development of a renewable electrolysis system integration simulation tool. No information is provided on milestones, work priorities, or costs projected for various elements of the project.
- In general, the proposed future work seems reasonable. The effort should be continued. Given the obvious commercial potential for electrolyzer-alternate energy integration, it is reasonable for the electrolyzer and utility industries to take over more of this work.

Project strengths:

- The project features very good systems analysis, reliability of data analysis, and testing protocol.
- Practical H_2 production (electrolysis) and alternative energy integration work are strengths of this project.
- Good research facilities have been accumulated at NREL. The project has good testing capabilities to provide third-party validation of technologies.
- Strengths include the experience and capabilities of NREL's team; NREL's credibility and collaboration with U.S. electrolyzer manufacturers; and the importance of improved knowledge and understanding about integration of renewable energy, H_2 production, and H_2 storage.
- The project has many strengths:
  - Incorporation of real-world renewable microgrid scenarios into a broad demonstration.
  - Significant amounts of data generated.
  - Strong team assembled for the effort across all key disciplines.
  - Leveraged other programs' previously purchased assets to keep costs down, making the project achieve even a greater degree of accomplishments compared to the cost.
  - Utilized actual wind profiles in the demonstration.
  - Included all domestic electrolyzer OEMs in the project.

Project weaknesses:

- The project team is trying to do too much, resulting in project dilution. The project should focus on testing and validation only.
- The project probably needs more financial support from industry.
- A minor weakness might be the lack of full system analysis and integration.
- This project seems to be doing the job that should be done by private-sector hardware developers—testing and evaluating commercially available equipment. The project should be refocused on precompetitive technology issues that would benefit the electrolysis community as a whole.
- The project may have taken on too many tasks—specifically the design, build, and test of an H_2 volumetric mass flow system. There are already commercial off-the-shelf products on the market for that.
- The broad scope of activities included within the project is a weakness. Resources are spread across too many types of work. Other weaknesses include the lack of a clear linkage among project activities, DOE technology targets, and barriers to achieving the targets.

Recommendations for additions/deletions to project scope:

- The project is almost over. Sharing the results with the Technical Director of the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Joint Concept Technology Demonstration is highly recommended. That effort is in the midst of performing a Military Utility Assessment on microgrids (to include renewables), with United States Pacific Command overseeing the effort. In response to a question, the PI stated that the primary project goals are testing of electrolysis H_2 production technology developed by industry, and improved understanding and insights about renewable energy to H_2 systems and related technologies. DOE should consider narrowing the scope and types of activities included within this project. A suggestion is to focus on creating a robust, integrated user facility capable of evaluating technologies and components developed by industry, universities, and other national laboratories. Other work, such as research on mass flow, technology development, and control strategies, could be performed by other contractors.
- The team should use an integrated wind/electrolyzer/storage/fuel cell system to verify models of variable wind energy storage. This may not fall under the scope of this project, but someone at NREL should conduct a dynamic analysis of a wind/electrolyzer/storage/fuel cell system, matching the dynamic supply of wind electricity in the Boulder region with the dynamic electricity load; thereby establishing the economic value of H_2 storage with different storage times (assessing the value of days, weeks, months, and hopefully seasonal storage). This project could then conduct the integrated experiment suggested above to validate the dynamic model.
- This reviewer had no recommendations.

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