2016 — Market Transformation
Summary of Annual Merit Review of the Market Transformation Program

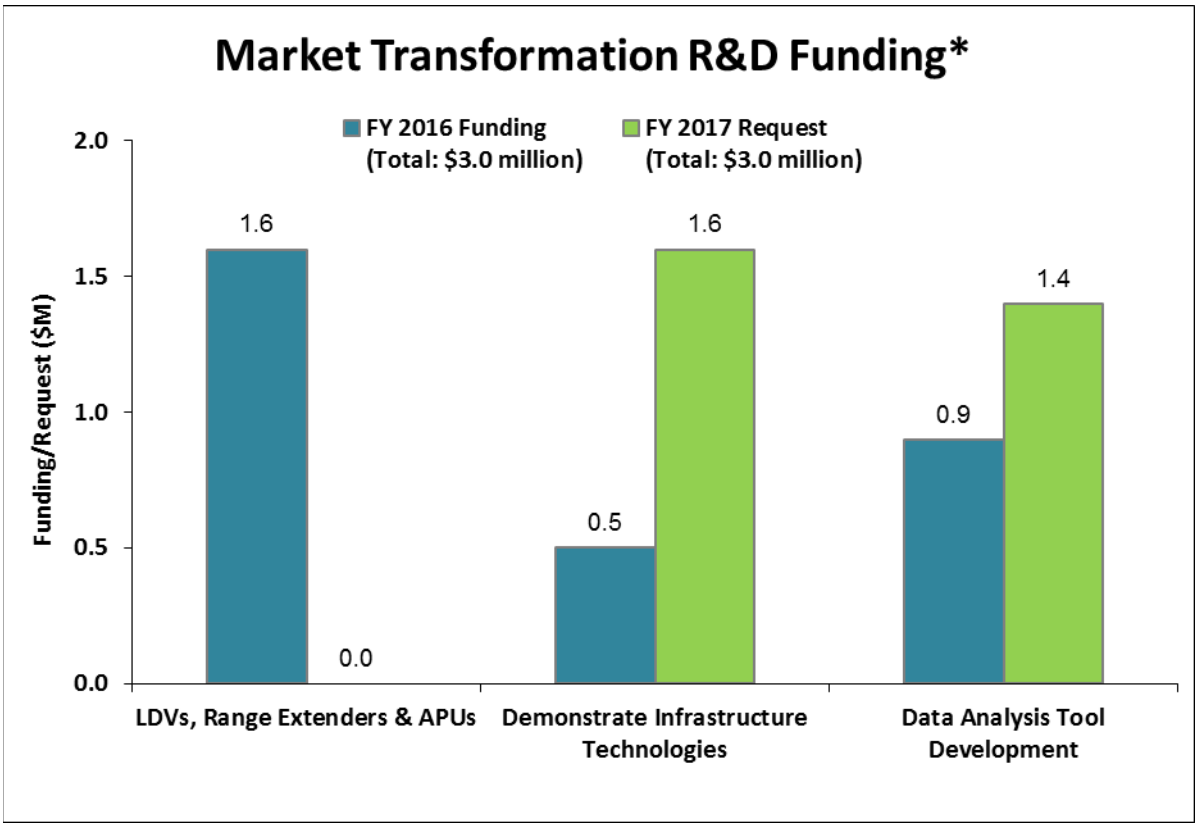
Summary of Reviewer Comments on the Market Transformation Program:

The purpose of the Market Transformation program is to spur market introduction by demonstrating pre-commercial technologies in real-world applications. By doing so, this program helps to identify and overcome market barriers and to reduce the life-cycle costs of fuel cell power through technical and non-technical solutions. Six projects were reviewed this year, and these projects are highly leveraged, with more than half of the funds provided by the U.S. Department of Energy's (DOE's) partners. This substantial commitment of external resources shows the high level of interest in exploring applications and markets in which the hydrogen and fuel cell industry can expand, and the technologies can play a valuable role.

Reviewers generally shared positive comments about the program's projects, with five of the six projects scoring at 3.1 or above. The reviewers noted that, as the projects advance, there is great potential to expand hydrogen fuel cell applications beyond the current established base in material-handling equipment and backup power. General recommendations were received to increase focus on addressing and overcoming specific barriers in each project and obtaining firm commitments for industrial partnerships.

Market Transformation Funding:

A new application begun in fiscal year (FY) 2016 was the battery/fuel cell light-duty hybrid service vans (LDVs), which will demonstrate a value proposition for utilities and other fleets used in operations and maintenance. The Market Transformation program budget for FY 2016 was $3 million.



* 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 Market Transformation program's projects were rated average to high, as overall ratings ranged from 2.7 to 3.4, with an average score of 3.1. The projects were judged to be relevant to DOE activities and to employ good or adequate technical approaches. Reviewers emphasized the need for data collection to develop business case reports that can be used to support further market expansion.

Airport Ground Support Vehicles: This project received an overall score of 3.4. Reviewers stated that this project has high potential to meet program goals and enable demonstration for a wide breadth of additional applications. Although reviewers were satisfied in general with progress made in terms of evaluation, design, and development of learnings, concerns about fuel cell stack performance and the timeline for completing the project were expressed. Reviewers also stated that the specific stack problems should also have been explained more thoroughly.

Hydrogen Energy Systems as a Grid Management Tool: This project received an overall score of 3.1. Reviewers stated that this project ties together multiple benefits (e.g., electrolyzer demonstration, renewable hydrogen for fuel cell deployments, enabling intermittent renewables) into a single package, and helps increase awareness and clarity of the permitting process for deployments. Reviewers stated that the proposed future work is similar to the future work that was proposed for 2015 and they are not clear on the reason for all the delays. For example, the MTA shuttle bus conversion was previously scheduled for September 2015 but is now listed as future work for 2016. Reviewers also commented that more attention to project execution barriers is needed.

Maritime Fuel Cell Generator Project: This project received an overall score of 3.3 for its efforts in developing, designing, and testing a first-of-its-kind hydrogen fuel cell power generator for maritime applications. Reviewers noted that this project's objectives were relevant: specifically, lowering emissions and technology/finance risk in a market that needs more efficient power technology. Reviewers commented that the project addresses DOE's goal to enable and accelerate expansion of hydrogen and fuel cell system use and that lessons learned from this deployment can be used for similar applications at other ports. They felt that development of a business case and identification of follow-on opportunities are imperative. Additional deployment phases with the current and concrete plans on how to expand the number of deployments are needed, according to reviewers.

Fuel Cell Hybrid Electric Delivery Van Project: This project received an overall score of 3.4. Reviewers stated that this application has great potential and that the project fits well within DOE's goals and objectives. Bringing one system online, evaluating its performance, and then deploying nineteen at various sites is a reasonable approach, according to reviewers. Some noted that, although there has been a setback with collaborators, evaluating duty cycles and designing appropriate system specifications was time well spent. One reviewer noted that more explanation on refuel planning is needed.

Fuel Cell Auxiliary Power Unit Project: This project received an overall score of 2.7. Reviewers agreed that the project is relevant and is a logical extension of other fuel cell applications, such as forklifts. Reviewers mentioned that very low operational time is hampering progress and specific go/no-go decision points were not expressed clearly. Also, reviewers stated that the timeline for the demonstration with the recently added partners is not yet clearly developed. Reviewers noted that progress has been slow and the degree of commitment on the part of the industrial partners is questionable.

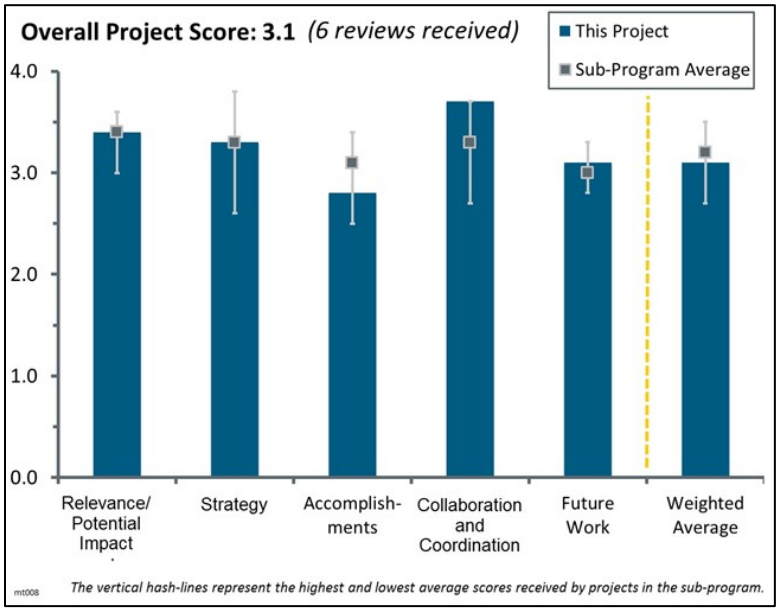
Fuel Cell-Battery Electric Hybrid for Utility of Bucket Trucks Project: This project received an overall score of 3.1. Reviewers noted that this application is an opportunity for near-term deployment of fuel cell technology, and this project is making progress toward evaluating the market. Reviewers commented that the potential impact of this project will be very limited without a better financial analysis. Insufficient information was provided to definitively understand the energy efficiency and air pollution reductions that could be achieved. Reviewers said that there is an absence of go/no-go decision criteria and that there is not enough detail on the battery storage system.

Project #MT-008: Hydrogen Energy Systems as a Grid Management Tool

Mitch Ewan; Hawaii Natural Energy Institute

Brief Summary of Project:

The objectives of this project are to (1) support development of a regulatory structure for permitting and installation of hydrogen systems in Hawaii and (2) validate the performance, durability, and cost benefits of grid-integrated hydrogen systems. The validation entails three tasks: (1) dynamic operation of electrolyzers to mitigate the impacts of intermittent renewable energy, (2) demonstration of the potential for multiple revenue streams from ancillary services and hydrogen production, and (3) introduction of hydrogen fuel for shuttle buses operated by the County of Hawaii Mass Transit Agency and Hawaii Volcanoes National Park.



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.

- The project is relevant to Fuel Cell Technologies Office goals for deploying hydrogen technologies and supporting deployment of renewable energy sources. By providing renewable hydrogen to support fuel cell deployments while simultaneously providing a sink to accept excess power from intermittent renewables, electrolyzer deployment could have a significant impact on market acceptance of several technologies of interest.
- This is an outstanding project, as its design is to maximize efficiency and effectiveness of grid energy production systems. The project and results are critical to fine-tuning one of the necessary applications of fuel cell systems: the ability to maximize other existing energy generators.
- This project meets several goals and advances research in multiple areas, including renewable energy, electrolyzers, using hydrogen for energy storage, permitting, contracting, public outreach, and state and federal collaborations.
- There was a good explanation of the project thesis and why it is relevant to the electric power grid. Identification of the relevance to U.S. Department of Energy (DOE) barriers was also good.
- The location and project concept are aligned with Hydrogen and Fuel Cells Program objectives.

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.

- The project effectively addresses multiple barriers, including the lack of private sector resources for deployments. The project is an effective illustration of the potential for renewable hydrogen to help with energy storage requirements and with grid frequency management.
- The presenter explained how the approach fits into the existing power sources and the interaction with the grid. There is clear justification for central site production and distributed distribution. The project

incorporates existing models developed for battery systems that can be modified to investigate electrolyzer applications for grid regulation. There is strong utilization of existing infrastructure to optimize the funding.
- This project is overcoming several barriers in the state of Hawaii and will be a good example for repeating the concept at other locations.
- Necessity seemed to reinforce the need to remain sharply focused on all barriers—not just the barriers listed but other unique challenges that could have scuttled the project.
- Deployment of actual equipment at the site has been significantly delayed, and it is not obvious how the project has addressed barriers. DOE funding was completed at the end of fiscal year 2015, and there does not appear to be a demonstration period of performance at the site or metrics that will determine the success of the demonstration.

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

This project was rated **2.8** for its accomplishments and progress.

- The project demonstrated progress in preparing components and understanding load profile and system limits. Baseline ramp rates were measured and were below battery exchange storage system ramp rates. The project determined that the electrolyzer system must be modified to provide proper response rates for the grid. The project demonstrated improved response rates, but these were still not adequate. The project is working with the electrolyzer manufacturer to resolve issues. The project demonstrated hydrogen production and pasteurization by the electrolyzer system. Fuel cell shuttle buses were evaluated. Hydrogen storage issues were identified, and solutions were presented. The project addressed permitting with Hawaii officials and senior fire department leadership, paving the way to these officials' accepting installation. The project demonstrated that a hydrogen energy system (HES) could be used to fuel a fuel cell battery hybrid bus system.
- The project focused on critical barriers to improve effectiveness of load management and, importantly, identified the shortcomings of the subject of the study. No weaknesses were noted.
- This project has been slowed owing to several barriers including siting issues, changes in public perceptions, funding, and contracting hurdles. The team has been addressing the barriers, but it has caused delays in the project.
- An electrolyzer system was commissioned and operated at Powertech, producing some useful results so far, including a better understanding of transient response that suggests that hybridization with a battery storage system may be required. Progress was also made toward installing a test site at the Natural Energy Laboratory Hawaii Authority. However, the lack of clear milestones and timelines for the work makes it hard to gauge progress achieved versus what was planned.
- New accomplishments since 2015 were not clear. It seems that there is a lack of progress. These delays have been explained, and it seems that instead of addressing the barriers, the project has only confirmed those barriers. It is not clear how this project is changing or removing those barriers. One interesting result is that difficulty in communicating with a commercial electrolyzer system limits the ability to quickly respond. The project should follow up with the National Renewable Energy Laboratory (NREL) electrolyzer team to more thoroughly address this issue, as it is not seen when there is detailed ability to control the electrolyzer system. Perhaps the project could develop best practices for electrolyzer controls for grid services. The potential of electrolyzers to provide grid support is already known. It is more valuable to understand specific aspects of an island environment and the specific challenges for grid support in the island environment, including costs, benefits, and the most valuable opportunities (selling hydrogen or providing grid services).

Question 4: Collaboration and coordination with other institutions

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

- There is a large, widespread mix of collaborative partners. Seven of the sixteen partners provided cost-share contributions. In addition, critical roles were identified for all the partners, including the local electric

company, which, while only an observer, is the critical potential future user (or non-user) of this technology.
- The collaboration on this project is outstanding. The team has been working with several entities to make this project a success. The team has had to meet requirements from each of the partners to make this a success, which has caused the project delays.
- The project has assembled a good team, including partners in state and local government and industry. Inclusion of an electrolyzer company (Proton Onsite) is especially valuable.
- The project has a strong list of collaborators that covers all aspects of the project.
- The collaboration team includes many local partners. It would be valuable to understand how these collaborations have addressed (or will address) barriers identified for this project. One example is hydrogen safety training. More examples are needed to avoid being in similar situations in which it takes more than six years to get one site completed.

Question 5: Proposed future work

This project was rated **3.1** for its proposed future work.

- The project is noteworthy in that while DOE funding has ended, the Hawaii Natural Energy Institute project was valuable enough that it continues to draw funding from other sources.
- The project identified a detailed list of future efforts.
- Equipment installation is planned for August 2016, but significant work must be completed before then. The August timeline seems aggressive and may not be achievable if any new barriers arise before then.
- The proposed future work is reasonable, though a timeline for completion is needed.
- Actual site completion is needed and will likely be completed this year. The proposed future work bullets are similar to those from 2015, and it is unclear why there are delays (e.g., "Complete mass transit agency shuttle bus conversion" was scheduled for September 2015 and is still listed as future work in 2016). Analysis of the performance data and the dynamic model is interesting, has potential, and will hopefully be worked on in collaboration with other electrolyzer grid services projects (e.g. Idaho National Laboratory/NREL dynamic grid electrolyzer validation).

Project strengths:

- The project ties together multiple benefits (electrolyzer demonstration, renewable hydrogen for fuel cell deployments, and enablement of intermittent renewables) into a single package. The project also helps increase awareness and clarifies the permitting process for deployments.
- The project has broken new ground and has had to work with many organizations to get the approvals needed to move forward. The lessons learned can be used as an example for similar projects. There is good leveraging of funds and participation from numerous groups. There is good partnership and development with Proton OnSite on improving the hydrogen system.
- The project developed a strong team with positive support from local and state officials.
- This is an honest look at a potential use for hydrogen.
- The island has many reasons to deploy electrolyzers owing to its goals for high renewable energy use.

Project weaknesses:

- Working with so many partners has resulted in lots of red tape, which has caused delays. When successful, this project will pave the way for more HES installations in Hawaii, but because it is the first of its kind, it has encountered barriers that prevented the project from meeting the original timeline.
- Delays in the project seem only to confirm that there are barriers; the project does not seem to be addressing the barriers.
- The project needs a clear timeline and a schedule of milestones so that adequate and timely performance can be demonstrated.
- It remains to be determined whether the electrolyzer can be modified to meet ramp rate requirements.

Recommendations for additions/deletions to project scope:

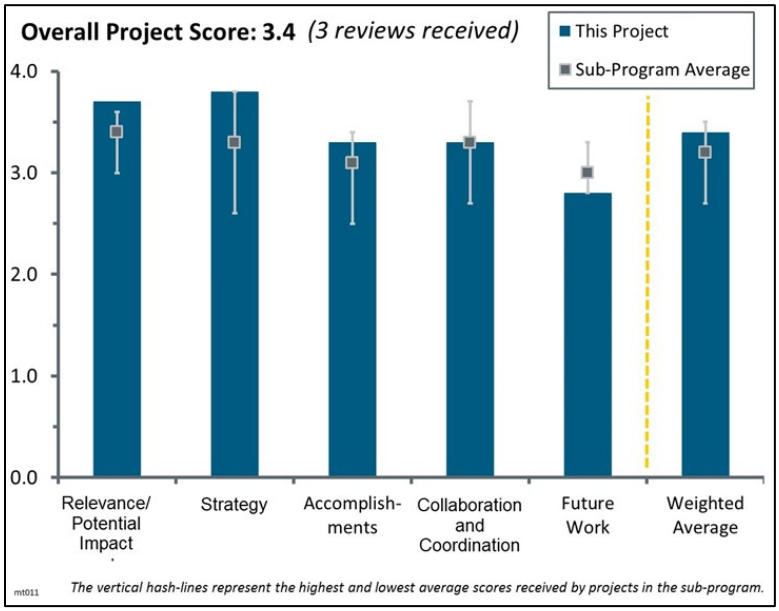
- The project should keep pushing the timeline so that no other delays occur.
- Interaction with the electrolyzer manufacturer should be accelerated. It is unclear what happens to a warrantee.

Project #MT-011: Ground Support Equipment Demonstration

Jim Petrecky; Plug Power

Brief Summary of Project:

The objectives of this project are to develop fuel cell-powered ground support equipment (GSE) that (1) are cost-competitive and more energy efficient, (2) are lower in carbon emissions, (3) reduce consumption of diesel, (4) decrease energy expenditures, and (5) validate the value proposition. These objectives are supported through vehicle testing of the Charlatte CT5E tractor, FedEx dollies, and shock testing at Memphis-Shelby County Airport and the Memphis Division of Fire Services.



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 **3.7** for its relevance/potential impact.

- The project is critical to the development of hydrogen and fuel cells because GSE could be the next major commercial application for fuel cell technologies (i.e., GSE could be the next major advancement after critical power needs, specialized applications, and lift equipment).
- This project, in particular, seems to have a high potential to meet Hydrogen and Fuel Cells Program goals and enable demonstration for a wide breadth of additional applications.
- The overview approach was very good. The "Relevance/Potential Impact" would have been rated as outstanding except the presentation did not relate the activities in the overview to the U.S. Department of Energy's (DOE's) barriers. It was unclear why the presentation did not respond to the DOE question on relevance.

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 project is well organized and structured and identifies the key elements for a successful deployment of the fuel cell systems. The project includes not only the fuel cell system but also the delivery, storage, and dispensing of hydrogen fuel. The project has addressed safety issues, including hazard and operability study and operator training. The project's approach could serve as the basis and reference point for future fuel cell system deployments.
- The presentation was extremely clear and direct; the processes were straightforward and understandable, and all barriers were addressed.
- Investigation of various possibilities for hydrogen procurement adds important value to this project. However, some of the details of the costs for the hydrogen pathways may need reconsideration or further explanation as they do not appear to align with other points of reference. In particular, the cost difference between procurement of gaseous hydrogen and liquid hydrogen alone seems to imply the two options were not evaluated on equivalent bases.

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 a very good project and presentation, fully focused on critical barriers. There are no recommendations for improvement.
- A lot of good progress had been made in terms of evaluation, design, and development of learnings. However, the difficulties described with the fuel cell seem like they have held up the overall project timeline. For a project in this program area, it seems the fuel cells chosen were not appropriate.
- Design and prototyping is well underway. The project reports the performance during year one fell short of the demonstration targets. The project did not explain why the airport truck demonstration missed the targets or what the specific problem components were. It was unclear whether the underperforming components were all balance-of-plant (BOP) components or whether there were stack components that also underperformed. Identifying these issues will help all fuel cell original equipment manufacturers (OEMs) and suppliers, which is an objective of DOE. How the project will correct these deficiencies and whether the alternatives meet the performance and cost objectives were unclear.

Question 4: Collaboration and coordination with other institutions

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

- Collaboration, especially with the demonstration host, seems to be essential for this type of project and seems to have been carried out well.
- The project has a well-organized team that includes end-user and application sites.
- The Plug Power team partnered with FedEx (the user), Charlatte (tractor OEM making the non-fuel cell part of the equipment), the Memphis-Shelby County Airport (the site where the activity occurred), and the Memphis Fire Department (the regulating authority). It is not clear what programmatic role any of Plug Power's partners had beyond FedEx agreeing to use fuel cell equipment, Charlatte modifying equipment they manufacture (if they did), and the airport and fire department performing business as normal (or close to it). While few in number, the role of each of Plug Power's partners appears to be very, very limited.

Question 5: Proposed future work

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

- The integration into the FedEx tracking system should receive particular focus, as it will be important to evaluate the implications for maintenance cost and work that the fuel cell system brings to the GSE application.
- From the presentation, the future work seems to be limited to maintaining and repairing equipment.
- It is unclear whether FedEx will take over service in order to address performance deficiencies with replacement parts. It was also unclear whether the proposed increase in FedEx's involvement suggests that Plug Power will always need to have its technicians onsite. Performing an economic evaluation of the total cost of ownership is a good idea. The presentation did not indicate whether the total cost of ownership will be evaluated without the federal government subsidy.

Project strengths:

- This projects seems like it has great potential for lessons that can be utilized in other applications. Expansion of the fuel cell system demonstrated in this work to other medium-duty applications, or into facilities with multiple platform opportunities (like this project's host airport where many types of vehicles and equipment are important), seems highly probable.
- The project has a strong team and leading experience in the development of the airport truck. Another strength is the project's broad coverage of the technology from the fuel cell system to hydrogen delivery, storage, and dispensing. Finally, the project has strong interaction among partners.
- The performance by Plug Power is a strength.

Project weaknesses:

- It seems that the fuel cell stacks chosen for the demonstration were not ready to be integrated into a market demonstration program yet. This is a concern for a project in this program area. Additionally, because the prime is a fuel cell manufacturer themselves and because the proposed solution is to use their own fuel cells in the next set of demonstration units, it is not clear why the first strategy for the project was to use third-party fuel cells. There may be valid technical reasons this approach was tried, but the discussion did not make this known.
- The project does not identify the components, either in the fuel cell stack or BOP, that are not performing to targets. This omission is not beneficial to the general public; rather, the omission only benefits Plug Power. DOE projects should not selectively benefit one class of people or one company. Fuel cell systems are still dependent on tax credits. Another weakness of the project was the limited contributions by Plug Power's partners.

Recommendations for additions/deletions to project scope:

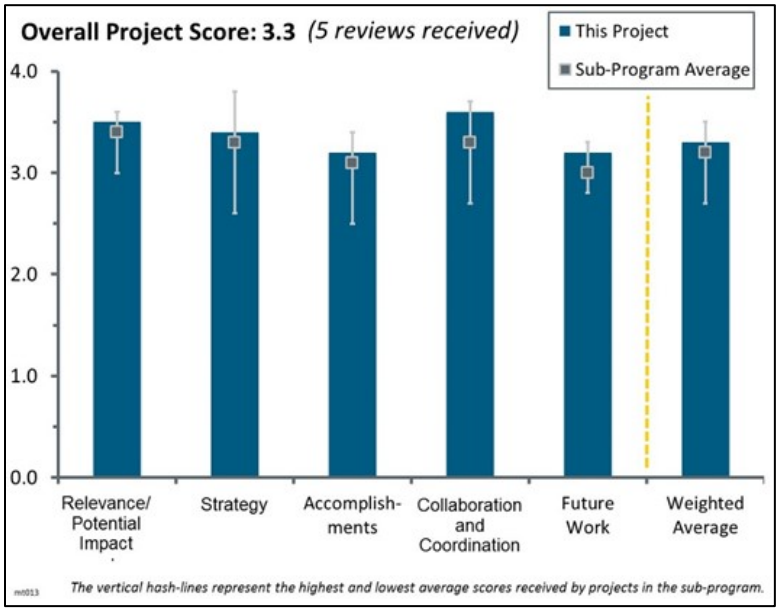
- The discussion of the comparison to incumbent technology should also consider a diesel (or other powertrain) hybridized option as a point of reference. The efficiency bonus of the fuel cell was presented, and the importance of regenerative braking in particular was mentioned as a key a factor. It therefore seems that an equitable comparison to diesel-powered vehicles would require consideration of a hybridized diesel to isolate the benefit of the fuel cell.
- The total cost analysis should be evaluated without the federal or state subsidies and tax credits.
- Although there was a lot of good work in the project, Plug Power might have improved its success if it had developed a stronger team effort.

Project #MT-013: Maritime Fuel Cell Generator Project

Joe Pratt; Sandia National Laboratories

Brief Summary of Project:

The overall objectives of this project are to (1) lower the technology risk of future maritime fuel cell deployments by providing performance data on hydrogen proton exchange membrane fuel cell technology in this environment, (2) lower the investment risk by providing a validated business case assessment for this and future potential projects, (3) enable easier permitting and acceptance of hydrogen fuel cell technology in maritime applications by assisting the U.S. Coast Guard and American Bureau of Shipping to develop hydrogen and fuel cell codes and standards, (4) act as a stepping stone for more widespread shipboard fuel cell auxiliary power unit deployments, and (5) reduce port emissions with this and future deployments.



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 **3.5** for its relevance/potential impact.

- Sometimes, more advancement and learning comes from mistakes and failure than from unequivocal success. Notable in this presentation was the frankness of the principal investigator's (PI's) admissions and the description of the lessons learned from those mistakes and failures. That said, the goals, relevance, and importance of this project are significant in that the project examined an application while also providing a venue for process improvement. The project and the PI did not just align with U.S. Department of Energy (DOE) research, development, and demonstration goals; the project very much exceeded, and provided great advancement toward, those goals.
- The Maritime Fuel Cell Generator Project plays a role in meeting the Market Transformation program goal to enable and accelerate expansion of hydrogen and fuel cell system use by targeting ports and other maritime applications. This project begins the process of raising awareness about possible applications, acceptance of the technology, understanding the hazards, and addressing the codes and standards related to this work. Even if the demonstration was not completely successful, the connections made and the inroads made are worth the effort. The outreach on this project was exceptional.
- Addressing maritime emissions in any capacity is a major advancement, especially considering the scale of the emissions reductions needed and the relatively low number of projects addressing emissions. This is a unique project, and the application has high value.
- The project has good relevance, specifically in lowering emissions and addressing technological and financial risks in a market that needs more efficient power technology.
- The project's relevance and potential impact focused on the application's benefits, e.g., lowering port emissions and reducing business risk. These are beneficial. The presentation did not associate relevance and potential impact directly with the DOE barriers. The project PI needs to recognize the DOE barriers are primary drivers for the project.

Question 2: Strategy for technology validation and/or deployment

This project was rated **3.4** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- This project adequately addresses the barriers identified. In terms of adequacy of standards, the project employed the American Bureau of Shipping to ensure the product met required codes and standards, and then it successfully navigated the permitting process. Some issues remain since system refueling is not performed on site. Although details are not provided, a Zero Emission Hydrogen Vessel Working Group and "train the trainer" safety training to address these issues seem like good ideas. The data gathered from the project should help demonstrate the benefits of fuel cells addressing the barriers of lack of cost and performance data and inadequate user experience. The project did a good job of involving all the major stakeholders for the project. As part of the final report, it will be important to include the lessons learned specifically for similar projects as well as generally for future demonstrations.
- The project team may have stumbled across some unforeseen barriers, but they addressed those barriers in a noteworthy and commendable way. The integration of the team's lessons learned experiences into overcoming future barriers appears direct and complete.
- The project outlined the systematic approach it executed to meet project milestones and demonstrate, validate, and deploy the technology.
- The planned approach seemed to be a complete and well-developed one. It is unfortunate that the unit has not yet been able to be deployed on the barge itself, as this would provide information about fuel cell operation in an environment, application, and platform that has not been very thoroughly investigated to date.
- One of the biggest challenges to this project is the strategy of demonstrating a prototype with a customer when that prototype has not gone through enough testing to be ready for customer validation.

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

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

- The DOE goal to enable and accelerate expansion of hydrogen and fuel cell system use was achieved, and the barriers to implementation of this technology were addressed. It is hoped that the lessons learned from this deployment can be applied to similar technologies and to other ports. One area of additional need is to evaluate the market share of the various port options, both in Hawaii and at other ports in the United States. This should be part of the future work business case.
- The team seemed to stumble into a number of barriers, both predicted and unforeseen, and appears to have done well to overcome those barriers as well as possible. It is unclear that the project team foresaw all the barriers, but that is at times the nature of research. The team seemed to learn and then demonstrated the moral courage to report openly and honestly.
- Getting the unit to the site for testing is a good accomplishment, as is the amount of outreach. Completing only 200 hours and 8 fills over 8 months seems too low. It is unclear what the project's expected or preferred operating goals were for those items.
- Progress on the demonstration itself certainly seems to have suffered. However, the reasons were discussed and understandable, given the intent of having the demonstration completed with minimal PI intervention. It will be important to ensure that the lessons learned developed through this project are well documented and communicated in the project deliverables.
- The project demonstrated operation with original equipment manufacturer (OEM) assistance for less than 48 hours. The project was active for nine months but accomplished only 200 hours of operation. It is unclear if that is a good or very limited operational result, and this needs to be explained by the PI. The project demonstrated hydrogen refilling. The project identified that inverters are a roadblock to widespread fuel cell generation deployment. This is somewhat of a surprise since stationary fuel cells using inverters is not a new technology and has been in use for more than 15 years. It is unclear if this issue was due to a particular supplier. It needs to be determined whether Hydrogenics has any suggestions for resolving the inverter issue. Operator issues suggest a poor interface with or commitment by collaborators. The project is working to resolve collaboration issues through outreach programs.

Question 4: Collaboration and coordination with other institutions

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

- The collaboration on this project was exceptional. All the major stakeholders were included and actively involved. Safety training was a key aspect of the project and was provided for all project partners. A significant amount of training occurred as a result of the "train the trainers" effort. It would be good to disseminate the project results beyond Hawaii to other ports, especially in California and the Northeast.
- The collaborations are key to this project's successfully addressing permitting and customer barriers.
- The coordination of this project is complex and requires a large number of collaborators to be involved, and the project looks to be managing the cooperative efforts very well.
- Sandia National Laboratory appears to have a large, balanced number of team partners and used them fairly extensively, i.e., the partners were active participants rather than markers to be added for a line count on a page.
- Collaboration was identified as an issue by the PI.

Question 5: Proposed future work

This project was rated **3.2** for its proposed future work.

- The top-priority activities for the future are the development of a business case, identification of follow-on opportunities, and continuing the outreach both in Hawaii and other ports, as identified by the project. Gathering lessons learned and addressing operational issues will help make the next deployment more successful. Additional deployments of this system are needed. Concrete plans for expanding the number of deployments should be created.
- The project team's focus is unclear. A number of unforeseen barriers seem to have arisen, and while it is unclear that the planning was complete enough, there is no question as to the team's integrity, the completeness of their report, or the team's value for future work.
- If the customer is not using the system as much as possible, it is unclear whether the project should continue trying to push operation and on-site fueling. It is not clear how much information is needed for the technical and business case analysis or how long that will take.
- Deployment on the barge was mentioned, though it was not clear that could be completed within the budgeted timeline for this project. If not, that will be a major loss for the project.
- The project identifies the next steps and is aware of technical problems. The project should identify more specific steps that would resolve technical and operational issues. The presentation did not provide a high level of confidence the future plans would resolve technical and operational issues.

Project strengths:

- The project's principal strength was the integrity of its management team. A second and nearly equivalent strength was the contribution made by the team to DOE's research, development, and demonstration goals.
- The team has identified an important application and is working with an experienced fuel cell OEM. The team is systematically solving issues as they arise.
- The unique application and market segment addressed by this project make it very important. It will be important to ensure that as many lessons learned are captured as possible and shared with future projects, especially in the context of maritime fuel cell operations.
- This project has strong collaborations and management.

Project weaknesses:

- The loss of operating time due to communication and staffing challenges with the operator are clearly the project's weakness. At this point, there may not be any change that can be made to address the issue, but lessons learned from the experience can and should be maximized.
- The project needs a firmer commitment from the Young Brothers if this is the source of the operator problem. Help from DOE and local government might improve the focus of the Young Brothers. The

inverter problem is a surprise because inverters have been used for more than 15 years. It is unclear whether this is because of a lack of support from Hydrogenics.

- It may be that the project has delivered a prototype to a customer without sufficient testing and improvements prior to field trials. The inverter issues and other non-technical issues related to operation highlight challenges with placing known technologies in operating conditions outside of the norm. The interface areas are often where issues arise, and not enough focus on development was given to these interface issues.

Recommendations for additions/deletions to project scope:

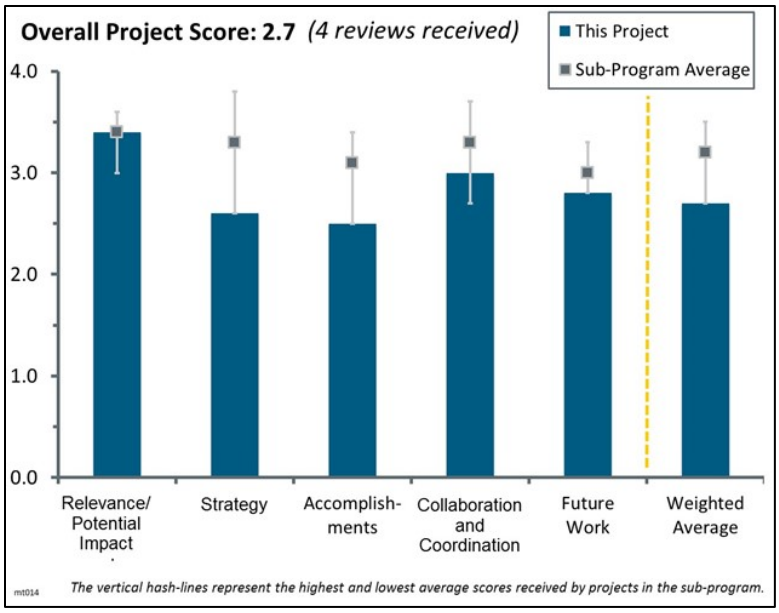
- The project should increase the interaction with both Hydrogenics and the Young Brothers to solve problems related to delays. Federal and local governments should be used to help with increasing the commitment of the Young Brothers and Hydrogenics. The impact of salt water spray on the performance of the fuel cell should be discussed.

Project #MT-014: Demonstration of Fuel Cell Auxiliary Power Unit to Power Truck Refrigeration Units in Refrigerated Trucks

Kriston Brooks; Pacific Northwest National Laboratory

Brief Summary of Project:

The purpose of this project is to demonstrate the viability of fuel-cell-based transport refrigeration units (TRUs) for refrigerated Class 8 trucks using demonstrations and business case development. Two fuel cell systems will be developed and deployed in commercial operations. Investigators will assess system performance and analyze market viability.



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.

- The potential impacts of TRUs in fuel cell markets can be significant, and the deployment of relevant technologies with suitable business models seems to be highly relevant to U.S. Department of Energy (DOE) goals and objectives.
- Project relevance is good because it is a logical extension of other fuel cell applications such as forklifts. The project can have significant impact on emissions and noise reduction goals.
- The project is relevant to the goal of accelerating market introduction of fuel cell technology, and the target market selected represents a reasonable opportunity for fuel cells to make inroads.
- The presentation provided a well-organized list of explanations of how the project would address commercial applications, socio-economic benefits, and barriers identified by DOE.

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 objectives and approaches of the project are well defined, with specific parameters for data collection regarding technology validation and business case development.
- TRUs are an appropriately sized market for commercialization efforts, and the clear advantages of fuel cell technology for this application suggest that fuel cells may be viable. The data collection and market analysis will help determine how much effort should be invested in this market going forward. The project team needs to get a better handle on the technical requirements, though. The reference to DOE targets for fuel cell auxiliary power units (APUs) is inappropriate for this application, as those targets were developed for heavy-duty truck APU applications using high-temperature fuel cells running on diesel fuel.
- Technology testing does not seem to be sufficient prior to customer deployment. Customer test locations are not necessarily tied into any other existing infrastructure, which makes it both more expensive and a higher risk for technical infrastructure issues because there may not be a good backup option.

- The project strategy for technology validation and deployment was hindered by the choice of fuel cell original equipment manufacturers. Nuvera fuel cell systems have had a mixed success record with DOE projects. Considering past history, it is surprising that DOE would continue to support projects with Nuvera fuel cells. The project approach is systematic and well organized. The data collection process is structured well.

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

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

- Nuvera's "supplier pause" makes the evaluation of accomplishments this year difficult. The supplier pause is from February 2015 to September 2016, so it is unclear if the accomplishments related to the supplier are from past years or the current year. The presentation is unclear, as it indicates that the fuel cell is less efficient since the system's hydrogen usage per day is higher than the gallon of diesel equivalent (GDE) for diesel usage. It would be good to see this comparison for emissions reduction in GDEs.
- Progress to date has been slow, apparently in part because of issues with the fuel cell system supplier. The recent addition of another supplier should accelerate progress. The first supplier (Nuvera) has been performing component and program-system testing and has integrated one system with a TRU for a four-hour test. Real world testing will not begin until next year.
- The presentation of the tipping point between positive, marginal, and negative net present values is very beneficial. DOE should consider similar presentations for its other projects. Project accomplishments are delayed because of Nuvera. Drawings of fuel cell systems were presented in some cases, and this suggests that the "real" fuel cell system has not been fabricated. It is unclear what the status of the fuel cell system is. The system has a very low operational time, at first 2.5 hours and then 4 hours. The fuel cell system may not have reached equilibrium operation point; if this is just beginning of life data it is not very beneficial.

Question 4: Collaboration and coordination with other institutions

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

- The supplier addition is good, along with other companies, but if a supplier has been added, it is unclear why "TBD" (to be determined) is listed on the collaboration slide.
- The project has been limited by delays in assembling a team. The recent addition of a new fuel cell supplier and demonstration partner will help.
- The Nuvera partnership does not appear to be beneficial.

Question 5: Proposed future work

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

- The project is scheduled to perform two 400-hour demonstrations next year and to analyze data from the demonstration to assess the viability of the TRU market for fuel cells. The timeline for the demonstration with the recently added partners is not yet clear.
- Considering all of the difficulties and lack of performance, the proposed future work should contain more detail. For example, a definition was not provided for "sized appropriately" for developing the system. The project should know this already. It is unclear why value propositions are only being identified now.
- A number of items related to the choice of demonstration sites and reliance on mobile refuelers do not appear to have been considered. It is unclear how mobile hydrogen is paid for and what happens if the mobile refueler is not available. It is unclear what plans are in place for when the demonstration is completed. It is unclear what go/no-go criteria have to be met before the integrated system is placed at the customer site.

Project strengths:

- The project presents an excellent market opportunity and good impact, if successful.
- The identified market appears to be a promising opportunity for near-term fuel cell commercialization.
- This project does not appear to have any strengths.

Project weaknesses:

- Project weaknesses include site selection, putting technology at too low of a technology readiness level with a customer, and schedule delays.
- Progress has been slow, and the degree of commitment on the part of the industrial partners is questionable.
- Nuvera is a primary weakness. Pacific Northwest National Laboratory (PNNL) does not appear to have other aspects of this program well organized. It is unclear why PNNL is defining the value proposition after operating the project three to four years. Nuvera will complete two 400-hour tests, but the approach calls for a test of 800–1000 hours.

Recommendations for additions/deletions to project scope:

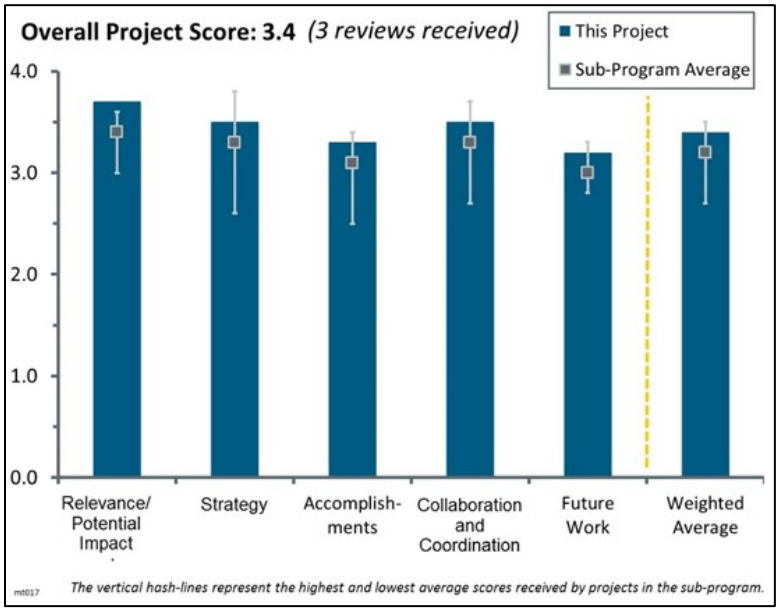
- One of the main goals of this project could be development of working business case models for an early fuel-cell-based TRU market. The project should conduct a detailed analysis of the customers' needs and expectations regarding TRUs and create solid risk management plans to enable the project to cope with potential system failures during the field demonstration; this would help with acceptance of the technology.
- This is a rare occurrence of a Fuel Cell Technologies Office (FCTO) project that is and has been in a lot of trouble. FCTO should consider terminating the project or having the project refocused with a totally new team.

Project #MT-017: Medium-Duty Parcel Delivery Truck

Thomas Griffin; FedEx Corporation

Brief Summary of Project:

This project will demonstrate hydrogen and fuel cell technologies in real-world environments. Fuels cells are being integrated into 20 battery electric pickup and delivery vehicles. Those trucks will operate in 10-hour shifts, 260 days annually, amounting to at least 5,000 hours per truck for a total of 100,000 hours over 1.92 years. The project is expected to reduce diesel consumption by 100,000 gallons and prevent 270 metric tons of carbon dioxide.



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 **3.7** for its relevance/potential impact.

- Fuel cells as range extenders for battery electric vehicles (BEVs) appear to be a large potential market, given the vast number of fleet vehicles throughout the United States. FedEx Corporation's willingness to step into this new market and invest in and evaluate the technology is commendable. This project fits well within U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program goals and objectives. Going forward, it would be beneficial if FedEx would advertise its use of fuel cells to encourage other similar companies to consider them. It is hoped that FedEx could label trucks with fuel cells to bring greater awareness and acceptance to the community as well.
- The relevance of DOE goals and the commercial goals of FedEx are clearly stated and consistent. FedEx's long-term goals to reduce greenhouse gas emissions, improve efficiency, and reduce operating costs are defined, and a vision of future benefits and applications is clearly stated. FedEx provides perspective for multiple applications of fuel cell systems in electric vehicles dependent on delivery requirements.
- This project has direct relevance to the DOE goals of demonstrating the viability and potential business case for fuel cells in a continually broadening range of vehicle-based applications.

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 strategy of bringing one system online, evaluating its performance, and then bringing on 19 systems at various sites seems reasonable. The information the team collects from each of the trucks should include the efficiency and maintenance required during the demonstration. This information will be beneficial to any future demonstration and to the fuel cell community at large. It is assumed that there will be feedback from the first truck and modifications made to the subsequent 19 units based on the lessons learned from the first one. However, that is not in the schedule. The schedule is very aggressive. The team should make sure that there is adequate time spent on addressing safety issues and first article testing of the integrated

system. It is good to see that durability testing and dyno testing are being performed. Poor performance and especially safety issues have impacts on the entire fuel cell community.
- The project seems to align with DOE's and FedEx's individual strategies, and this was discussed, but there was not substantial discussion of details in the project's strategy.
- The approach and milestones status are reported. It is not clear why plans for Task 2 through Task 5 of Demonstrations need to be revised. It is not clear whether there was an error in Task 5 for the revised plan or whether Task 5 was accelerated (Chart 10). The presentation should have identified what barriers the approach was addressing.

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.

- The project is just getting started, so not much progress has been made. The reviewer looks forward to evaluating the project progress next year. It is good to see that a model has been developed to optimize the sizing of the battery and fuel cell. It would have been useful to show the assumptions of the model and the design space evaluated to optimize the system.
- There has clearly been a setback with collaborators. However, interesting work has been completed in the meantime, especially the evaluation of the duty cycle and the design of appropriate system specifications.
- The project is in the startup stage, and its progress/status is reported. The project is defining drive cycle limits for system development (although it is unclear what a 60 mile "stem" length means). The project is defining the right-sizing of operation and predicting usage of fuel cells and hydrogen, which offers a good perspective of the issues and requirements for the fuel cell and hydrogen storage. It is not clear why a replacement electric vehicle original equipment manufacturer (OEM) was identified; it was not explained on the slides.

Question 4: Collaboration and coordination with other institutions

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

- A strong, experienced team was identified. The fuel cell systems OEM is highly experienced, and the National Renewable Energy Laboratory is a well-established contributor for data collection. Vehicle safety regulations will be covered by Transportation.gov.
- The collaborators selected appear to be sufficient to perform the demonstration with all the right expertise. It would be beneficial to the Fuel Cell Technologies Office (FCTO) to have other collaborators that could participate at a low level and be aware of progress so that they could eventually have a similar demonstration of their own.
- It appears that the project had some initial difficulties with coordination, but the project has recovered from the setback. This ability to move past the setback is important.

Question 5: Proposed future work

This project was rated **3.2** for its proposed future work.

- Topics are listed but lack the detailing of responsibilities for team members. A top-level overview of the effort is needed. The Future Effort slide could include startup month and responsibilities.
- There is no discussion in the future work as to how hydrogen is going to be provided for refueling both in the short and long terms. A major piece of the FCTO objective is to address the development of the hydrogen infrastructure. How this will be advertised and how that outreach will be planned is also important.
- The project seems to be budgeted for 21 vehicles; however, there was no discussion of contingencies in case unexpected delays or difficulties appear with the first demonstration unit. It is not clear how the budget for the remaining 20 vehicles will be managed in this case.

Project strengths:

- The principal investigator is from an experienced company with well-established goals consistent with DOE goals. The fuel cell OEM is experienced and has demonstrated a commitment to success in other projects.
- The real-world setting and operating requirements, and a selected set of partners to demonstrate this, are real strengths of this project.

Project weaknesses:

- The presentation was a bit short on details for the work plan. Other than this, no major weaknesses are identified.
- It is too early in the project to identify whether there are weaknesses.

Recommendations for additions/deletions to project scope:

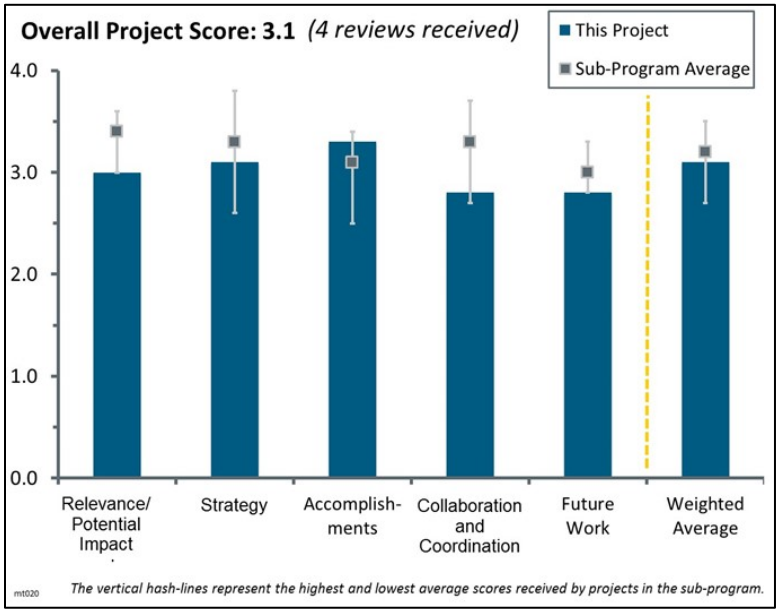
- The project should provide additional inputs on the responsibilities of partners and how achievement of FedEx goals addresses the elimination of DOE barriers.

Project #MT-020: Fuel Cell–Battery Electric Hybrid for Utility or Municipal Medium- or Heavy-Duty Bucket Trucks – Fuel-Cell-Powered Auxiliary Power Module

Abas Goodarzi; US Hybrid Corporation

Brief Summary of Project:

Medium- and heavy-duty bucket trucks are used daily by line crews employed by utilities, telecommunications companies, and municipalities to repair infrastructure. An electrified powertrain reduces operating costs from fuel and maintenance and enables improved handling and noise reduction. US Hybrid Corporation (US Hybrid) is developing fuel-cell-powered auxiliary power modules (APMs) and identifying the most promising APM in terms of commercial viability. This APM will be integrated into a bucket truck for a 200-hour demonstration. Investigators will collect data during operation and provide performance and energy analysis.



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 **3.0** for its relevance/potential impact.

- Bucket trucks and other similar truck applications appear to be an excellent niche market for fuel cells. The reason for their use is quite compelling. These vehicles are distributed throughout the United States and could help increase the use of fuel cells and build out the hydrogen infrastructure. There is concern that the bucket hydraulics and the trucks themselves do not have high enough utilization to justify the increased cost of a fuel cell. If they are used only in the event of a power outage or repair, for example, the cost per hour of usage could be very high. It would be wise to determine the yearly utilization.
- The project would reduce greenhouse gas emissions and oil consumption. There is not enough information to understand definitively the efficiency of the energy conversion. It would reduce air pollution with quiet operation. This has the potential to make a positive impact on the bucket truck industry, but given the complete absence of cost and budgets, and the projected unit costs, it is unknown whether it would be saleable. No economic analysis results are provided. However, after the poster session, it was learned that the project is funded via the Small Business Innovation Research (SBIR) program, not as a full multi-million dollar funding opportunity announcement (FOA) project. The project has made very good progress.
- The potential impact will be very limited without a better financial analysis. It is widely known that fuel cells are clean and quiet, so the functionality of a fuel-cell-powered bucket is not in question in a one-off demonstration. However, one has to show a business case in order to make an impact.
- The project has conducted a paper study on the viability of fuel-cell-powered bucket trucks. Commercialization of fuel cells to power the hydraulic boom and other non-motive power needs appears possible, though cost (including fueling infrastructure) will limit this market to niche applications in the near term.

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 project strategy is to perform an analysis to select the most viable configuration of a fuel-cell-powered bucket truck (Phase I) and to produce and deploy a bucket truck in a demonstration project at the Hawaiian Electric Company (HECO) (Phase II). This represents a reasonable strategy to assess the viability of fuel cells in the target market.
- No barriers were specifically called out in the poster presentation as required by the DOE Hydrogen and Fuel Cells Program Annual Merit Review (AMR) formatting. However, it seems that several barriers were addressed, including the following: C. Inadequate private funds available for infrastructure development and F. Inadequate user experience for fuel cell applications. Barrier C could be better addressed if potential funding mechanisms were defined and the market was sized to give some idea of the cost and size of increased infrastructure development through bucket trucks and similar fleet applications. Barrier F will occur as the project proceeds and efforts are made to publicize the demonstration and its results. Other barriers may also be applicable. US Hybrid is well suited for leading the project, and the scope of the work is very feasible.
- There are no detailed demonstration plans beyond the statement that it will be demonstrated for 200 hours by HECO. It is unknown whether this includes only 200 hours of operations or 200 hours of possession. There should be independent data collection and testing, and there should be dynamometer testing. As presented, it does not appear to be a well-designed project, and there is an absence of go/no-go decisions. There is no detail on the battery storage system in terms of a manufacturer and organization support in the integration. While slide 11 lists Phase II future work, it is not tied by dates to the tasks in slide 12. There is minimal information about the supply of hydrogen infrastructure in terms of storage and speed to fuel. While the infrastructure is not part of the project, it is critical to success. However, again, it is an SBIR-funded project, so for this level of funding, the approach details are appropriate.

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.

- The funding for this project was not provided as required in the overview AMR format. In spite of this, as a Phase I SBIR, this was not a large project. The researchers did estimate the duty cycle and emissions, evaluate system configuration alternatives in order to down-select to one option, estimate fuel use and operating costs, and select a possible demonstration location. This is substantial progress for an SBIR project and is beyond nominal expectations.
- In Phase I, the project has analyzed duty cycles and produced simulated fuel usage profiles to compare several system configurations. The results of the study support initial commercialization in niche markets of bucket trucks in which non-motive loads are powered by a fuel cell system. Reduction in fuel cell costs could enable more widespread commercialization.
- There are not any performance indicators with which to determine the accomplishments and progress succinctly. However, the SBIR status negates this.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.8** for its collaboration and coordination.

- There is good collaboration in Hawaii with Hawai'i Natural Energy Institute (HNEI) and HECO, and in New England with the Massachusetts Hydrogen Coalition and Eversource Energy.
- Two commercial partners in different regions of the United States have been selected and a possible demonstration drive cycle delineated. It would have been good to discuss more of what is planned for a demonstration in Massachusetts and what the drive cycle looks like for this location.

- US Hybrid will integrate its technology into a commercial bucket truck, and HECO will demonstrate the truck in operation. Other listed partners include HNEI, the Massachusetts Hydrogen Coalition, and Eversource Energy, but the roles and responsibilities of the various partners were not clearly presented.
- It was stated that HECO would demonstrate the vehicle for 200 hours, but there is no indication of the collaboration and coordination with HNEI, Eversource Energy, or the Massachusetts Hydrogen Coalition. It is mentioned that HECO and Altec Inc. will tune the operations; the PI discussed neither what the relationship was between HECO and Altec Inc. nor the scope of the tuning operation.

Question 5: Proposed future work

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

- Proposed future work (in Phase II) consists of integration of a fuel cell power system into a commercial truck and deployment with HECO for a 200-hour demonstration. This demonstration will provide performance data and operating experience that will be used to evaluate the market potential of fuel-cell-powered bucket trucks. This is a reasonable plan, though more details on the integration plans would be helpful.
- Future plans are well laid out in terms of steps and responsibilities moving forward into SBIR Phase II. It would have been beneficial to have additional detail on appropriate decision points and to consider barriers to goals. An important part of any of these demonstrations is the development of a solid business case. Future work should include the development of this business case in terms of sizing the potential market, evaluating potential purchasing approaches, and understanding market needs.
- While the future tasks are listed on slide 11, there are no known go/no-go decision points or identification of potential barriers.
- There is no indication of the cost planned for the future work, so there is no way to assess whether the cost and work are commensurate.

Project strengths:

- This project provides a good demonstration of the benefits (clean, quiet, and energy efficient) of a fuel-cell-powered bucket truck.
- Bucket truck applications may represent a good opportunity for near-term deployment of fuel cell technology, and this project is making progress toward evaluating the market.
- There is a clear need for an economically viable bucket truck that does not use an internal combustion engine to power the accessories and electric power take-off.

Project weaknesses:

- The degree of industry and utility interest in adopting fuel-cell-powered bucket trucks is not clear at this point, and while fuel cells present some clear advantages in terms of noise and emissions reductions, it appears unlikely that they will provide any cost savings when fueling infrastructure costs are taken into account.
- There is no financial information provided, no specifications, no independent testing to support DOE decision-making, no calendar-based timeline, no return on investment analysis provided, no go/no-go decisions, and no information about the battery, including the chemistry, the battery management system integration, and how the battery pack will be charged. Also, the SDU should be explained.
- No convincing business case is presented. There is nothing in the poster related to the cost of the fuel cell system or what the payback time from fuel savings might be.

Recommendations for additions/deletions to project scope:

- The project should conduct a realistic business case analysis, taking into account the cost of the fuel cell system and the cost of the hydrogen fuel.
- A more thorough explanation of the project is needed to fully understand the scope. Clearly, independent testing is warranted during the demonstration phase. The project owners should compete for an FOA if an appropriate one is offered by DOE.