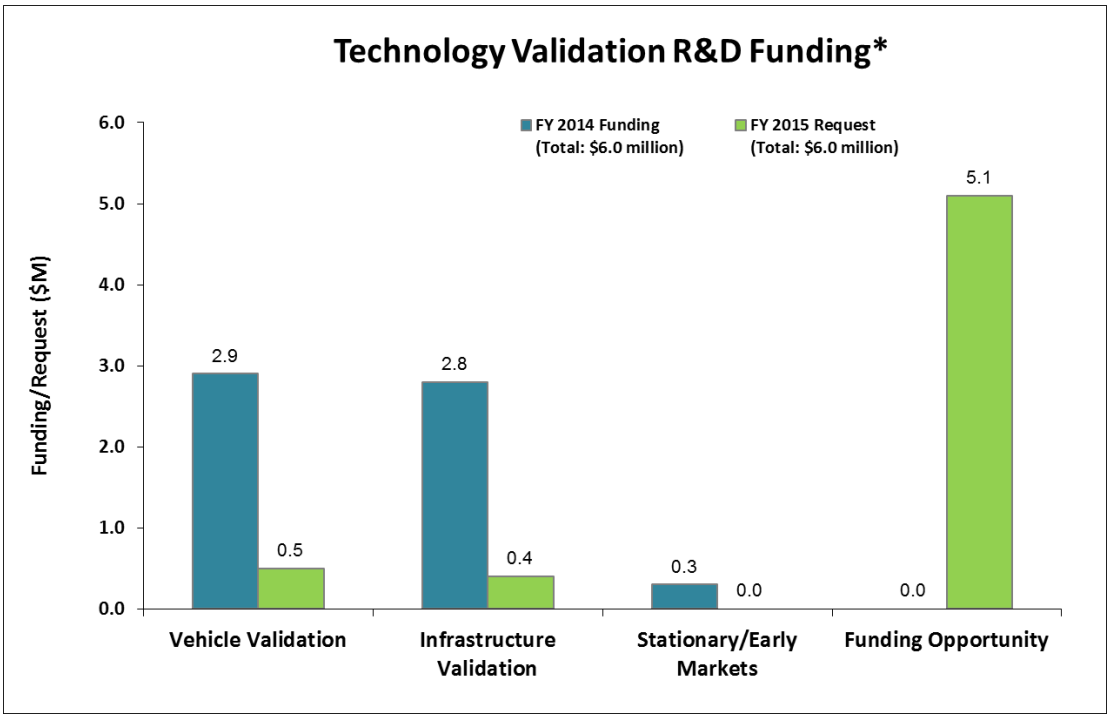
2014 — Technology Validation
Summary of Annual Merit Review of the Technology Validation Sub-Program

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

In general, the reviewers believed the sub-program area was adequately covered. They noted that the role of the Technology Validation sub-program within the structure of the Fuel Cell Technologies Office was clearly identified. Reviewers stated that progress related to projects was clearly presented, and that plans were identified for addressing issues and challenges. They characterized the partnership with NREL's data collection/analysis team as key to the success of the sub-program's efforts and to achieving its goals and objectives. Given the high failure rate observed with compressors, reviewers saw continuing to evaluate and validate compressors as important. Reviewers also suggested that the sub-program more explicitly state the top challenges in each validation area.

Technology Validation Funding:

The Technology Validation sub-program's funding portfolio will enable it to continue to collect and analyze data from fuel cells operating in transportation applications (e.g., light-duty vehicles, medium-duty trucks, and buses), stationary and early market applications (e.g., material handling and backup power), and hydrogen infrastructure activities (e.g., fueling stations and components). Analysis of several hydrogen refueling stations and fuel cell electric vehicles in California and the Northeast will be the main focus of the data collection activities. The fiscal year (FY) 2014 appropriation was $6 million. The FY 2015 request of $6 million is subject to congressional appropriations.



***** Subject to appropriations, project go/no-go decisions, and competitive selections. Exact amounts will be determined based on research and development progress in each area and the relative merit and applicability of projects competitively selected through planned funding opportunity announcements.

Majority of Reviewer Comments and Recommendations:

The reviewer scores for the eight Technology Validation sub-program projects that were reviewed had a maximum of 3.8, a minimum of 2.5, and an average of 3.3. Key strengths identified by reviewers in all of the Technology Validation projects were (1) the excellent participation from collaborators and (2) the potential for the projects to contribute valuable data to gain enhanced insights and to successfully deploy hydrogen and fuel cell technologies. Reviewers also observed that NREL's approach for collecting, securing, and analyzing data is well established and trusted by project collaborators.

Fuel Cell Electric Buses: Reviewers noted that the fuel cell electric bus data collection project is critical to the wide-scale adoption of fuel-cell-powered electric buses, with tangible results providing a consistent history of technology performance and cost improvements over time as well as valuable insights for both U.S. Department of Energy (DOE) project managers and transit fleet operators. Reviewers suggested that more transit agencies should be involved in the evaluations, and that performance and reliability data from similar applications in other countries should also be considered.

Stationary Fuel Cells: Reviewers remarked that the data evaluation process for stationary fuel cells should be more clearly linked to key research or technology deployment questions, and that feedback should be given to DOE about the gaps in technology performance and market status. They also suggested that it would be valuable to evaluate stationary fuel cell deployments in various other states.

Material Handling and Backup Power: Reviewers observed that NREL's business case analysis of the economic and operating performance of fuel cell forklifts and backup power systems added value to the commercialization of niche market hydrogen and fuel cell technologies, as well as contributed to the commercial ramp-up of these systems. Reviewers recommended that industry should be encouraged to keep providing data, and that qualitative verbal feedback from operators of these systems could be obtained to provide enhanced insight.

The hydrogen component validation project's evaluation of compressor failure mechanisms was seen to have the potential for a large impact because compressors present key reliability issues in hydrogen stations. Reviewers also suggested obtaining input from other compressor suppliers and performing a technoeconomic analysis of the impact of the project.

Reviewers viewed the validation of an advanced high-pressure electrolyzer as a project with a real-world strategy and the potential to lower costs. An area identified as needing more attention was cost targets and estimation, along with evaluation of the economic impact of installing high-pressure electrolysis. Reviewers also wished to see evaluations of how the technology could be scaled up.

Fueling Stations: The hydrogen fueling station established at California State University, Los Angeles, was viewed by reviewers as having the potential to identify optimization potentials for components of electrolysis-based hydrogen fueling stations, while having an educational aspect as an added benefit.

The Gas Technology Institute and Linde collaboration to build and evaluate five hydrogen fueling stations in various California locations was viewed as having the potential to enable comparisons across stations and help expand the network of stations nationwide. Risk analysis and addressing costs targets were suggested as additions to the project goals.

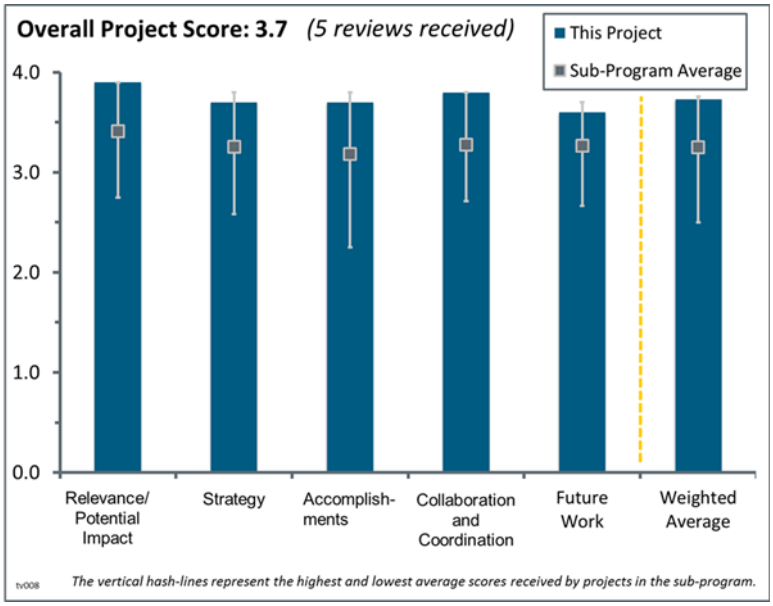
The Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) project was viewed as having the potential to contribute to the deployment of hydrogen stations and to address real-time technology performance and operation issues, but it was also perceived as too new to comprehensively evaluate. Reviewers suggested that further attention be devoted to characterizing H2FIRST and that indicators of project success be measurable.

Project # TV-008: Fuel Cell Bus Evaluations

Leslie Eudy; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) validate fuel cell electric bus (FCEB) performance and cost compared to U.S. Department of Energy (DOE)/U.S. Department of Transportation (DOT) targets and (2) document progress and lessons learned on implementing fuel cell systems in transit operations to address barriers to market acceptance.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.9** for its relevance/potential impact.

- The DOE Hydrogen and Fuel Cells Program (the Program) has devoted substantial resources to fuel cell electric vehicle (FCEVs) and hydrogen infrastructure technology development and validation. Buses are an important target 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, have made a vital contribution to understanding the status of technology development relative to DOE 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 making decisions on public and private investment in technology research, development, and commercialization. Over the past decade, this work has been an important contributor to achieving unbiased and supportable conclusions about progress toward DOE and DOT targets—bus fuel economy, FCEB utilization, fuel cell lifetime and durability, road call frequency, cost, and other metrics.
- This project continues to produce tangible results and excellent analysis on FCEBs used by transit companies in real-world conditions.
- This project is highly relevant because the deployment of FCEBs is key to getting widespread acceptance of hydrogen and FCEVs.
- This data collection of FCEBs is highly relevant and has high impact potential.
- The continued monitoring of field tests is essential to advancing commercialization of fuel cells for transportation.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.7** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- Since commencement of bus evaluations in 2003, the principal investigator (PI) and the project team have steadily refined this project's data collection, analysis, and reporting activities. With ongoing feedback from data providers and users, NREL has developed superb procedures and protocols for data collection

and processing. Relevant results of NREL's analyses are provided to each transit agency associated with the project. NREL publishes reports—including an annual FCEB status report—that provide comparisons among FCEBs; conventional buses; and other buses with advanced technologies, such as hybrid electric buses. These reports provide outstanding documentation for industry, government, and the public. During the past year, data has been collected from three transit agencies operating a total of 34 FCEBs. Characteristics of these buses, including the fuel cell hybrid power plants, are included in the project presentation. Data are collected on conventional diesel buses, as well as natural gas and diesel hybrids, for comparison purposes. Actions have been taken to continually improve project results and benefits. These actions include acquiring data on the performance of advanced technology hybrid electric buses, and analysis of the factors that contribute to bus downtime and non-availability.

- The project has a consistent approach and is reaching out to other transit agencies to increase the number of buses to be evaluated and to replace buses that are already evaluated. The technology readiness levels developed by NREL help in assessing the progress toward achieving the technical targets. The iterative process adopted will lead to a successful evaluation of technology performance.
- The reviewer cannot imagine how this evaluation of FCEBs could be improved.
- All the key aspects are covered.
- The analysis includes a nice mixture of technologies and locations. Perhaps the team can get more details on the duty cycle for each FCEB, because there are so few. It would also be useful to know if the miles between road calls are prescribed by the manufacturer, and if the project team is being overly conservative. Additionally, the project team should highlight which systems had the least and greatest maintenance costs. It is not clear whether there is some way to get details on the power plant's actual useful life. If possible, it would be beneficial to compare current U.S. findings to those of Europe and other countries to get a sense of how close this technology is to commercialization.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.7** for its accomplishments and progress.

- This project provides the best, most objective, and most independent indicators of progress toward the government's targets and goals for metrics associated with FCEBs and related hydrogen infrastructure. The PI's presentation includes readily understandable graphs that enable the reviewer to compare targets and bus performance for key metrics. These metrics include fuel cell hours of operation, bus availability, fuel economy, and reliability (miles between road call). Results are generally distributed by month for each transit agency. FCEB performance is compared to that of other buses. The comparisons are made to previous generations of FCEBs; details are provided on the improvements in performance and progress toward targets. 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 (e.g., hours in service before repair or replacement) of fuel cells used in operational buses.
- The cost and performance of these buses have been tracked for quite some time, and it is good that new technologies are continually being integrated. The analysis is consistent and provides an excellent history of performance and cost improvements over time. A total of 34 buses are evaluated. Recording more than 7,000 hours on the fuel cell power plant that was used to run the buses is a real accomplishment. The miles between road calls have shown improvement from the first to second generation.
- There is an excellent set of accomplishments. There is a very good comparison between stage one and stage two.
- It is difficult to see how this project could be improved, other than through the deployment of more FCEBs, which is obviously beyond the control of this project.
- This is nice work. The summary report is something to look forward to.

Question 4: Collaboration and coordination with other institutions

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

- As indicated, particularly on slide 19, NREL's FCEB data project involves collaboration and routine communication with many transit agencies throughout the United States. Funding for many of the buses evaluated is provided through the National Fuel Cell Bus Program managed by DOT's Federal Transit Administration (FTA). 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 who 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 projects. NREL's team also maintains excellent communications with many organizations sponsoring related activities, both in the United States and internationally.
- This research is all about coordination with the transit agencies. NREL has done an excellent job in working with them over time. Most likely, the transit organizations also appreciate working with DOE and NREL on this project.
- The PIs are striving to put in place as much collaboration with FCEB activities as they can.
- By definition, the PI must collaborate with the bus agencies to collect these data and must collaborate with the fuel cell and bus manufacturers to interpret and analyze the data.
- It is nice to see a schedule of current and future transit agency participants. It would be beneficial to know how this project compares with Europe and other countries doing similar programs.

Question 5: Proposed future work

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

- The decision to find additional transit companies and establish a relationship is a good way forward. NREL should continue to work with different fuel cell configurations, such as hybrid FCEBs versus FCEBs. NREL has seen significant progress, but the ultimate technical targets need to be realized and demonstrated.
- 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 FTA's National Fuel Cell Bus Program. Slide 21 of the presentation provides an excellent display of fuel cells and other advanced technology bus demonstrations that will begin during the coming year. It is anticipated that NREL's FCEB evaluation project will include fewer FCEBs; however, it will acquire data and report on FCEBs located in both California and other states. Data collection will begin in Birmingham, Alabama, and Austin, Texas, later in 2014. NREL's team intends to continue its dialogue with transit agencies and others regarding data collection at new sites.
- The plan to expand coverage to FCEBs in the East will help expose public and transit agencies to a wider audience than just the West Coast.
- The future work is well focused.
- The team should add information from other countries to gauge how close to commercialization this technology may be.

Project strengths:

- There are numerous project strengths: the experience and expertise of the NREL team leader and her team, funding support from FTA, active collaboration and interactions with manufacturers and users of advanced technology buses, the quality of information in reports published by the project, and a solid contribution to FCEB progress for a relatively small expenditure of total Program resources.
- The project covers all of the important aspects and provides valuable information.
- The experienced PI and staff who have analyzed FCEB performance for many years are a strength.
- The PI has been very thorough in her evaluations and reports, reflecting professionalism and expertise in working with transit organizations.

- The relationship with a number of transit agencies is commendable.

Project weaknesses:

- The BC Transit buses are going out of service this year. There will need to be some clarity on the related statistical analysis.
- The impact of the fact that the BC Transit buses are no longer in operation is not clear.
- A better job could be done of leveraging global relationships to understand time to commercialization for the technology.
- 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 FCEB designs, the variability of duty cycles, and differing service profiles. Changes in bus fleet management can cause problems in acquiring data needed by NREL for analysis. This is an issue that NREL is currently addressing at two agencies, as noted in reviewer-only slide 25.

Recommendations for additions/deletions to project scope:

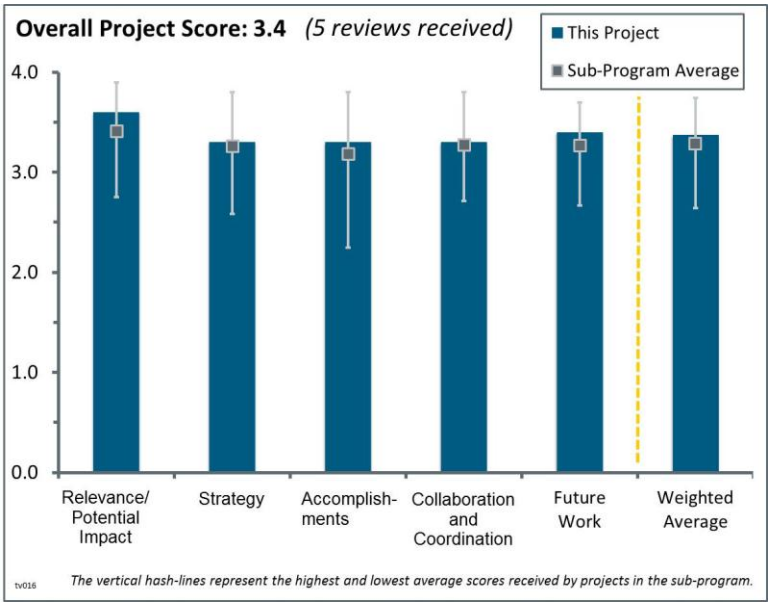
- DOE is encouraged to maintain and continue using NREL bus data analysis expertise, which has been built as a result of this project. Ideally, all FCEBs operating in the United States should be included in NREL's evaluation project. DOE and DOT managers should do what they can to ensure that this is the case. The PI mentioned sharing information with organizations in other countries. Continuing this initiative is encouraged, leading to comparisons of performance results for FCEBs around the world.
- The project team should add more transit companies.
- The project team should add details on the best-available FCEB technology from other countries.

Project # TV-016: Stationary Fuel Cell Evaluation

Genevieve Saur; National Renewable Energy Laboratory

Brief Summary of Project:

The objective of this project is to independently assess, validate, and report operation targets and system performance for stationary fuel cells under real-world operating conditions. Research addresses the lack of data on stationary fuel cells in real-world applications and provides data and context for codes and standards.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.6** for its relevance/potential impact.

- The project is well targeted and beneficial to the research goals of the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program (the Program). Having these data is essential for evaluating models that forecast ownership cost.
- The project provides a necessary service to measure how well stationary fuel cells compete.
- The project is a very good initiative to gather data from existing demonstration projects, taking into account the accessibility of data, which is on a voluntary basis and makes the project very challenging.
- The project relevance is high.
- The project appears to have good coverage of the different types of fuel-cell-combined-heat-and-power (CHP) applications and fuel sources. The project also appears to capture data from a meaningful proportion of the market, and in that sense it could be considered to be representative, although the fact that data collection is based on voluntary participation means that there could be bias in the data (poor performers may be less willing to share data compared to good performers).

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.3** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- This is a very good strategy for data collection. The proprietary nature of the feedback provided to companies is an incentive for them to participate.
- The project has set up good partners and collaborations for the collection of data.
- The goal of this effort is to collect more data on stationary fuel cells in real-world applications. This effort addresses the dearth of information on how stationary fuel cells work in practice and provides important supporting information for setting codes and standards, as well as for defining best practices. The research effort has focused on independently assessing, validating, and reporting operation targets and stationary fuel cell system performance. This project makes strong and effective use of the National Fuel Cell Technology Evaluation Center (NFCTEC) and the National Renewable Energy Laboratory (NREL) fleet analysis tool. There are concerns about statistical and data evaluation methods used in the effort. These concerns arise in part because the principal investigator, both in the presentation and during questioning, did not communicate how the project is dealing with issues such as data quality, aggregation of data, and

representativeness of data. The design of the data collection process was not clearly linked to a key research question or a DOE technology-deployment question. One of the key strengths of this effort is making links between detailed data products and composite data products (CDPs). However, the researchers were not fully aware of the limits that arise from the structure of the data compilation process. A broad range of systems are being assessed, such that there could be limited data for some CDPs, and are raising questions of statistical power, which should be addressed. When collecting data, it is important to have some concept of how the data might be used. This is a potentially very valuable data set, but it would be even more valuable if the data collection/evaluation process were better linked to some key DOE questions.

- The project gives a good overall picture of where the fuel-cell-CHP market stands (e.g., in terms of installed capacities and number of projects) in relation to competing technologies. However, there is a lack of disaggregation according to technology sub-categories, such as specific CHP capacity ranges (small/residential and large/industrial), operation under different climatic conditions, etc.
- The strategy is good; however, mixing all ranges of applications and types of technology creates aggregated data, which might cause the project to lose credibility when trying to extrapolate data, e.g., for 1 kW systems. The manipulation of data is very simple and based on too many assumptions; the average is not representative for all validated data. The purpose of collecting the data is unclear; perhaps NREL is going to analyze the data and forecast an evolution over the next 20–30 years.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.3** for its accomplishments and progress.

- There are very good accomplishments.
- The project is well focused on key barriers to expand and understand the use of stationary fuel cells. The project is on budget and on schedule. The researchers have made very good progress with regard to both the specific project goals and the broader goals of the Program. The work is up to date with respect to all project goals. However, it should be noted that, based on the project milestones, the researchers have just started to collect operations data; this is an important opportunity for future work, and attention needs to be given to the statistical data quality and data relevance issues.
- The project is directly assessing market status compared to DOE targets on costs, efficiencies, availability, and operation. What is missing is the feedback from this aggregated information into the orientation of the Program and efforts. A snapshot of the market is useful; however, recommendations should be made regarding gaps in the technology performance and market status coming out of the data/analyses that should be addressed by the Program.
- Although similar recommendations were already provided last year, not much progress has been made in defining the different power applications and collecting/reporting data for each of them. Missing sufficient "points" should not stop NREL from collecting literature data/benchmarking data from other units in the field.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.3** for its collaboration and coordination.

- This project has very strong and essential collaboration with agencies that provide data. The research team has been very effective in establishing initial collaborations, but it needs to expand these collaborations in order to have more robust and relevant data. It is not clear that there is a sufficiently strong link with statisticians who are experts on data evaluation with regard to the reliability and credibility of the conclusions drawn from collected data.
- There is excellent communication with the California Self-Generation Incentive Program in collecting data from the portfolio of projects that can possibly provide the data.
- The coordination with California stationary fuel cell projects is excellent.

- The project appears to have good collaboration with state bodies and with original equipment manufacturers for data collection. However, some data, such as the 27% electrical efficiency figure, is surprising, and leads one to question whether there is adequate coverage of the market.
- There is not so much of a team, as there is NREL, plus a reviewer, a subcontractor, and five suppliers.

Question 5: Proposed future work

This project was rated **3.4** for its proposed future work.

- The proposed work is in line with the plan and recommendations from reviewers in previous years.
- The researchers have organized the work to meet project goals in a sequential and logical manner. In planning their future work, it will be important for researchers to address an analysis of sensitivity about cost/use with regard to data quality and relevance.
- The future work is very reasonable.
- The researchers have foreseen the disaggregation of the data into sub-technologies and applications, and they are also addressing the need for more data, although it is not clear what the probability of success will be in establishing such partnerships for data collection.

Project strengths:

- The project is leveraging a large pool of data that has been collected at NREL. It makes strong and effective use of NFCTEC and the NREL fleet analysis tool. The project is well focused on key barriers to expand and understand the use of stationary fuel cells.
- The project is necessary and will bring to DOE some data about the performance of stationary fuel cells and how far they are from the commercial stage.
- This is a well-designed project with useful market data and analyses.
- The large number of California stationary power projects is a strength.

Project weaknesses:

- Greater data points are needed to make conclusions at more disaggregated technology/application levels. The researchers should provide feedback, based on the analyses, regarding technology performance areas that are behind and potential gaps to feed into the present and future orientation of the Program.
- Currently, the project does not address metrics of reliability in the collection and interpretation of data. It is also limited by having access to only California data. The researchers do not make clear how they control for and/or address small data problems, particularly in the process of data aggregation (that is the effort to produce composite data).
- More information is needed to clarify the related market segments in the United States for stationary fuel cells. If necessary, information from literature should be sought and a better aggregation of data should be performed. The average cost per kilowatt is not credible (already below the target of DOE), while the electrical efficiency is very low (27%).

Recommendations for additions/deletions to project scope:

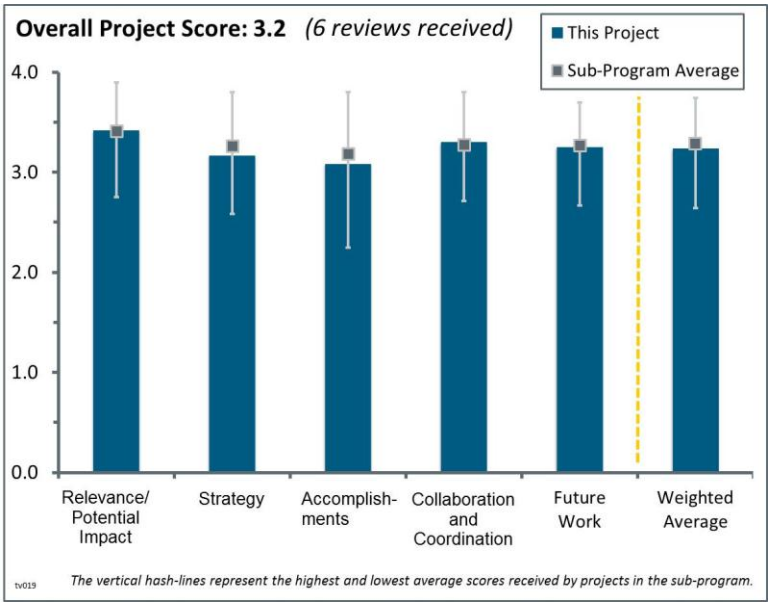
- More data should be analyzed, and a better aggregation/sensitivity analysis should be performed. As a possible usage of data, scenarios should be looked at and forecasts should be produced.
- More state partners are needed to provide geographic variability. In the data collection design, it is important to consider research hypotheses that will be explored using these data. It is still not fully clear what these data will be used for. The researchers should spend some time with DOE and its California collaborators to make some “value of information” assessments with regard to what and how much data to collect.
- It would be nice if this project could be expanded to cover nationwide stationary power systems.
- Collection of more data (which the project is already doing) and feedback on the Program gaps and areas of focus needed to cover those gaps is recommended.

Project # TV-019: Hydrogen Component Validation

Kevin Harrison; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) perform highly accelerated life testing on hydrogen infrastructure components to reproduce failures on a shorter time scale; (2) correlate results to real-world usage with statistical methods; and (3) work with a manufacturer to improve designs and reduce downtime for air, dispenser, control electronics, and hydrogen compressor systems.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.4** for its relevance/potential impact.

- Compressors are a key reliability issue in stations, and improved characterization of failure mechanisms is critical to improve performance. Available data is also lacking, so this is an important addition to the knowledge base.
- Data collected on hydrogen stations confirms that compressor failure is a leading contributor to downtime and maintenance requirements. Therefore, focusing attention and resources on understanding failure mechanisms—and determining corrective measures to extend compressor life and improve performance—is appropriate. Project objectives include both accelerated testing to determine causes leading to failure and working with a manufacturer to address causes and solve problems through improved design.
- Compressors are a key aspect of the refueling station, yet they are high cost and have inadequate reliability. Consequently, a technology validation project to better characterize and understand them, as well as lead to higher-reliability compressors for hydrogen application, is a worthy goal.
- This is a highly relevant project for distribution of hydrogen fuel to vehicles.
- The project is very relevant for addressing one of the main components, which is the source of more than half of total maintenance hours. If successful, it might have a big impact (however, it is difficult to judge the real impact because no estimation of cost reduction has been produced yet).
- It is critical to focus on validating compressors, which have a significant impact on system reliability.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.2** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- Presentation slides 5–10 provide extensive coverage of the National Renewable Energy Laboratory's (NREL's) approach to the project. Equipment targeted for accelerated testing is incorporated into NREL's Integrated Renewable Hydrogen System at the National Wind Technology Center. The compressor currently being tested is manufactured by PDC Machines. In order to reach failure more quickly, a recirculation loop has been added so the compressor can be run without producing hydrogen. The test compressor is well instrumented. Test data is shared with the Pacific Northwest National Laboratory

(PNNL) as input for its dynamic compressor modeling activity. That is good. Slide 9 lists project targets, activities, and milestones. All in all, the project approach and test plan being implemented by NREL and PDC Machines seem logical and complete.
- The project is placing emphasis on compressor failure, the major component problem.
- Highly accelerated life testing is typically a good approach for device testing. Instrumenting of the system will be important to gather failure data. Using a high sampling rate and analysis for early indicators is a rational approach for a validation project.
- The strategy is good and follows the original plan; however, after only 100 hours of operation, out of the 1,000 hours planned, it is difficult to judge the possible results. The real target of the project is not clear either. No technoeconomic analysis of the total impact on the operation costs is provided so far. The approach is limited to only one technology; comparison with other existing technologies is missing.
- Overall, the strategy is worthy, but it has some weaknesses. Specifically, the "accelerated" test program is not accelerated by the normal definition of the phase. As currently structured, the plan is just to run the compressors continuously to amass hours of operation. Instead, what should be done is exploration of the specific failure modes of the compressor and then an intense repetition of those things that will make it fail. That would be a truly "accelerated" test.
- Detailed information on accelerated testing and the basis for selecting this approach is lacking.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.1** for its accomplishments and progress.

- The PDC Machines compressor has been installed and testing has been initiated. Slides 12–15 provide selected graphics and data related to test compressor performance. Slide 14 has an example of data being transferred to PNNL. The information provided is quite effective in making the case that the project is moving well toward achieving its objectives. However, significantly more test hours will be required before final conclusions about project results can be determined.
- Excellent progress has been made on evaluating compressors.
- A 6,000 psi accelerated testing compressor system is now operational, and a 12,000 psi test compressor system will soon be operational.
- The project follows the original plan and complies with the proposed objectives.
- It appears that the project is more than halfway through, and only now is preliminary pressure/energy performance data being collected. Even accounting for the upfront cost of the compressor, it seems like the project is progressing slowly with little (so far) to show for it.
- It is still very early in project: there are <100 hours of data. It is hard to tell how much progress has been made.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.3** for its collaboration and coordination.

- There is good collaboration with PDC Machines on equipment and instrumenting. It is also good to see two laboratories working together with the addition of PNNL's analysis of data.
- Evidence of collaboration between PNNL and NREL exists, and the collaboration proved to be effective to predict possible failures.
- NREL's collaboration with PDC Machines is an important element of the project and seems solid.
- Information sharing with PNNL should result in significant additional benefits for the project.
- Two cooperative research and development agreements are in place with compressor manufacturers.
- It appears that the only compressor coordination has been with the project partner, PDC Machines. This may be appropriate, but benefits would be gained from discussion of failure modes with other (non-PDC Machines) compressor companies.
- Inputs from other component suppliers are desirable.

Question 5: Proposed future work

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

- The future work is nicely summarized on slides 17 and 18. The test plan is well designed, and project plans include extensive reliability analysis. In his oral presentation, the presenter noted that NREL would like more compressor models and types to be offered for testing. Testing could take place at multiple NREL sites, including the new Energy Systems Integration Facility. In response to a question, he stated that compressor testing like that at NREL may not be unique, but it is probably the only compressor testing that is integrated into a complete hydrogen production system.
- The proposed future work is appropriate.
- The future work looks quite reasonable.
- The proposed future work is in line with the original plan.
- A good test plan had been laid out. However, it is questionable whether a meaningful mean time between failures value can be obtained with the small sample set.

Project strengths:

- There is a clear project focus on compressor performance and reliability. The project has a well-structured approach to accelerated failure testing and use of test results. Collaborations with PDC Machines and PNNL are also project strengths.
- The project is addressing the improvement of one of the components that requires most of the maintenance hours during operation; therefore, if improved, it can have a very high impact and reduce maintenance costs.
- The project addresses a key area that has had little transparency in the past.
- Development of compressor accelerating testing would benefit the entire hydrogen community.
- Accelerated testing and data analysis are the project strengths.
- This is a well-focused project.

Project weaknesses:

- There is no specific mention of a plan for sharing and dissemination of test and analytical results, other than with PDC and PNNL. Slide 19 includes a general statement on technology transfer.
- A better definition of direction and project metrics is desired.
- The accelerated compressor testing plan is not really accelerated.
- It is not clear if it will be possible to reduce the maintenance time and associated costs. Moreover, it is not clear if this can be applied to the other technologies.

Recommendations for additions/deletions to project scope:

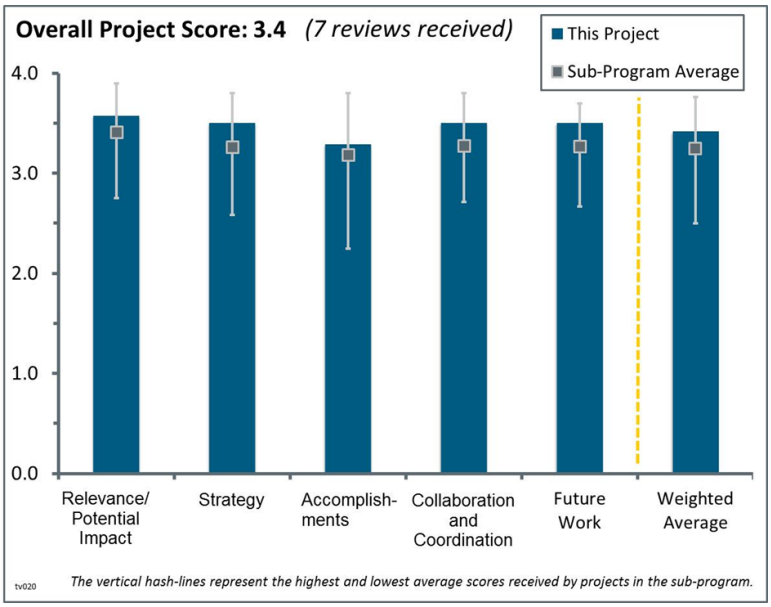
- DOE should work with NREL, compressor manufacturers, and other stakeholders to identify additional compressor models and types for inclusion in a future—and perhaps expanded—project. Test results achieved during the next year should inform a decision on continued support for similar testing of additional and redesigned compressors.
- Technoeconomic analysis of the impact of the project should be provided. NREL should explore the possibility of developing a “generic” tool that can be further used by the other technologies.
- The project needs to devote more attention to defining the specific compressor failure modes. Only then can an accelerated test plan be devised.

Project # TV-020: Validation of an Advanced High-Pressure Polymer Electrolyte Membrane Electrolyzer and Composite Hydrogen Storage, with Data Reporting, for SunHydro Stations

Larry Moulthrop; Proton OnSite

Brief Summary of Project:

The objectives of this project are to: (1) save up to 8 kWh/kg hydrogen compared to a commercial 30 bar polymer electrolyte membrane (PEM) for advanced PEM membrane electrode assemblies (MEAs), (2) save up to 3.6 kWh/kg hydrogen compared to 30 bar hydrogen supply for an advanced 57 bar PEM water electrolyzer, (3) double the usable storage per unit volume compared to first-generation storage tubes for advanced composite hydrogen storage, and (4) collect and report SunHydro station performance and technology reliability data.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.6** for its relevance/potential impact.

- The project is very relevant to a crucial need for infrastructure. The principal investigator's (PI's) presentation was exceptional: clear, direct, and complete. It was a complete and thorough presentation of a project, presenting a useful and needed data set of knowledge to advance the critical challenge of hydrogen refueling infrastructure. In the presentation, Proton OnSite states that it expects the U.S. Department of Energy (DOE) to compare and contrast Proton OnSite's evaluation to data from other projects and technologies. That comparison might be worthwhile.
- This project is extremely relevant. It aims at the important cost and infrastructure barriers to practical hydrogen fueling stations via on-site, high-pressure electrolysis and improved high-pressure composite storage.
- The project aligns well with DOE objectives and has the potential to lower operational, as well as capital, costs.
- The project fits well with DOE goals to decrease the hydrogen production costs for PEM-electrolysis-based fueling stations by improved electrolyzers and optimized system components.
- The project directly addresses the barriers outlined in the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan. The integrated approach of using other fuel cell successes in the cell stack is nice.
- Clearly, if this project can hit the cost, permitting, safety, reliability, and performance targets, it will move stakeholders much closer to behind-the-gate fast-fueling for fleets. However, if the design does include containerized high-pressure hydrogen storage, there would be concern about unplanned releases. If there is an unplanned high-pressure release, the team would want to have the hydrogen quickly vent away before a major upset could happen. There will be controlled venting, but it is not clear whether that will provide the right level of safety. Also, this concept would probably not play out at a forecourt, but it is a good initial step.
- Because SunHydro already has a fuel cell electric vehicle (FCEV) fleet and operating stations, it is in a good position to provide real-world data on vehicle fueling.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.5** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- The project's strategy is practical and excellent. It aims at the cost and infrastructure barriers to practical hydrogen fueling stations via on-site, high-pressure electrolysis and improved high-pressure composite storage. A key deliverable will be real-world operating data, especially cost data, hopefully within the $2–$4/gge DOE target range. The project is indeed well designed, feasible, and integrated with other efforts to achieve a real-world and highly instructive validation analysis. It includes all-important codes and standards considerations.
- The team is building a better cell stack to use 57 bar gas—then the compressor will be more efficient. It is good that safety, codes, and standards (SCS) are part of this project. Data collection on the SunHydro station is a plus for this project. Making equipment more efficient results in improved costs.
- Proton OnSite's presentation of specific improvement metrics was well received and appreciated. Proton OnSite offered a detailed discussion and approach to improving high-pressure fueling.
- The approach for cost reduction by integration of the new PEM stack technology and new advanced composite hydrogen storage vessels seems to be a good solution to reach the hydrogen cost targets.
- The project approach is solid and has decision points that are well thought out. The goals and objectives align with DOE targets.
- The U.S. Department of the Navy's high-pressure electrolysis unit does offer proof of concept; however, because this unit exists, it seems that there would be more details around cost targets. Also, Proton OnSite has known for some time that the voltage reduction target was a challenge, yet there was no information on any new approaches to address this issue.
- The project seems to be a reasonable approach to evaluating electrolytic hydrogen stations.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.3** for its accomplishments and progress.

- This is an extremely complete and impressive project, with extensive accomplishments and progress. During the Proton OnSite presentation by the PI, it became clear that not only was the presenter prepared for the DOE Hydrogen and Fuel Cells Program Annual Merit Review presentation, but the focus of Proton OnSite on its project task was remarkable, complete, and commendable. The presentation of its data seemed to answer every possible question before it was asked. The project was outstanding across the board.
- The team has completed the cell stack and proven it can produce gas at 57 bar. The team has six new storage systems. The project had some delays, but it was worth it. The compression, storage, and dispensing container will finally be plumbed. It will be 40 feet long, and the team is making good headway with it. The data collection and analysis has been helpful toward achieving DOE goals to produce hydrogen.
- The project has made good progress so far. Data submissions from the first station are underway, and the second should begin data collection soon. The progress is reasonable, considering the project start date.
- So far, the project has made good progress toward providing a higher-pressure MEA electrolyzer (30–57 bar), compressor system, and improved composite storage tanks. Data acquisition systems are in place and operating for SunHydro-1 and almost in place for the improved SunHydro-2. The project is slightly, but not seriously, behind schedule in a couple of areas. There are no significant new problems detected. A contractor reported a seven-month delay in the delivery of six new 280–870 bar storage tubes but indicates that the end result should be newer and better technology.
- The team seems to be making reasonable progress on implementing higher-pressure electrolysis.
- The data presented are promising in terms of cost reduction. However, it would be helpful to have adequate data for the total energy consumption (kWh/kg hydrogen) of SunHydro-1.
- The late arrival of the cylinders, the slow spend rate, and the less-than-transparent progress on permitting serve as flags that some critical potential showstoppers need to be addressed.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.5** for its collaboration and coordination.

- Anytime a project has good partners, such as Air Products and Chemicals Inc. (APCI), SunHydro, and Toyota, there is bound to be good collaboration. This project has great partners and is taking advantage of their expertise as well as their technology development.
- The principal collaboration is with SunHydro, a manufacturer of fueling stations whose vested interest is strong enough to provide cost sharing. FCEVs are provided by Toyota and storage tanks and associated instrumentation by ACPI. This is an excellent working collaboration of real-world partners.
- While Proton OnSite only had three other partners (SunHydro, Toyota, and APCI), the coordination between the four appears to be a true partnership, with each bringing its strength to the team. Proton OnSite does not appear to have added members to build its roster; instead, each team member brought its strength. It was suspected that this was a solid, high-performing team, and those results were evident in the presentation.
- The project has a strong combination of collaborators, suppliers, and other partners.
- The project seems to have good collaboration between the component suppliers.
- Collaborations are as expected, and the project partners are coordinating to meet objectives.
- The collaboration with Air Products, SunHydro, and Toyota seems routine.

Question 5: Proposed future work

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

- This is an outstanding project that would be truly difficult to improve.
- The future work is appropriate and should proceed as planned. The validation and operating data derived should be valuable to DOE and all hydrogen technology shareholders.
- The team still has to complete Phase II and determine if it is a go/no-go project. The team will continue to collect operating data and improve the components. This project's future work will likely be successful and will help toward commercializing the technology at the station level.
- The future work plan seems to be well outlined.
- The plan seems reasonable.
- The future plans are as expected for the project.
- It looks fine, as long as there are no serious bottlenecks.

Project strengths:

- The project strengths include a good existing station base and FCEV fleet; an excellent company electrolyzer history, including high-pressure electrolysis; a good platform to demonstrate a low-cost, factory-built containerized hydrogen station; and the ability to minimize cost with appropriate, separate safety zones.
- Project goals include increasing efficiency—this should contribute to lowering overall costs. Reducing the station footprint will contribute to commercialization because it could facilitate adoption at more sites where space is constrained.
- The project is completely professional in all respects: well thought out, well executed, and well documented.
- The project can clearly show which components are able to reduce the overall electrical costs for electrolytic-produced hydrogen by PEM electrolysis for mobile applications.
- The project has an excellent real-word technology validation and partnership.
- This project will be useful and will likely result in tangible results for hydrogen infrastructure.
- The team of experts that will be working on the project, including APCI, gives some additional confidence that the system will be set up and monitored properly, albeit not likely cost effectively.

Project weaknesses:

- There are no weaknesses.
- There are no weaknesses to identify.
- There are no visible major weaknesses.
- It would be good to see this project palletize the components, including all the safety features, in one pallet in order to enable ease of shipping and transportation.
- It is not clear whether the team is incorporating knowledge already gained from the previous technology validation and Clean Urban Transport for Europe (CUTE) projects, especially with containerized high-pressure hydrogen in International Organization for Standardization (ISO) containers. It would have been helpful if the team had given a high-level review of key findings during hazard identification analysis and hazard and operability analysis. The project needs a deep dive on costs.
- The team has not shown any propensity to conduct hydrogen cost estimation or determine the economic impact of installing higher-pressure electrolysis. The PI could not answer simple questions, such as the total energy requirement for electrolysis; all he showed was the net savings in energy in kWh/kg of hydrogen (and even here, he showed two estimates for savings—3.8 kWh/kg and 8 kWh/kg—and did not explain the difference).

Recommendations for additions/deletions to project scope:

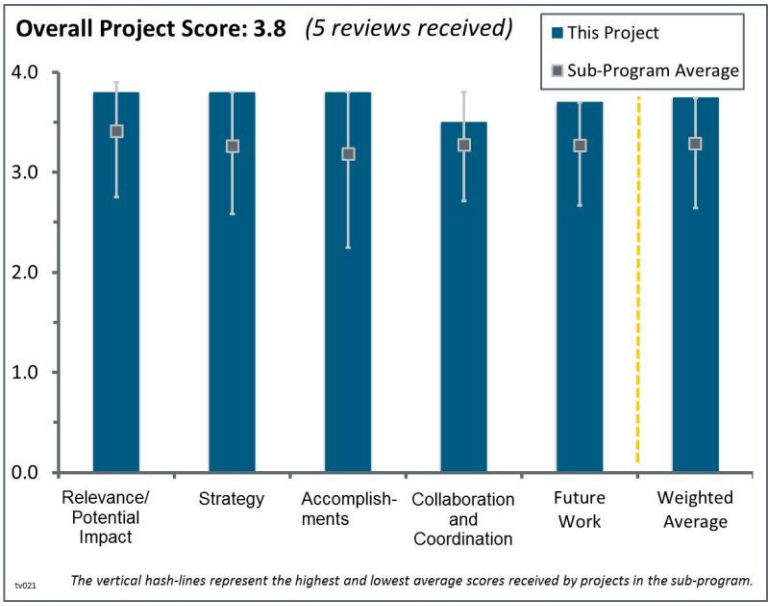
- The team should integrate the two 40-foot containers showing all the required SCS. It is not clear whether it is possible to integrate all components into one pallet. The reviewer believes that Teledyne had a similar product, which it produced. The team should check this out.
- It would be nice to see more on how the station could be scaled up to meet a need for larger quantities of hydrogen as station load increases. It is not clear whether this would increase the footprint to a size where it would not be easily integrated into any site.
- It would be helpful to see the overall and single-component power consumptions of this project.
- Scale-up work is needed in due course.
- The team should add a task to estimate the full cost of electrolytic hydrogen (capital and operating cost) for the existing lower-pressure electrolyzer. It should then compare that with the estimated costs using the higher-pressure electrolyzer, as well as compare these costs with the DOE target of less than $4/kg.

Project # TV-021: Forklift and Backup Power Data Collection and Analysis

Jennifer Kurtz; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) assess fuel cell and hydrogen technology status in real-world operations, (2) establish performance baselines, (3) report on fuel cell and hydrogen technology, and (4) support market growth by evaluating performance relevant to the markets' value proposition.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.8** for its relevance/potential impact.

- The American Recovery and Reinvestment Act (Recovery Act) provided significant resources to demonstrate fuel cell systems for material handling equipment (MHE) and backup power requirements. With this project, the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program (the Program) is leveraging that investment to ensure that fuel cells and the associated hydrogen infrastructure performance is well documented. The project also leverages the world-class data processing and analysis expertise resident at the National Renewable Energy Laboratory (NREL), which has been built over the years as part of DOE's support for vehicle and other fuel cell demonstrations. NREL's collection and analysis of data, and reporting of results, have made a vital contribution to understanding the status of technology development relative to DOE's goals and targets. 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 readily understood by those making decisions on public and private investments in technology research, development, and commercialization. Results achieved by the team at the National Fuel Cell Technical Evaluation Center (NFCTEC), including those for this project, are an outstanding and integral element of DOE's support for hydrogen and fuel cells.
- It is wise to evaluate the numerous backup systems funded under the Recovery Act to determine their durability during operation in real-world commercial settings. This project is adding value to the commercialization of niche market hydrogen technologies. This project is therefore highly relevant to the Program goals.
- The project is well targeted and very beneficial to the research goals of the Program. The cost of ownership data are very valuable and well characterized in terms of reliability and uncertainty. The work is also very valuable to the overall Program in illustrating the effective use of sensitivity analysis.
- The project is clearly very relevant and is helping to address barriers to widespread near-term applications of fuel cells.
- Per the definitions associated with the scores, and combined with the nature and results of data collection for this project, compared to a project that directly advances and/or improves hydrogen infrastructure, fuel cells, or the like, it became difficult to assign a grade higher than 3.5 to this project. While measuring and analyzing forklift and backup power data is of great importance, projects that fundamentally advance the actual deployment of fuel cells and hydrogen infrastructure may have an advantage in this category.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.8** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- The NFCTEC's approach to collecting, analyzing, and reporting real-world operational data is captured quite nicely in presentation slide 5. The approach reflects NREL staff's extensive experience gained by working on a variety of technology validation projects. With ongoing feedback from data providers and users, NREL has developed superb procedures and protocols. The result is an outstanding and constantly expanding collection of Composite Data Products (CDPs) and Detailed Data Products (DDPs). The milestone information on slide 4 is outstanding. The reviewer recommends this as a model for how milestones can be displayed for other projects being reviewed—and commended it at the oral presentation. Slide 3 has an excellent statement of project objectives.
- There was a good quarterly analysis provided and a final report on backup power systems. It is a good strategy for the NFCTEC to allow end users and academia to access the collected data and related analyses. Everyone will then benefit from such analyses. This is a solid approach to maximize the benefits of this project's results.
- The general goal of this project is to collect and analyze data that promote early commercialization of fuel cells in key markets, with a specific focus on forklift and backup power applications. This effort collects the data needed to address barriers to early commercialization and support efforts to assess the technology status in real-world operations, establish performance baselines, report on fuel cell and hydrogen technology, and support market growth. The work gives appropriate attention to the types of questions and metrics needed to confront these barriers. One of the challenges the researchers confronted was how a limited numbers of observations impacts the reliability and relevance of their results and recommendations. They have been very effective in addressing this issue by reporting confidence intervals and using a sensitivity analysis. This effort creates an important opportunity to use sensitivity analysis to set goals for future data collection.
- This project is a relatively routine data collection effort for numerous fuel cell backup power and materials handling systems in service. This is indeed the correct strategy. The data will be very useful in documenting and summarizing the owner costs and performance data relative to diesel and battery alternatives.
- There is little doubt that this team's presentation at next year's DOE Hydrogen and Fuel Cells Program Annual Merit Review (AMR) presentation will be significantly improved. Given the presenter's professionalism and follow-up since the AMR presentation, it is a certainty that the presenter and her team will significantly improve a year from now. The principal investigator's (PI's) patience and professionalism during her presentation, her patience during the reviewer's persistent questioning during the question-and-answer session, and her extraordinary post-AMR follow-up were much appreciated.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

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

- The 32 backup power analyses were outstanding. The amount of work performed was outstanding, namely, 252 of the 852 operational systems were evaluated. The project also completed analyses on backup power that clearly show that the cost of fuel cell backup power systems is equivalent to that of backup power systems powered by diesel. The variable costs include the permitting process—this piece of information is not trivial. Fuel cell systems with incentives are comparable with diesel-based systems, with up to 72 hours of runtime. Researchers found that 94% of the fuel cell backup systems had no interruptions in operation or start-ups. This is a significant finding. The results on hydrogen safety for forklift operations sound really valuable and should be more widely published. Fuel cell forklifts have demonstrated more than 2 million hours of operation, using more than 275,000 kg of hydrogen safely. These same forklifts had 10,000 hours of operation with less than 10% degradation in power output. These are outstanding accomplishments.

- The presentation has 14 slides that show project accomplishments. They are packed with information on the number of fuel-cell-based MHE and backup power units deployed; backup power operations, performance, and cost; fuel cell MHE operation and performance; and hydrogen infrastructure use. The project has produced 32 backup power CDPs and 75 CDPs related to MHEs and the associated infrastructure. A report, "Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison," has been published. The results of a sensitivity analysis, relevant to the cost of ownership, are summarized in the presentation. Metrics studied for sensitivity include capital cost, installation cost, discount rate, operational life, maintenance cost, and fuel cost. Project accomplishments associated with MHE include results on fuel cell voltage degradation, hydrogen fueling station usage, and the contribution of selected infrastructure equipment to maintenance requirements. This project provides the most objective, comprehensive, and independent indicators of fuel cell progress for MHE and backup power applications. All in all, the project is a good deal for about $200,000 annually.
- The project is well focused on key barriers to understand and expand the use of early market fuel cells. The project is on budget and on schedule. The researchers have made very good progress with regard to both the specific project goals and the broader goals of the Program. The work is up to date with respect to all project goals.
- Substantial quantities of data have been collected, analyzed, and reported to date. In general, the results are positive and will help DOE in promoting early fuel cell applications. The low in-service fuel cell degradation levels are especially encouraging. The cost disadvantages of battery storage were clearly quantified.
- While the presenter and her team are performing a necessary task, their approach and findings are questionable. For example, their presentation of data on page 9 of their presentation appears to mix both actual cost data with projected cost data. While both sets are probably valid, mixing the actual cost data with projected cost data without delineation between the two should be avoided. Furthermore, the chart appears to be seeking a result rather than reporting a result, because the chart does not account for refueling, indicating that the cost of fuel for fuel cell and diesel systems is minimal for two, three, or seven or more days. The chart should have included the additional and full cost of delivering additional fuel in an emergency and the near impossibility that could occur for certain instances (e.g., lower Manhattan 3–7 days after a 9/11-type event). If a cost curve that demonstrates that the cost of batteries would be ridiculously expensive after a certain point is going to be generated, the truth is that fuel cells and even diesel generators may equally not make economic sense. There were also other problems with other data on other charts.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.5** for its collaboration and coordination.

- As indicated on slide 20, this data project has involved collaboration and routine communication with fuel cell users, fuel cell manufacturers, and hydrogen providers. The project has also contributed to safety and risk assessment initiatives. NREL's data collection and analysis team has earned the trust of all organizations participating in the Recovery Act and other demonstration projects. Contributing factors include ongoing communications, opportunities for input and feedback on the process, and NREL's system for the protection of sensitive and proprietary information. Excellent communications are maintained with many stakeholder organizations, both in the United States and internationally. Slide 28 (reviewer only) has an impressive list of publications and presentations since the 2013 AMR.
- The list of partners and collaborations to date is outstanding.
- The presentation has demonstrated good links to collaborating partners. The analysis is well informed by the questions that are most relevant to technology validation. This came about through thoughtful planning and through listening to and interacting with partners.
- Collaborations are widespread and apparently excellent. The result is excellent real-world data collection and analysis.
- While collaboration partners were listed, collaboration could be improved—little discussion detailed the collaborators' roles.

Question 5: Proposed future work

This project was rated **3.7** for its proposed future work.

- The final report and project closeout will be highly anticipated by everyone involved and for early market adopters.
- Presentation slide 21 clearly describes work to be done during the coming year. A final report on backup power will be completed, as will final CDPs for MHE operations. The PI stated that the project will be completed with the winding down of the MHE and backup power fuel cell demonstrations funded by the Recovery Act. Slide 22 states that MHE validation will continue with data voluntarily supplied by industry collaborators.
- The researchers have organized the work to meet project goals in a sequential and logical manner.
- The project is almost finished. The proposed lists of final work for fiscal year (FY) 2014 and FY 2015 are fine.

Project strengths:

- The project's strengths are the following: the experience and expertise of the NREL project team and project leader, the active collaboration and interaction with manufacturers and users of fuel cells for MHE and backup power applications, the quality of information in reports published by the project, and the continuous improvement of CDPs and DDPs. This is a solid contribution to fuel cell and hydrogen infrastructure progress for a relatively small expenditure of total Program resources.
- The researchers are very effective in both meeting project goals and in providing results that are relevant to Program goals. The researchers were also very effective in identifying and evaluating key assumptions.
- There is good real-world data and analysis for early market fuel cell applications of backup power and MHE. These are likely to be the first widespread commercial applications for fuel cells.
- Outstanding sensitivity analysis is provided on slide 12 that helps to evaluate various options for backup power.
- The PI appears to be more interested in being accurate and getting things right versus appearance.

Project weaknesses:

- No project weaknesses were identified.
- Mixing data types to prove a point is a weakness of the project.
- It is not yet fully clear how future research will be used to guide data collection in ways that reduce uncertainty, increase reliability, and address the data that are most sensitive to presented findings and conclusions.

Recommendations for additions/deletions to project scope:

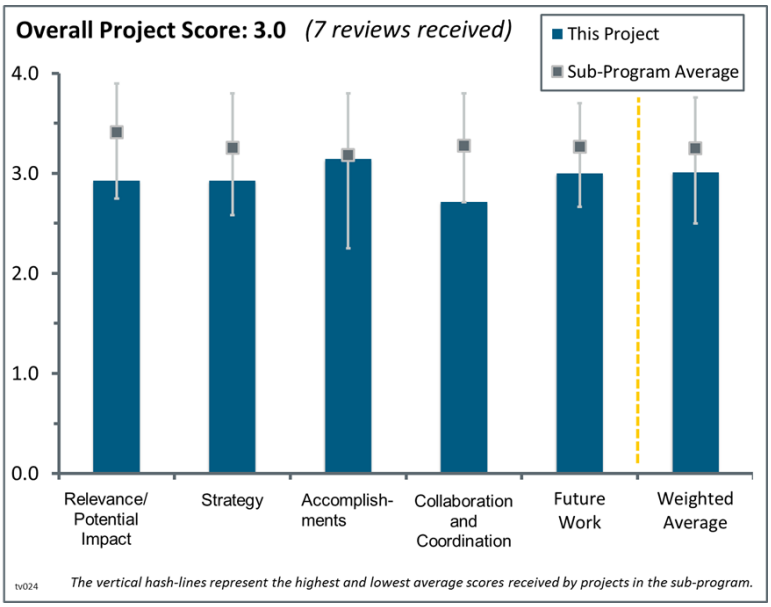
- This project is expected to be finished in conjunction with completion of the Recovery-Act-funded MHE and backup power projects. It is recommended that DOE and NREL investigate whether industry would continue to provide data voluntarily on operations of MHE powered by fuel cells, as well as on current and new installations of fuel cell backup power systems. DOE should encourage industry to collaborate with NREL on continued data collection, analysis, and reporting.
- The team should consider including qualitative verbal comments from operators, especially those who have experience with diesel and battery systems.
- It is still not fully clear how these data will be used for informing decisions at DOE and other entities. The researchers should spend some time with DOE and project collaborators to make some "value of information" assessments with regard to what and how much data to collect.

Project # TV-024: California State University, Los Angeles, Hydrogen Refueling Facility Performance Evaluation and Optimization

David Blekhman; California State University, Los Angeles

Brief Summary of Project:

The objective of this project is to test, collect data, and validate hydrogen refueling architecture deployed at California State University, Los Angeles (CSULA) and its individual components in a real-world operating environment. The performance data will be provided to the National Fuel Cell Technology Evaluation Center at the National Renewable Energy Laboratory (NREL).



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **2.9** for its relevance/potential impact.

- The CSULA project aligns with and meets the goals of the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program (the Program), as well as DOE research, development, and demonstration (RD&D) goals, but the advancement of progress can best be described as incremental rather than significant. The principal investigator (PI) and the project presented some improvements and are deserving of recognition. However, when the PI was asked if the project offered evolutionary or revolutionary improvements, he confirmed that it offered "gradual" improvements, and the PI may have a point—that the advancement of hydrogen and fuel cells needs both evolutionary gains and also the less-spectacular "gradual" gains of projects such as this. This PI did a good job on the project and a better job on the response because the PI was right—not all necessary gains will be spectacular. Often, the very necessary, if not the key advances, will be gradual rather than dramatic.
- In theory, the potential seems to be almost outstanding; however, without a clear technoeconomic estimation on the possibility for cost reduction following this project approach, the impact cannot really be measured.
- The project fits well with DOE goals and can help to identify optimization potentials for components of electrolysis-based fueling stations.
- Evaluation of hydrogen station performance is important for the deployment of more stations and fuel cell electric vehicles (FCEVs).
- The team's expectation for thousands of FCEVs in California in 2015 seems overexaggerated. This kind of integrated project, where hydrogen production and dispensing are combined, is excellent, and the educational aspect is very practical as a side benefit. The main areas of work include (1) integrating hydrogen stations with smart grid technologies, (2) "full scale hydrogen station operating in real life," and (3) educating students. The operating data will be collected and sent to NREL. The safety aspects of this project, such as first respondent training and education, are also good.
- This project has a weak alignment with DOE goals and targets. The presentation does not outline specifics for how the project will address barriers and help further the development of hydrogen station technology.
- It is not clear how this project will have impacts on reducing the costs of hydrogen production and delivery.

Question 2: Strategy for technology validation and/or deployment

This project was rated **2.9** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- This project has an excellent design, and its phased approach allows for go/no-go decisions. Phases II and III and Tasks 4–7 look reasonable. This project is slated to produce tangible results to improve station performance.
- With the view that improvements are not always spectacular and that CSULA's approach was academic and methodical, the reviewer believes that the CSULA project effectively contributes to the Program, as well as DOE RD&D goals. With that, and because of the PI's answers during the question-and-answer session, the reviewer would have preferred to have graded this section as a 4.0 but could not determine a way to fairly do so.
- The approach for cost reduction by complete systems validation seems to be an effective tool to identify the weaknesses of single system components of hydrogen fueling stations based on electrolysis.
- The approach seems reasonable.
- The project does not provide sufficient detail on what is being done to help meet goals and targets for the technology. There appears to be no defined plan for optimizing the station to increase efficiency or address costs. The plan for data collection and submission is solid.
- A detailed description of the approaches employed in the work (e.g., data acquisition) is lacking.
- The approach misses details on grid connection (e.g., it is not clear if there is any smart grid approach) and clarity on which impurities of hydrogen are to be addressed.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.1** for its accomplishments and progress.

- The project can produce up to 60 kg per day with pressure up to 10,000 psi. The project can fuel 15–20 FCEVs per day. The project has power meters that help the control interface. These power meters help the flow of hydrogen to the compressor. The successful installation of components to collect data is set, and progress on this project looks excellent. The project can generate data over time to determine the performance of compression and dispensing components. The team installed buffer tanks to take care of car manufacturer concerns. The team expressed thanks to The Linde Group for its excellent work in this area. A hydrogen purity unit was purchased at a cost of $512,000. This is a huge investment by the project developer—CSULA. Dispensing meter testing is being demonstrated. The team hosts students and foreign visitors to look at this demonstration project. This is helping DOE to achieve its goal of education of hydrogen technologies.
- The CSULA project aligns with and meets the goals of the Program, as well as DOE RD&D goals, but the advancement of progress can best be described as incremental rather than significant. The PI and the project presented some improvements and are deserving of recognition, but when the PI was asked if the project offered evolutionary or revolutionary improvements, he confirmed that it offered "gradual" improvements, and the PI may have a point—that the advancement of hydrogen and fuel cells needs both evolutionary gains and also the less-spectacular "gradual" gains of projects such as this. The PI did a good job on the project and a better job on the response because the PI was right—not all necessary gains will be spectacular. Often, the very necessary, if not the key, advances will be gradual rather than dramatic. With that perspective, the CSULA project appears to have clearly been focused on the systematic collection, validation, and testing of hydrogen refueling infrastructure in order to advance the hydrogen economy. Compared to other presentations/projects, CSULA's adaption of equipment and equipment improvements appears less impressive, but it was its academic approach and results gathering that were impressive, worthy of significant grading, and worthy of continued effort.
- The data collection and automation is a great start. The project needs to outline the plans and objectives for optimizing the station. At this point, it seems to be random research and not focused with specific goals.
- There seems to be reasonable progress to date.
- From the presentation, it looks like the project is on track (as originally planned).

- A hydrogen fueling station has been established.
- There is not enough data presented to say something about the progress of the overall project.

Question 4: Collaboration and coordination with other institutions

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

- The team has excellent partners, including the California Air Resources Board, AAA, DOE, and the California Fuel Cell Partnership (CaFCP). CaFCP is essential in providing its long history of expertise in developing such a hydrogen station.
- The project collaboration with California Weights and Measures is good and will contribute to allowing the sale of hydrogen as a fuel.
- This reviewer cannot justify more than a satisfactory grade (2.5) for collaboration—CSULA's only stated partner was Hydrogenics, and CSULA seems to have performed the work, as stated in the presentation. However, the reviewer is not sure how this project could have been done differently, given its nature and its great and necessary accomplishments.
- The collaboration with Hydrogenics, the electrolyzer supplier, seems ordinary. The team should be reaching out to other organizations in the arena of hydrogen purity; for example, coordinating with government agencies and possibly others measuring hydrogen purity.
- Collaboration with other organizations that have developed hydrogen fueling stations is strongly recommended.
- There are no noticeable collaborations with other institutions and industrial partners such as Hydrogenics.
- The collaboration with the University of California, Los Angeles (UCLA) is not clear (some steps have been taken, but there is no formal commitment in this respect).

Question 5: Proposed future work

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

- The proposed future work is 100% outstanding—CSULA appears very sharply focused on performing the necessary grunt work that is important to advancing the hydrogen economy.
- The plans for future short-term and long-term work are excellent. Smart grid and load shedding are areas the team wants to study in the future. The emphasis on continued data collection and educational outreach is essential and important.
- The future work plan seems to be well outlined.
- The proposed work is again in line with the plan.
- The team hints at a possible project to evaluate the utilization of intermittent renewables, such as wind. This would be valuable, but the team did not show how it might accomplish such a project without direct access to wind turbines. Because it has three hydrogen compressors, it would be beneficial if the team could assess the reliability (or lack thereof) of its compressors, but the team may not have the capability for compressor testing.
- A more detailed description of future work with the focus on meeting the project objectives is recommended.
- The proposed future work is poorly described. It is unclear what, if any, progress will be made toward moving the technology to commercial readiness.

Project strengths:

- The project strengths include the educational outreach, collaboration with CaFCP, and establishment of high-quality components in operation with data collection.
- The project provides data on another hydrogen station, which will be valuable for DOE's technology validation activity. Education and awareness of the public will be important for future adoption of hydrogen.
- The project addresses one of the main issues to be solved before going into commercialization and real deployment of fuel cell and hydrogen technologies; therefore, the impact can be very high.

- Project strengths include CSULA's laser-like focus on the task at hand, and the incremental advancement of technology validation. While a great leap forward would have been desirable, the PI correctly pointed out that progress is not always spectacular, and that when it is incremental, one can do no more than only report the incremental, but necessary, progress.
- The project seems to have good instrumentation capabilities. The project has an excellent opportunity to educate and expose new students to hydrogen and fuel cell technology.
- The project can clearly show which components are able to reduce the overall electrical costs for electrolytic-produced hydrogen by alkaline electrolysis for fueling stations.
- A hydrogen fueling station was established.

Project weaknesses:

- There are no weaknesses to identify.
- Beyond the apparent absence of greater collaboration with partner organizations, no weaknesses were noted.
- The project needs more emphasis on SCS.
- Without a technoeconomic plan to assess the economic advantage of the proposed solutions, it is difficult to judge if the approach is correct and to quantify the benefits.
- There are unclear project objectives and metrics.
- The team does not seem to have any idea how to reduce the cost of the station; because this is a university, it needs to release some of that creative academic talent on analyzing the station cost and suggest avenues to reduce costs in the future.
- The project is not well defined and does not have measurable goals for meeting technical targets. There are no apparent plans to address cost barriers. The project presentation did not include some required elements—specifically, it did not address comments from past reviewers.

Recommendations for additions/deletions to project scope:

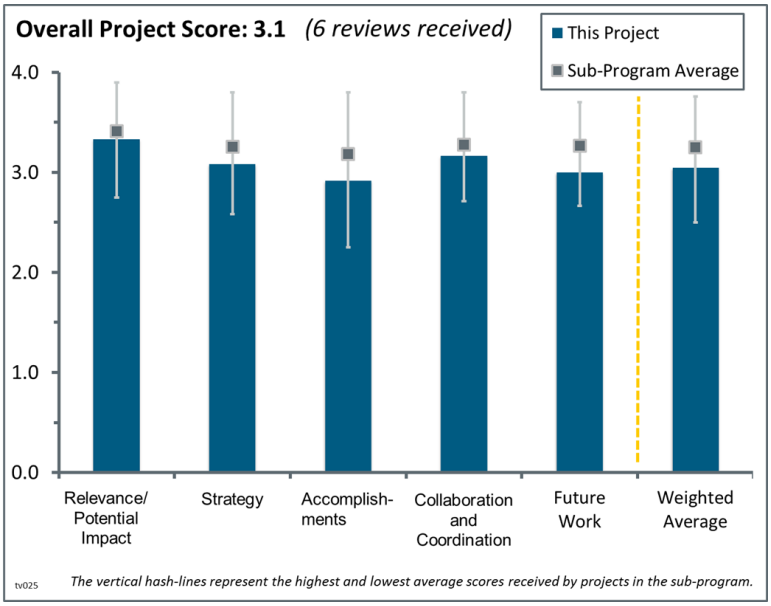
- The team should work more closely with other California state universities, such as Irvine, Fullerton, San Diego, and Santa Barbara, and private colleges in Los Angeles, such as the University of Southern California.
- It would be helpful to see the overall and single-component power consumptions.
- A technoeconomic analysis of the proposed solutions should be introduced. Clarification and use of possible collaboration with UCLA should be better addressed.
- The team should add a task to analyze station cost and make creative suggestions about how to reduce capital and/or operating costs.
- The researchers should review the goals and technical targets in the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan, as well as develop specific, measurable goals and objectives for addressing barriers and meeting technical targets. Further funding would not be recommended until this project demonstrates that it has value other than for educating the current student body.

Project # TV-025: Performance Evaluation of Delivered Hydrogen Fueling Stations

Michael Tieu; Gas Technology Institute

Brief Summary of Project:

The objectives of this project are to: (1) integrate largely nonintrusive data collection systems at five 100 kg/day delivered hydrogen fueling stations located in California for a 24-month period, (2) submit station data specified in the National Renewable Energy Laboratory (NREL) Hydrogen Station Data Templates, and (3) provide useful data to accurately characterize stations' performance.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.3** for its relevance/potential impact.

- This project's relevance is outstanding. What the team is proposing to do—namely, develop a data collection regime at five existing stations—is good. This requires analysis of permitting, construction delays, and integrated fueling equipment.
- Acquisition of accurate data on "real-world" hydrogen stations is important. Such data—if properly collected, organized, and analyzed—can contribute significantly to understanding actual station performance relative to the U.S. Department of Energy's (DOE's) development targets for hydrogen fueling systems.
- The project is highly relevant to the optimization of hydrogen delivery stations.
- The project is expected to provide valuable data on hydrogen stations to validate the technology and better understand performance.
- It is impossible to tell from the information provided the extent to which this project will be successful in delivering the expected results, because no actual data collection has begun yet. It is expected that the data will start to be collected during the fourth quarter (Q4) of 2014 for the first station. Thus far, only the design and drawings have been completed, and some of the equipment has been ordered/received.
- It is not clear why a third party has to come in to measure station performance. It is not clear why the project does not rely on The Linde Group (Linde) to report on its own progress.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.1** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- The team's strategy for this project is outstanding. The phased approach looks reasonable. The team expects to collect data at five fueling stations in California in a 24-month period. Then the team will share the data in the way NREL expects it, which will result in outstanding benefits to the progress of the technology.
- Five seems to be a reasonable number of stations for which to collect data. This will enable comparisons across stations to determine the degree of consistency in station performance, better understand factors that

affect performance, and identify issues requiring further development. The station data to be collected and submitted will be as defined in NREL's Hydrogen Station Data Templates. It will be provided to the National Fuel Cell Technical Evaluation Center (NFCTEC) at NREL for storage, processing, and analysis. This link to NREL is vital to the achievement of project goals and for the comparability, objectivity, and confidentiality of results. The approach to the project, summarized on presentation slides 4–6, and the brief task descriptions seem straightforward and reasonable. Based on the information on slide 5, the $800,000 budget (slide 2) is sufficient only for collection of data on two stations. During his oral presentation, the principal investigator (PI) stated that Linde has obtained the funding for Budget Period 2 projects. The reviewer assumes that the $400,000 from DOE will be sufficient for data collection from all five stations. If that assumption is not correct, a clarification is needed. A slide showing the project's original and current milestones would enhance the section on project approach and strategy.

- The team seems to have a reasonable approach to monitoring the liquid hydrogen stations.
- Data collection will be unobtrusive to the Linde station operation.
- The presenter has not indicated what barriers the project is addressing, instead indicating the barriers that the project is facing. This should be corrected for the next review. Presumably this project is addressing Barriers C, D, and E. No details are given as to the performance parameters that are being measured/validated. No connection is made between the work that is being done and the goals of the DOE Hydrogen and Fuel Cells Program (the Program). It is not clear why the project chose to base the entirety of its activities on newly constructed stations (which have a lead time), rather than using, even partially, already existing stations to test the data collection systems and generate data during the construction phase of the new stations. There is potential for the project to contribute to Barriers C, D, and E, but it is unclear whether the approach of using only new stations is the most efficient. The project appears to be feasible, however. The project proponent should ensure that the way in which the project addresses technical barriers to facilitate proper evaluation of this metric is directly addressed.
- The barriers listed in the overview slide do not align with those identified in the Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development, and Demonstration Plan (MYRDDP). While the barriers listed could pose a problem for hydrogen stations, they are not the primary focus of DOE. It is unclear how the project will address those barriers or how the solutions will be shared with the industry.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **2.9** for its accomplishments and progress.

- As described in presentation slides 7–11, progress has been made during the Budget Period 1 (BP-1) work. Accomplishments include station permitting, initiating the construction bid process for a station, completion of station data acquisition system design and drawings, and acquisition of instrumentation and data logger components. The small amount of project funds spent during the first year (slide 2) was noted and questioned. The PI stated that permitting for the station planned at San Juan Capistrano has been held up. In response to a question, he said that a no-cost extension has been requested, to reflect a six-month delay in completing actions required to provide an operational station.
- The project developers recognized that the permitting processing in the state of California took longer than expected. This is surely part of the lessons learned. This has been the case in many other technology validation projects and needs to be documented well. There has been excellent planning and accomplishments with regard to the purchase, installation, and testing of the instrumentation and data logger components needed for this project.
- Accomplishments are reasonable, considering the time from project start.
- Progress during the past year is good, but one would have liked to have seen more. Perhaps this was due to issues outside the control of the investigators. It is not clear whether the initial data collection will be finished in BP-1, as per the go/no-go.
- It is not possible to evaluate this metric, because no results have been generated from the project yet. The first sets of results are expected during Q4 2014 for the first station.
- The team has just installed monitoring equipment, so it is too early to judge the accomplishments.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.2** for its collaboration and coordination.

- The Gas Technology Institute (GTI) and Linde have a good relationship with well-designed and delineated responsibilities. This will make for a good partnership. Linde is the subcontractor on this project, and it will likely perform, as usual, in an outstanding manner. GTI is an incredible organization and its results from this project are something to look forward to.
- Project partners GTI and Linde are well qualified to carry out the project. Slide 14 nicely summarizes the respective roles and responsibilities of GTI and Linde. The quality of collaboration and communication between GTI and NREL will be a key factor in the smooth functioning of the project and reporting of results. There was no mention in the presentation about collaboration/communication with California state and local government agencies. Slides 12 and 13 provide a glimpse of GTI's and Linde's capabilities and experience. However, they do not provide information that is particularly relevant to the project being reviewed.
- The project includes good collaboration so far. Project partners are working together to meet objectives.
- Collaboration between the project partners appears to be good and well-coordinated.
- The project appears to have a good collaboration with Linde.
- The team seems to be working with Linde and the California Weights and Measures representatives to resolve the issue of selling hydrogen by the kilogram.

Question 5: Proposed future work

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

- Finalizing component integration and data collection plans at the last three stations, which Linde has already planned, looks reasonable and indicates how reliable this project will be going forward. A no-cost time extension was approved for this project.
- The proposed future work is expected for the level of effort.
- The proposed future work seems like routine monitoring work.
- The future work should produce more rapid progress with data collection.
- There is no apparent strategy for risk identification and mitigation. There is no identification of go/no-go decision points.
- The work to be done during the remainder of 2014 is summarized in slide 15. The presentation should provide more information on plans for the remainder of the project. It should include, for example, at least a few major milestones, such as the months in which data will begin to be delivered to NREL for each of the five stations. The lack of detail on future work could cause a reviewer to conclude that the plans are not yet developed and that time frames for completing activities are not settled or important.

Project strengths:

- The partnership between GTI and Linde is a huge plus for this project. The collaboration brings an incredible array of talent and experience to the table for such a project. Outstanding results can be expected.
- The project adds data from three more stations to DOE technology validation efforts. This is important for validating the performance of station components, including compressor technology and other components.
- GTI and Linde are well-qualified organizations. They have the expertise and experience to successfully accomplish the project goals. Project data will be submitted to the NFCTEC. Among the states, California is a leader in promoting and investing in hydrogen infrastructure.
- The project has the potential to contribute to data collection and validation. It expands the network of fueling stations.
- There is good data monitoring and instrumentation experience.
- The collaboration with Linde is a project strength.

Project weaknesses:

- The project timeline is dependent on factors outside the control of the investigators.
- The project goals do not appear to include addressing cost targets.
- There is a lack of information on original and current project milestones. It would be helpful to have a better understanding of the factors considered in selecting sites for the stations that will be included in the project and what organizations GTI and Linde must coordinate with in making decisions on station locations.
- The lead times for the construction of new hydrogen refueling stations as well as delays in the construction (six months) have meant that no project results are available to date. The project does not demonstrate its relevance to the Program by highlighting its goals and achievements in relation to goals and technical barriers addressed by the Program. There does not appear to be risk planning, which could affect the feasibility of the project.

Recommendations for additions/deletions to project scope:

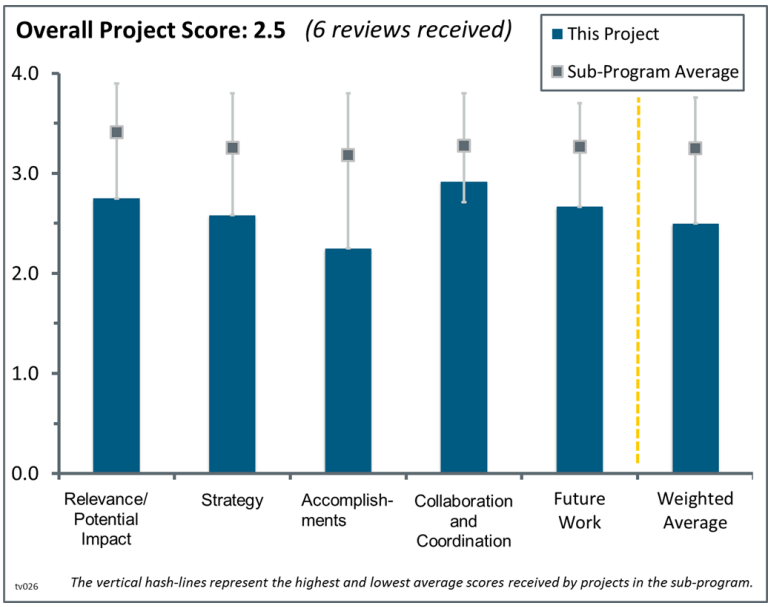
- Decisions on changing scope should wait until after data is being successfully acquired and submitted for at least a few stations.
- If possible, the researchers should report on the performance of the Linde ionic compressor. They should also determine why Linde would use the ionic compressor instead of a liquid hydrogen pump to provide high-pressure gaseous hydrogen.
- Project partners should review the FCTO MYRDDP to ensure that the goals align with technical barriers and targets. The project intends to address the barriers of permitting and construction delays, but it does not outline how this information will be shared. To ensure that the learnings from the project are shared, the project partners should develop a plan for documenting this for the industry.
- The project should evaluate whether it will be feasible to implement all foreseen stations within the specified time, given that a period of data collection of two years is designated, and given the delays in the construction in the hydrogen refueling stations.

Project # TV-026: Hydrogen Fueling Infrastructure Research and Station Technology

Brian Somerday; Sandia National Laboratories

Brief Summary of Project:

The long-term objectives of this project are to: (1) reduce the cost of hydrogen fueling stations to be competitive with conventional liquid fuel stations; (2) improve the availability, reliability, and cost of high-pressure components while ensuring their safety; (3) focus a flexible and responsive set of technical experts and facilities to help solve today's urgent challenges and the unpredicted needs; and (4) enable distributed generation of renewable hydrogen in a broader energy ecosystem.



Question 1: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **2.8** for its relevance/potential impact.

- The project's objective is articulately stated as ensuring a positive fueling experience, and thus covers all aspects that could be a problem. The structure of this project facilitates a positive outcome, through execution, communication, and follow-through.
- This is a highly relevant project. This is a key part of the H2USA partnership.
- It is still very early for this project, so there are relatively few concrete achievements to date, but the scope is meaningful because the project seeks to address real-time technology performance and operation problems related to hydrogen storage and hydrogen refueling stations, while gathering data for these for technology validation.
- This project is too new to evaluate. It has the potential to contribute to the deployment of hydrogen stations, but the team did not provide sufficient information to judge its potential.
- Almost any project related to advancing hydrogen fueling infrastructure has to be good, and while this project in particular appears to fully align with U.S. Department of Energy (DOE) goals, there was almost no discussion on how the Sandia National Laboratories (SNL)-National Renewable Energy Laboratory (NREL) team would meet the challenge. It appears the team's time was spent on the fact that there was a relationship between the two organizations, instead of on the how and what. For example, slide 11 advises that a laboratory was brought in to the project, but there is no discussion on that page or subsequent pages of what that laboratory has done or will do for this project. Accomplishment slides lack information on accomplishments.
- Presentation slides 2–4 were confusing. The budget (slide 2) is $400,000; plans likely anticipate this or a similar amount to be provided annually. On slide 3, the first objective is "Reduce the installation cost of a hydrogen fueling station to be competitive with conventional liquid fuel stations"; there is a huge and obvious disconnect between the budget and objectives. DOE and others are spending tens of millions annually to achieve what are stated as H2FIRST objectives. Therefore, the presentation has a communication deficiency right off the bat. H2FIRST may be understood by its planners, DOE, and H2USA participants; however, the presentation content and the 30-minute oral presentation did not clarify the objectives and relevance of a project with a $400,000 annual expenditure.

Question 2: Strategy for technology validation and/or deployment

This project was rated **2.6** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- The project appears to be well designed and feasible. Some groundwork has been done in setting up the various technology support panels; at the same time, the project appears to have the flexibility to set up and disband panels according to how needs evolve. Barriers appear to be effectively addressed, and there is significant coordination with established entities in the public and private sectors, building on existing competencies and ensuring representation of industry and public interests.
- The project seems well thought out and logically divided into project teams.
- The approach is nicely targeted at optimizing cost, reliability, and public acceptance of hydrogen fueling stations.
- This reviewer had difficulty discerning the SNL-NREL strategy from the presentation.
- The project approach, as communicated in slides 5–8, does not alleviate this reviewer's confusion and concern about the rationale for, and merits of, this project. There are some nice goals, such as "ensure relevance of activities through appropriate industry engagement," but no clear project approach. Slide 7 provides a glimpse of what H2FIRST is about. The approach is evidently to create a coordination panel and manage project teams, which will support H2USA. No task descriptions or milestones are provided for the project.
- This is just a concept, and there is too little information to make a reasonable judgment as to how it might succeed.

Question 3: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

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

- The project has just begun, but the project is primed for rapid progress.
- The project is still in its early stages but seems to have convened initial meetings in most of the project team areas. The signing of the SNL-NREL Memorandum of Understanding (MOU) is a big achievement. However, this achievement marks only the start of the process, not an end goal.
- The accomplishments and progress are tough to judge. The SNL-NREL team does not appear to really have done anything yet, but that may be almost wholly a function of a single factor: the effort is new and the team is just getting started.
- It is impossible to say what the progress is at this time because the project has not yet started to generate concrete results in terms of its objectives. With some teams there appear to be clear, measurable indicators with which results can be evaluated (e.g., reference stations); however, for others it is less clear (e.g., station acceptance).
- On slides 11 and 12, SNL and NREL capabilities and facilities are cited as "Accomplishments"—presumably project accomplishments. This is certainly curious and confusing. The accomplishments so far seem to be an MOU, a meeting, and the establishment of project teams. On slide 13 it was unclear what has led to the determination that this initiative is needed to fill gaps in an environment that already has many hydrogen-related initiatives, projects, plans, analyses, etc. Hydrogen stations are being planned, built, and accepted now. It is unclear how the H2FIRST project team will accelerate that process. It is assumed that some project funds are being used by SNL and NREL to provide H2FIRST leadership and management. During the oral presentation, it was stated that project funds are supporting a reference station project team, which will address near- and mid-term technical challenges associated with deploying hydrogen stations. The presentation materials and a half-hour briefing were not enough to educate the reviewers about this project.
- There has been no progress, other than some preliminary meetings.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.9** for its collaboration and coordination.

- The project has an excellent collaborative team, as well as excellent facilities and expertise with high-pressure hydrogen.
- The project can easily become unwieldy, given the varied subject matter and number of collaborators involved. The listing of collaboration entities seems logical and appropriate for tasks.
- A lot of partners are listed, but when questioned, the presenters indicated that not much effort had been forthcoming from the listed partners. Nevertheless, the score is mitigated by the fact that the project is so new.
- The list of collaborators was satisfactory, but the team should try to include Ford Motor Company, General Motors, and Daimler AG.
- A number of project partners are listed on slide 19. Curiously, SNL and NREL are not among them. Roles and responsibilities of the various project partners are not defined.
- There seems to be a significant degree of collaboration across DOE laboratories and with the H2USA partnership. The composition and indicated modus operandi of the project teams also indicate that a significant degree of collaboration and coordination among the involved entities will be engendered and will indeed be required for these teams to be effective. The project will also use data from other validation projects and experiences to establish what has been achieved and determine the way forward, so there is also collaboration with other DOE projects. Care should be taken to make the entities involved in various parts of the project manageable so as to be efficient.

Question 5: Proposed future work

This project was rated **2.7** for its proposed future work.

- The future work is directed at beginning key projects.
- The team seems to have a good plan to bring people together, but there is no basis to judge how it might turn out.
- Further work needs to be devoted to articulating and characterizing H2FIRST. Presumably, most of the future work described on slide 20 will not be funded by the project. However, it is unclear if research tasks or the reference station design task will be led or managed as part of H2FIRST. It was not made clear that the H2FIRST project will not displace the processes by which programs, priorities, solicitations, etc. have been previously determined and accomplished.

Project strengths:

- The project meets a “catch all” need—it troubleshoots all aspects of the fueling experience. The PIs appear to be very well suited to the project. The organization of the project teams allows the project to simultaneously be focused and have a wide range of topics under investigation.
- This is a key project for the successful development of a hydrogen fueling infrastructure.
- The project is well thought out and well structured. It has significant potential to make real-life impacts.
- Two good national laboratories are leading the charge.
- There are no project strengths yet.
- No project strengths were noted.

Project weaknesses:

- Specificity of goals/objectives within each project team will be vital to project success.
- There is a risk that significant effort may be spent in coordination of various groups and interactions if not managed carefully. Care should be taken to ensure that indicators of the project’s success are measurable; at this stage it is not clear how the success of certain aspects of the project will be measured.
- Basically, it is not clear where H2FIRST fits in the world of hydrogen plans, programs, and initiatives being pursued by both public and private interests. The value added is not clear.

- There is too little progress to make a meaningful presentation. The researchers' plan is too vague.

Recommendations for additions/deletions to project scope:

- DOE should review this initiative with major hydrogen stakeholders in the public and private sectors to check on expectations that it will add value. Adjustments to H2FIRST should be made based on feedback.