2017 – Market Transformation
Summary of Annual Merit Review of the Market Transformation Sub-Program

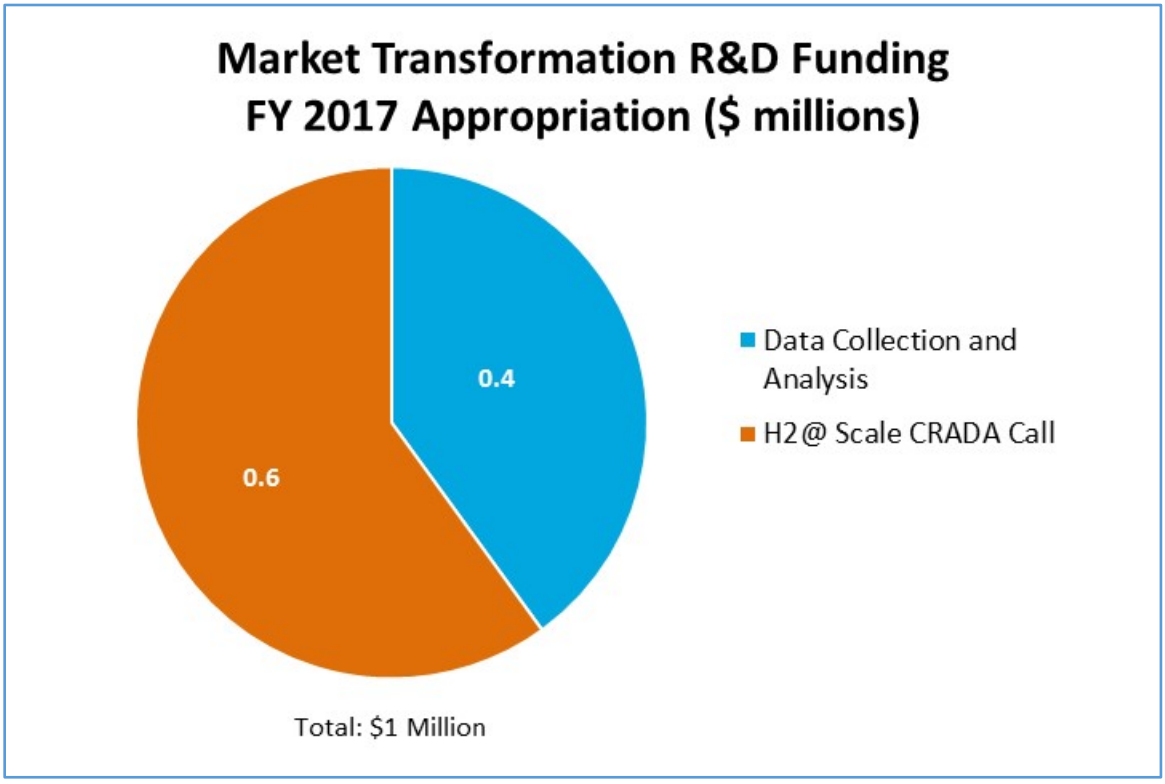
Summary of Reviewer Comments on the Market Transformation Sub-Program:

The purpose of the Market Transformation sub-program is to spur market introduction by demonstrating pre-commercial technologies in real-world applications. By doing so, this sub-program helps to identify and overcome market barriers 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 sub-program's projects, with four of the six projects scoring at or above 3.1. The reviewers noted that there are appropriate targets for demonstration, good leadership, and good results. General recommendations involved developing additional information on economic systems analysis describing costs, value, and market potential.

Market Transformation Funding:

The fiscal year 2017 Market Transformation sub-program funding totaled $1 million. These funds were used primarily to support data collection and analysis for continuing demonstration projects and to support projects selected from the H2@ Scale cooperative research and development agreement (CRADA) call.



Majority of Reviewer Comments and Recommendations:

The Market Transformation sub-program's projects were rated above average to high, as overall ratings ranged from 2.8 to 3.5, with an average score of 3.2. 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 technoeconomic reports that can be used to support further market expansion.

Airport Ground Support Vehicles: This project received an overall score of 3.5. Reviewers commented that significant progress has been made in moving to the prototype and advanced testing phase. They commented that the emphasis on drop-in-place technology resolves many of the system design requirements in this application. Reviewers commended the project's strong emphasis on safety, which is required for moving emerging technology to the marketplace. However, they expressed concern about the length of the project and suggested accelerating the implementation time for technology deployment. Reviewers asserted that since the team is five years into the project, there should be a complete dataset and determination of the value proposition.

Hydrogen Energy Systems as a Grid Management Tool: This project received an overall score of 3.4. Reviewers noted that the strategy to integrate motive power with grid management was excellent. However, they identified some areas that need attention, including utility involvement for controller operation and integration with grid operations; technical and economic investigation for design and/or selection of energy storage with battery, capacitor, or hydrogen production and storage; and refinement of controller management for economic dispatch of power products for energy, peak load management, capacity, and/or diversion for transportation fuel.

Maritime Fuel Cell Generator Project: This project received an overall score of 2.8 for its efforts to develop, design, and test a first-of-its-kind hydrogen fuel cell power generator for maritime applications. Reviewers commented that the design of the inverter appears not to match the project requirements and that downtime data analysis was not adequate. While collaboration with stakeholders was commended, a suggestion was made to develop a guide or information resource to enable easier permitting and acceptance for future projects.

Fuel Cell Hybrid Electric Delivery Van Project: This project received an overall score of 3.2. Reviewers stated that the project has realistic operational requirements for daily range, operation duration, and annual performance. Reviewers commended the project's approach to directly replace the electric vehicle's small combustion engine with a fuel cell, noting that this approach avoids a lot of integration work since most of the propulsion system has not changed. There was concern about the project's ability to meet safety barriers and challenges, as a safety plan has not yet been completed and the hazards and risks of the entire project have not been fully evaluated.

Fuel Cell Auxiliary Power Unit Project: This project received an overall score of 3.1. Reviewers supported the approach and commented that leveraging fleet operations to extend the value proposition of fuel cells and hydrogen will expand the use of fuel cells for transportation and related applications, paving the way for broader use. Suggestions included better explanation of the trucks' technical specifications and the potential commercial value proposition.

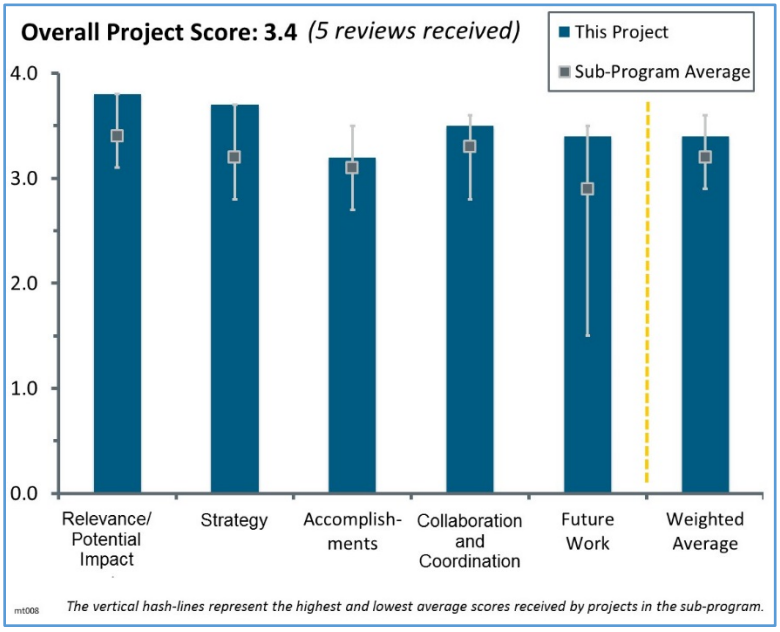
FCRx200 Development and Demonstration Project: This project received an overall score of 2.9. Reviewers suggested that the team should complete an economic assessment of this application and establish a duty cycle early in the project. Another comment was that safety planning and a hazard assessment needs to be completed with all participating partners before the operations testing phase starts.

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

- This project has very significant relevance in terms of the key elements of H2@ Scale. The combination of demonstrating grid frequency management using an electrolyzer as a load management device, creating a potential market locally for the oxygen produced (aquaculture), and supporting bus fueling with the hydrogen produced is very valuable for furthering development of the grid–hydrogen tie and creating a visible set of properties to encourage private investment in the technology. Codes and standards/permitting challenges were noted. However, it sounds like the project so far is also resolving those challenges, if not as quickly as desired, so those resolutions are also valuable in providing experience that will benefit future installations. Objectives include assessing electrolyzer durability under the transient demands of grid stabilization, looking at multiple revenue streams (aquaculture, grid service, hydrogen), and supporting fuel for hydrogen shuttle buses, as well as supporting development of regulatory structure for permitting of hydrogen systems in Hawaii—an important aspect.
- Conceptually, the use of the electrolyzer/fuel cell/hydrogen value chain is potentially a game changer to help manage intermittent load on the grid. With the introduction of more renewables to the grid, this value chain is a potential solution to the energy storage challenge.
- This is a relevant project to integrate values of zero-emissions vehicle transportation and grid management; however, these topics (fuel cell electric vehicle [FCEV]/hydrogen and grid management) are both complex and difficult projects to manage individually and even more so when combined. Nonetheless, the integration of the two areas is of high value.
- The project appears well aligned to the Market Transformation sub-program goals and objectives.
- Almost every fuel cell study hinges on the cost of the hydrogen. This project may offer a way to produce low-cost hydrogen. It also supports long-term use of renewables, which tend to destabilize the grid.

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.

- Having the central production facility at a state-of-Hawaii facility has allowed for strong political and financial support and good cost share. The incorporation of the pin-off application to try to use a pipeline to take hydrogen to the airport for ground support and to public hydrogen stations at airport entrances is an excellent opportunity to demonstrate the benefit of "aggregated demand." It would be very valuable to include some economic/cost analysis of what the project can demonstrate and lead toward in terms of hydrogen cost/price and investment opportunities. In addition, the modeling component—comparing operation of a 10 MW electrolyzer with operation of 1 MW battery (which is used in Hawaii) for grid stabilization—is expected to demonstrate the benefit of having both battery and electrolyzer. It would be helpful to understand the economics.
- The strategy for validation and deployment of the project for integration of motive power with grid management is excellent. Areas that need attention include increased collaboration with local officials for application of codes and standards and siting approval; utility involvement for controller operation and integration with grid operations; technical and economic investigation for design and/or selection of energy storage with battery, capacitor, or hydrogen production and storage; refinement of controller functions for cost-driven management in addition to frequency-driven management; and refinement of controller management for economic dispatch of power products for energy, peak load management, capacity, and/or diversion for transportation fuel.
- The modeling done to date provides a good idea of how this project can help solve some of the utility-scale challenges. The technology just needs to actually get into the validation stage.
- This is a strong project in that regard.

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

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

- Progress and accomplishments are good, although there have been some delays—but not significant ones. Progress has been challenged by issues related to codes and standards, vendor selection, and the need to bring in the private sector and utilities for dispatch to the grid and/or use of energy products for transportation fuel. Project management is aware of these issues and is addressing them with potential solutions.
- The reported accomplishments in 2017 (developing the electrolyzer dynamic modeling tool, obtaining site permits from Hawaii County, starting site infrastructure installation by the Hawaii Natural Energy Institute [HNEI], getting equipment delivered, modifying hydrogen transport trailers to improve cascade fill utilization so that the trailers can deliver 90% of the hydrogen, and converting three buses) are significant steps toward the overall project objectives. It would be useful to see a timeline or Gantt chart of the tasks/ milestones so that the reviewers can get a better idea of the overall project's complexity and the percentage complete.
- The project is behind schedule. However, it has managed issues well given the unpredictable setbacks and obstacles. The use of the booster pump and use of portable fuelers for station hydrogen supply were innovative.
- All progress is timely while at the same time facing the usual fuel cell infrastructure issues, i.e., locals not familiar with the fuel cell.
- There have been too many delays in the project to date. Some were unforeseen, but several could have been anticipated. This evaluation should rise in the next merit review because of accomplishments in installation and operation.

Question 4: Collaboration and coordination with other institutions

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

- HNEI has done an outstanding job of engaging multiple stakeholders and agencies, especially with regard to gaining increased funding, and technical support from multiple sources. While the collaborators and their contributions are all noted, it would be helpful to show, possibly graphically, how they interconnect and which parts of the project are supported by each.
- Collaboration appears appropriate. The use of Boyd Hydrogen to interface with code officials is noted as a beneficial collaboration.
- Collaboration is good, but utilities and competitive suppliers need to be brought in for analysis of dispatch on cost and energy products.
- Although the progress has been slow, the expansion of the team and collaboration with stakeholders has been noteworthy.
- Coordination is good, but more interfacing with the electric utility Hawaiian Electric Light Company would be helpful.

Question 5: Proposed future work

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

- The project has provided significant benefits beyond the scope of the project itself, specifically using lessons learned to write a request for proposals for the bus hydrogen station at Honolulu airport. Lessons learned were also transferred to Costa Rica in setting up a demonstration with an ex-Connecticut Transit fuel cell bus. Equally important are the potential future elements (such as tying into a hydrogen fueling station at the airport) that have been provided for in the project—it is very encouraging to see the planning for this project having a "multiplier effect."
- The project has very good potential and the manager is addressing issues.
- Proposed future work will demonstrate the value of the project. Since it is without further DOE funding, it will be critical to find a revenue stream to help support and continue the project.
- The future work appears consistent with needs to complete the project objectives.
- More is needed on economics, and discussions with utilities with large amounts of renewables on their system—such as Germany—would be useful.

Project strengths:

- The great strength of this project is the integration of multiple uses of the hydrogen and multiple economic drivers and aggregated demand for the same project (hydrogen supply to multiple uses such as grid ancillary services and oxygen for aquaculture).
- One of the real strengths is the engagement with many stakeholders and the collaboration among those players. Another is the concept of using the technology in providing grid management capability.
- Strengths include integrated value to combine zero-emission vehicle transportation, renewable dispatch, and a controller for multiple applications.
- This is a good technique for strengthening the grid as renewables become more prevalent.
- The principal investigator is committed.

Project weaknesses:

- More economic analysis/summary information would be very helpful; it is not clear how all the elements of the project are contributing to reaching a target price of hydrogen. This would be very valuable in helping quantify the investment, revenue, and price contributions of each element of the project.
- There have been some delays, although they are not significant. There have also been issues with codes and standards, issues with vendor selection, and a lack of direct utility and energy supplier participation.
- More outreach to domestic and foreign utilities would be beneficial.
- At this point, the lack of true field data after seven years under development is a weakness.

Recommendations for additions/deletions to project scope:

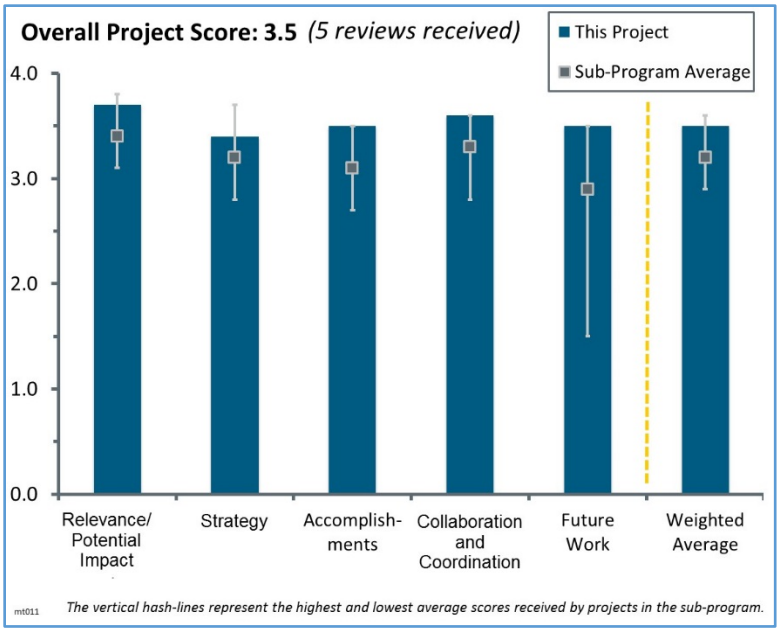
- The project should seek to involve utility and competitive energy suppliers; add cost as a driver for the controller to better understand if, when, and how much economic dispatch is possible; and consider a capacitor bank as a potential substitute for a battery.
- The project should press for the direct export of hydrogen to fueling stations using the FRP pipeline to supply a nearby location, if at all possible.
- The project should make sure the results from the implementation and operational phase are shared widely.
- More interfacing with utilities is recommended.

Project #MT-011: Fuel-Cell-Powered Airport Ground Support Equipment Deployment

Jim Petrecky; Plug Power

Brief Summary of Project:

The objectives of this project are to develop fuel-cell-powered ground support equipment that (1) is cost-competitive and more energy-efficient, (2) is lower in carbon emissions, (3) reduces consumption of diesel, (4) decreases energy expenditures, and (5) validates the value proposition. This project will deploy 15 fuel-cell-powered units for two years at Memphis–Shelby County Airport. The fuel-cell-powered cargo tractors will be located in Memphis, Tennessee, where FedEx Express has a fleet of 1,383 cargo tractors to manage 270 flights per day.



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.

- This highly relevant project establishes a pathway for research and development (R&D) efforts sponsored by the U.S. Department of Energy (DOE) to demonstrate their viability to meet the goals of the Fuel Cell Technologies Office (FCTO) and the overall DOE goals. With industry participation with both technology and cost share, this project demonstrates the diverse applications the FCTO-funded R&D products of the national laboratories, universities, and industry contribute to meeting environmental requirements and energy savings.
- Clearly, the objectives of the project to refine the value proposition and demonstrate technical performance are in line with FCTO/Market Transformation sub-program goals and objectives.
- The project's activities appear well aligned to the goals of the sub-program's market transformation activities. The project's learnings may be impactful to the DOE Hydrogen and Fuel Cells Program (the Program) and beneficial to similar projects.
- This seems like an ideal early application for a hydrogen fuel cell, with economics at $3,000 per kilowatt.
- This is an excellent topic for market transformation, with good potential for commercialization.

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.

- Using the airport hub for multiple users is an excellent approach. Identification of value areas (low noise, no idle, zero emissions, low maintenance, cost, and economics) is all good.
- The strategies for the multiple project activities are listed in detail as demonstration and commercialization requirements. Chart 8 details the value propositions, benefits, market drivers, and commercial benefits that will validate the fuel cell applications. The above-referenced requirements and the identified value propositions are the guidelines for the strategies for this project's successful conclusion.

- The length of this project points to a continuing need to reduce the implementation time for this technology's deployment. Five years into the project, data collection and determination of the value proposition are still not complete. While recognizing the delay with third-party vendor stacks, it still continues to point to maturity of the market and the industry supporting it. We should be able to get to a point at which project design/approval/construction is less than one year.
- While project barriers were addressed but not presented, this project helps remove barriers.
- All barriers have been addressed except for durability of the stack, which has a huge impact on economics.

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

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

- Significant progress has been made with the development of fuel cell systems consistent with the application requirements of moving the fuel cell from the bench to prototype and advanced testing. The emphasis on drop-in-place technology resolves many of the system design requirements. A strong emphasis on safety demonstrates recognition of moving emerging technology to the marketplace.
- This project points specifically to the need to have backup plans for the technology. There is a need to develop a more robust "supplier" base, and that has been highlighted in the project. The project will be able to make an advancement in defining the value proposition for airport-type operations.
- The project did well at providing progress toward goals. Steps taken to address early fuel cell stack issues were impressive. The presenter suggested ideas for enhancing the value proposition of this application by expanding the approach to other services such as other airport equipment and delivery vehicles. To help DOE achieve its goals, it would have been good to see the project take this further to evaluate the potential for such activities.
- The accomplishments speak for themselves.
- There were some short-term delays associated with early selection of stack vendor and stack durability, but the problem has been solved.

Question 4: Collaboration and coordination with other institutions

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

- Collaboration could not be any better.
- There are excellent partners, with public and private participants.
- Working with FedEx and tractor manufacturer local authorities seems to have been spot-on. The project team has managed through all aspects of the project so far.
- A strong project team was assembled.
- While basic collaboration was identified, deeper collaborations may be beneficial to the Program. For example, closer work with the Hydrogen Safety Panel and sharing of information from interactions with code and permitting officials could help future programs address roadblocks and barriers.

Question 5: Proposed future work

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

- Future work looks very promising for commercialization. Preliminary findings (for high-duty cycle fleet use, single fuel use, need for financing, use of preferred vendors, education for service providers, need to provide economic justification, need to manage demand charge for electricity use, and use of mobile refueling to take fuel to equipment) are all very sound and provide good advice for future work.
- A well-organized statement of future work is provided. Future activities will resolve the value proposition and establish an operator maintenance program.
- Proposed future work appears appropriate for the remaining time and scope of the project. Perhaps the project team could formally document the learnings from the project to share with other projects.
- The focus should be on durability of stacks in application.

- There did not appear to be solid plans to perform the future goal of leveraging the infrastructure to support local fleet-type arrangements.

Project strengths:

- The project has chosen a good "captured" fleet environment to explore the value proposition. The large number of pieces of equipment offer the opportunity for increased usage and lower costs. This is a good testing ground to arrive at a successful value proposition.
- Strengths include the public–private team, excellent project management, and the focus on economic viability for commercial operation.
- The project has a well-experienced team that was responsive to changing project conditions and challenges. Learnings from the project are good.
- Strengths include project management by FCTO and Plug Power and the commitment of project partners such as FedEx.
- The good cooperation of many organizations is a strength.

Project weaknesses:

- Weaknesses include a lack of participation from utilities to resolve the demand charge issue, lack of participation from airport management for project implementation, and lack of input from state air regulators for Clean Air Act State Implementation Plan regulation of non-attainment areas with zero-emission equipment.
- There should be more emphasis on DOE barriers and activity from the project to address them, as well as greater collaboration with DOE and the Hydrogen Safety Panel to consider safety issues and document safety learnings.
- The length of time for the project and the delay created by the third-party stack supplier continue to point to a weakness in the supply/vendor chain.
- There is a need to advance the hydrogen infrastructure.
- Emphasis on stack durability is needed.

Recommendations for additions/deletions to project scope:

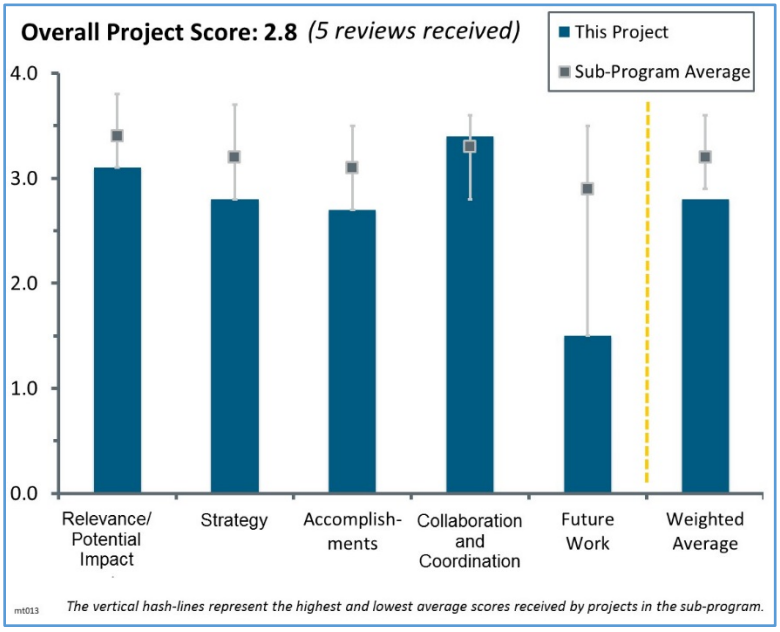
- The project needs to bring in utilities as participants to resolve the demand charge issue, airport management as a participant for project implementation, and state air regulators for Clean Air Act State Implementation Plan participation for regulation of non-attainment areas with zero-emission equipment.
- The project should look for other non-tractive airport applications of fuel cells, such as backup power to use some of the hydrogen.
- The project should define more explicitly the plan to expand and leverage for customers outside the airport—the last item in the project goals.
- Project learnings (including interactions with code officials) should be formally documented.

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 polymer electrolyte 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 the 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 **3.1** for its relevance/potential impact.

- The project focuses on identifying new applications that can achieve high energy efficiency and a reduction in localized pollution using fuel cell systems and supports the Fuel Cell Technologies Office (FCTO) goals.
- Being able to design and deliver a cost-effective "modular" solution has applicability in many environments.
- One of the goals of the project is to enable market introduction of fuel cell technology. This project is relevant to that effort and could help to reduce barriers to further deployment of fuel cells.
- Based on the most optimistic of economics, the fuel cell case is, at best, worse than the baseline diesel case.

Question 2: Strategy for technology validation and/or deployment

This project was rated **2.8** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- Barriers were well identified and addressed during the project. There clearly was a focus to understand and learn how to solve some of these barriers.
- The project did a good job evaluating all the barriers, permitting, etc. to any unit in this application, getting input from all the stakeholders.
- The strategy for this project should have been examined more closely before the project began. While ports seem to be a potential market for fuel cells, the economic analysis conducted by this project suggests that fuel cells are unlikely to be cost-competitive with diesel generators. Even if the fuel cell could somehow cost only $50/kW (unlikely to happen in the foreseeable future), the analysis shows that the fuel cell still has a higher life-cycle cost than a diesel generator. The principal investigator's response indicating that port

operators may adopt fuel cells because of some other intangible benefits was not satisfying. Individual consumers may make emotional decisions about finances, but businesses will not.
- The project does not appear to be well designed for deployment. The major problem is with partner Young Brothers, Ltd., which has a low interest in the project and appears to consider it a hindrance that interrupts the operation of its business. The prime contractor should have established an agreement for adequate support for this project from Young Brothers, and FCTO should have met with Young Brothers and other subcontractors to get their buy-in prior to funding the effort.

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

This project was rated **2.7** for its accomplishments and progress.

- The project has good organization, identifying all the impediments and solutions, with the exception of economics.
- The project aligns wells with some of the FCTO/Market Transformation sub-program goals and objectives.
- It is not clear why maximum continuous run time is so low. The average gross power and the maximum five-minute gross power indicate low usage of the fuel cell power system's capability. The 30% efficiency gain is only at partial load; the gain at full load is unknown. Design of the inverter appears not to match requirements. The downtime chart (slide 13) does not give downtime over how many actual or anticipated days of operation and does not provide complete data analysis. Labor issues are a major problem.
- The project faced many challenges that prevented it from achieving its goals. The number of technical issues that caused downtime was too high, and the system never made it onto the barge as planned. This type of demonstration project should show potential customers that fuel cells are a viable candidate to replace incumbent technologies, but in this project, the high amount of downtime probably sent the opposite message.

Question 4: Collaboration and coordination with other institutions

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

- One of the clear strengths was the collaboration among many different stakeholders.
- All the stakeholders were present; the project did a great job.
- The project had excellent collaborations.
- Labor/manpower issues are unacceptable and demonstrate poor choice of collaboration with Young Brothers (Foss Maritime).

Question 5: Proposed future work

This project was rated **1.5** for its proposed future work.

- Since the economics are poor, the project should attempt to identify and quantify other benefits.

Project strengths:

- Partners were good. Clearly a good deal of work went into this project.
- Collaboration among the stakeholder team was very impressive.
- The project has a good principal investigator and project collaborations.
- Identifying steps needed to get "it allowed" was good.
- It is difficult to tell what the project strengths are. Hawaii Natural Energy Institute and the Hawaii Center for Advanced Transportation Technologies appear to be the strongest collaborators.

Project weaknesses:

- No weaknesses were noted.
- Young Brothers (Foss Maritime) limited this project's success.
- Weaknesses include a lack of foresight about potential technical and non-technical issues and lack of a sound business case for the idea. A more detailed cost–benefit analysis should be performed before doing this type of deployment to determine whether the application makes economic sense.
- The economics are terrible, and there is no qualification of other benefits. Perhaps the project could ask the barge owners why they are interested in fuel cells.
- Sandia National Laboratories (SNL) did not identify strong collaborators that could contribute to the success of the project.

Recommendations for additions/deletions to project scope:

- Monitoring the progress of Hydrogenics in locating and selling to those who require modular power solutions should continue.
- Perhaps a guide or information resource could be developed to enable easier permitting and acceptance for future projects. If so, perhaps it could be shared on the H2Tools.org portal.
- FCTO should review with SNL management how the project was operated and how the proposal was developed. SNL should have an internal review of how projects that require strong contributions from collaborators are developed and proposed.
- Until there is some reason that this application can make sense, it does not justify continuation.

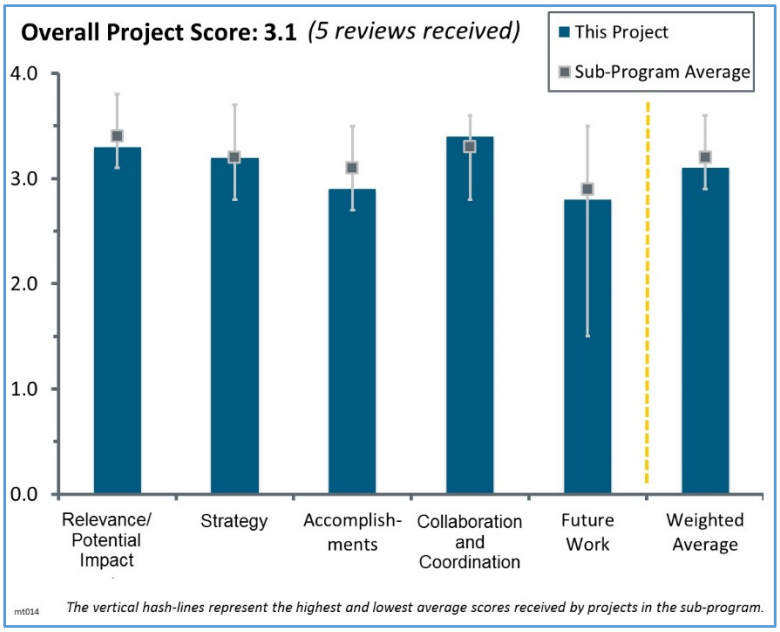
Project #MT-014: Demonstration of Fuel Cell Auxiliary Power Unit to Power Truck Refrigeration Units in Refrigerated Trucks

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

- Regarding relevance, this project has been/is useful to determining the market for auxiliary power units (APUs) to power truck refrigeration units. It looks like hub/spoke distribution with trucks returning to the central facility daily until there is widespread hydrogen fueling infrastructure available (following over-the-road truck applications). Some distribution centers already have hydrogen for forklifts. The project also needs to look at packaging/mass and continue to drive economics (very important). From the results reported, it looks like this will be an opportunity only in a market in which there are both emissions regulations restricting use of diesel TRUs and hydrogen-fueled forklifts so that there is aggregated demand to share the capital cost of hydrogen fuel. Perhaps there is an opportunity for designing a complete integrated TRU based on fuel cells. It seems like the need to produce 480 V three-phase power to satisfy existing refrigeration needs is driving cost/mass into the system.
- The project supports the development of new commercialization opportunities and brings in leaders in the fuel cell industry and the TRU industry. These should be good partners that can evaluate the adequacy of these applications. The business case analyses provide guidance for commercialization.
- The project has a good approach to solving the cost barriers of the hydrogen infrastructure issue. It also helps alleviate the problem of operating diesel APUs in environmentally constrained city systems.
- The project is attempting to leverage fleet-type operations to expand the value proposition for fuel cells and hydrogen. This continues to expand the consideration of using fuel cells for transportation and transportation-related scenarios, paving the way for broader use and introduction when the auto industry adopts fuel cells in a much bigger way.
- The project has a good topic and a good application for potential commercialization.

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.

- The approach to identifying the benefits and commercialization prospects is very strong. Barriers are addressed to minimize risk for investors and demonstrate the concept's feasibility for industry. Distribution concepts are identified, and costs relative to the existing technology (diesel engine) provide industry with information for making investment decisions. The project has a detailed approach for development of the fuel cell system and establishment of hydrogen infrastructure.
- The approach is as follows: develop and demonstrate, then assess performance, then analyze market viability. The use of the clear project phases (slide 5) and the use of the go/no-go assessment were good. Also, there was an honest assessment of the economics and, for one of the partners, the honesty to say "no-go." While the use of a "battery box replacement" approach to packaging a "diesel genset replacement" unit is understandable (as opposed to designing the complete refrigeration system around the fuel cell system), this may have hurt cost and mass.
- The project as designed explores the topic in a sound manner and way. There is a challenge: if the prime mover is probably still a diesel engine for the foreseeable future, you would have to support two fuel types. Most users would likely not see that as a desirable outcome.
- The true barriers are the environment under the truck and its impact on the fuel cell and the cost. Neither was sufficiently addressed. The project could simulate the air environment under the truck in a laboratory and not wait for the whole power plant to be constructed. Likewise, the project should assume that fuel cell cost of twice that of diesel was not optimistic enough.
- The hub-and-spoke strategy is good, but successful project development is questionable, with delay and change of business focus by a key participant.

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.

- The project made very good progress in identifying the fuel cell system necessary for the TRU application. Chart 12 clearly identifies the impact of low diesel cost for the competition. The high cost of fuel cell systems and the loss of the 30% federal Business Energy Investment Tax Credit were barriers that could not be overcome. However, these barriers were not the focus of the project.
- While specific project deliverables and milestones have been met, the project has gone very slowly.
- Progress is still a bit slow. The Nuvera team has yet to get the prototype in the field, and therefore, there is not much detail to report.
- Progress is questionable, with a change of the business focus by one of the key participants and a no-go decision by another key participant.
- There have been no great accomplishments.

Question 4: Collaboration and coordination with other institutions

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

- The team organized by Pacific Northwest National Laboratory consists of leaders in both the fuel cell system arena and TRUs. The project was able to resolve many of the barriers as a result of this strong team.
- Being able to form two teams and trying to solve the problems was an interesting and noteworthy approach. It allowed for participation from several additional stakeholders.
- Despite the fits and starts with Nuvera (Nuvera/Thermo King have built hardware but not yet found a demonstration partner), Ballard/Carrier/Walmart seemed to work well together as a team. On the one hand, it may be prudent to have a completed design to show to prospective partners, but on the other hand, the complete execution and getting to the go/no-go point and an actual demonstration would have gone faster if

the demonstration partner had been on board at the beginning. It seems like some things could have been done in parallel.
- Collaboration with DOE and private businesses was excellent, but project management is challenged with a change of focus by a key participant and no-go decision by another key participant.
- More input is needed from manufacturers about the reason for their interest in the fuel cell.

Question 5: Proposed future work

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

- While the project needs to drive to the Nuvera go/no-go decision and get a demonstration underway if it is a go decision, it seems like there are further opportunities to hone the project more to find a niche where it would work commercially. Perhaps some thought should be given to doing further analysis, for example, on an emissions comparison with diesel (which might help to pinpoint a market in which there might be a pull) as well as a well-to-wheels-type efficiency comparison. Perhaps there is also a low-carbon fuel standard opportunity.
- The future work addressed design of the Nuvera fuel cell for field testing (it seems that a prototype is assumed). The safety assessment and demonstration efforts need more detailed descriptions.
- The work plan is good, but success of future work to meet project objectives will be difficult because of a change of focus by a key participant and no-go decision by another key participant.
- With the Ballard team's departure and the lack of an end user defined for the Nuvera team, future work and utility are unclear.
- More studies could be conducted on the impact of several fuel cell costs and laboratory tests of the impact of undercarriage air quality on fuel cell life.

Project strengths:

- Strengths include the project topic, early selection of team participants, focus on project value, and early identification of barriers.
- This project has a strong timing/execution plan, and the decision to have two teams to compare work/ results is also a strength.
- The collaborators are the primary strength. They brought real-world operational experience to the project.
- Collaboration among developers and users is a strength.
- The project identified most issues.

Project weaknesses:

- The early work products are consistent with objective project evaluation; however, costs may be unreliable owing to a change in focus by a key participant that resulted in a no-go decision by another key participant. These changes have produced concerns for selection of platform design, with tank and fuel cell locations on the trailer underbelly subject to road damage, unreliable cost estimates, the questionable disparity of operational costs compared to conventional fuel vehicles, and high system costs that represent a major development issue. These issues will be difficult to overcome for an objective evaluation.
- The length of time to get the project to the demonstration phase is a weakness, along with the disconnect between the APU and prime mover fuel needs, which could be a barrier to adoption.
- There was no laboratory stack testing using a simulated air undercarriage environment. Also, the project was too pessimistic on fuel cell cost.
- The project perhaps did not ask enough questions or look at different levels of integration, so the opportunities to get to a viable "go" result are limited.

Recommendations for additions/deletions to project scope:

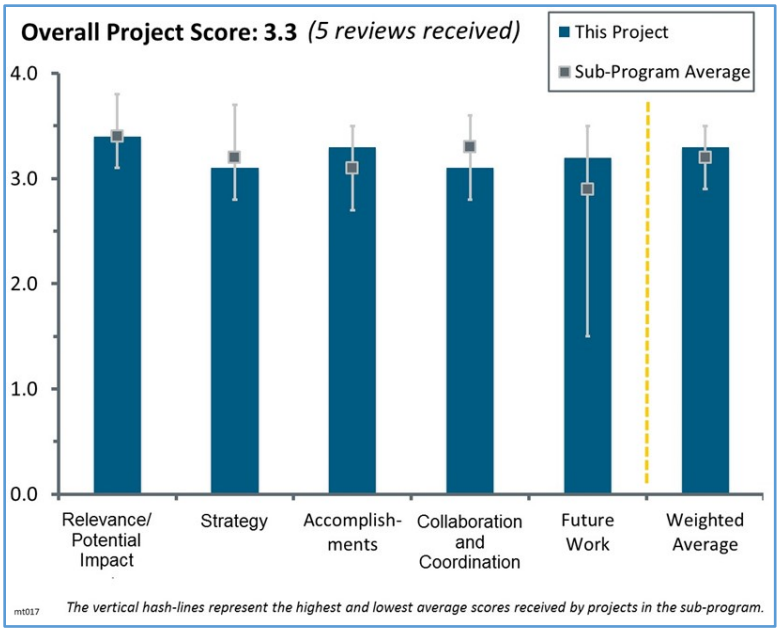
- It might be wise at this time to consider bringing in a new vehicle/system integrator that has a business focus for design and development of a motive fuel cell APU, and seeking to restart the evaluation with the user (Walmart).
- At this stage, quick selection of an end user for the Nuvera team is recommended. Also, comparison against other battery/electric solutions might be appropriate.
- Analysis of different systems integration approaches beyond just a direct replacement of a diesel genset might yield some potential configurations that do better on cost/mass.
- More parametric measures are needed on the impact of several fuel costs. Stacks should be tested at the laboratory level.

Project #MT-017: FedEx Express Hydrogen Fuel Cell Extended-Range Battery Electric Vehicles

Imran Ahmed; FedEx Express

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

- Regarding relevance, the project is seeking to find the right technical solution for the range needed for the specific solution ("right vehicle, right route" concept) for zero-emission delivery. The focus is on using a fuel cell as a range extender for battery electric vehicles to get 150 miles or more of range (20,000–40,000 miles annually). This is good because the project team has done the sensitivity analysis on vehicle size, range, and hybridization balance.
- The opportunity to create a demand situation in these fleet-type roles is spot-on. The relative cost of this project seems a bit high based on some of the other funded projects, but if the value proposition is there, then a relatively quick adoption of the technology with FedEx is probable (at least where infrastructure to support might reside).
- This is an excellent topic for potential commercialization.
- For relevance, energy independence may no longer have the importance it did 10 years ago. The high cost of fuel cell systems without the federal subsidy may make total cost of ownership a difficult prospect. The on-board traction charger has been done for batteries. It is not clear what is unique about this system.

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 Workhorse electric vehicle chassis has two battery packs (80 kWh) and a small combustion engine with 200 kW traction motor. The project is a direct replacement of the combustion engine with a fuel cell. This is a good approach because it avoids a lot of integration work since most of the propulsion system is not changed.
- The project has an excellent spoke-and-hub approach with realistic operational requirements for daily range, operation duration, and annual performance.
- The project has a well-organized approach to addressing milestones that meet strategy statements.

- The project has a straightforward approach to establishing the value proposition for the light- and medium-duty vehicle fleets. Because the initial deployment will be in the Albany area, the opportunity will not necessarily be replicated at other locations.
- "Unknown ability to meet safety" is identified as one of the barriers addressed by this project. As noted in the presentation slides, the project is 85%–90% complete for Phase I. It appears that a safety plan has not yet been completed for this project. Additionally, it is not clear whether the hazards and risks for the entire project have been fully evaluated. The principal investigator suggested that each project partner performs at its own risk analysis and that the vehicle is provided with substantial construction and a bumper. Given the location of the hydrogen storage tanks at the rear of the vehicle (with tank valves and manifold piping facing oncoming traffic), the answers do not suggest a strong technical basis for safe deployment of the vehicle. Other topics needing further safety consideration include evaluation of and basis for tank safety (SAE J2579 provides testing only for light-duty vehicles) and evaluation of vent paths for performance under overpressure conditions.

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 timeline is perhaps the most aggressive of any reviewed within the Market Transformation sub-program. The project seems to have well-defined dates and, so far, has met each within reason. Design and build of the prototype reflects solid management.
- The project is well organized and has made significant progress in multiple subsystems (hydrogen storage, safety, cooling, vehicle interface). The demonstration/development vehicle is complete, if several months behind schedule.
- There was some early delay, but the project appears to be on schedule with good progress identifying and resolving barriers.
- Accomplishments are well described and demonstrate a well-organized project. It is unclear why the two fuel cells are operated individually or where the system prevents interaction between the independent fuel cells, e.g., perhaps if one fuel cell fails, the other fuel cell provides enough power to maintain battery charge. It appears that the on/off start point is a 20 kW operation; therefore, both fuel cells must be functional for the system to operate. Perhaps fuel cell system redundancy is a limit based on fuel cell manufacturers not developing a 20 kW fuel cell. The graph presented in Chart 17 indicates that the optimization (variable output) has not been demonstrated. It is not clear whether both fuel cells operate at the same operating point in variable operation or how this is controlled. What was done in Tasks 1 and 2 is also unclear. The fuel task list was not provided.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.1** for its collaboration and coordination.

- There are excellent partnerships with DOE and appropriate private businesses.
- Collaboration between the team and DOE is good.
- Collaborators include Plug Power, Workhorse, and Morgan-Olson (body builder), as well as DOE, the National Renewable Energy Laboratory (NREL), and Pacific Northwest National Laboratory.
- There was no indication of collaboration on safety planning or hazard evaluation.
- The difference between collaborators and sub-recipients is unclear, nor is it evident what work was done by Workhorse and Plug Power, e.g., whether Plug Power just delivered the fuel cell system.

Question 5: Proposed future work

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

- Planned work is consistent with the work plan and with expectations for a high-value product.
- The proposed schedule and planning appear on target.

- Getting to the completion of the first demonstration truck and going through the testing/demonstration phase will provide the critical output from the project. The cost share for the second phase (after the go/no-go gate, assuming the result is go) is not completely clear but might need to be more biased toward private cost share. It would be helpful for DOE/NREL to get the operational data from the 19 trucks but not necessarily pay to build/operate them.
- Future work is well organized up to Task 5. Phase II work is unknown.
- A complete project hazard assessment and safety plan involving all project partners should be an immediate focus. Failure to do this could have serious safety and potential cost implications.

Project strengths:

- This is a real near-term opportunity with a strong industry end user. This is the only project currently being reviewed for which the end user is the sponsor/advocate.
- Strengths include the team partnerships, appropriate private business participation, and thoughtful early identification of barriers to be resolved.
- The project has a clear project plan and good collaboration to complete multiple subsystems in parallel.
- FedEx, Plug Power, and Workhorse form a strong team.
- Strengths include experienced project partners.

Project weaknesses:

- No weaknesses were noted.
- More detail is needed on performance and cost of the project vehicle compared with the standard platform internal combustion engine (ICE) hybrid vehicle.
- It would be good to have more information about the project financials, particularly the Phase I/Phase II budgets and the expected operational costs.
- The presentation has a weakness because there was no discussion of Phase II.
- Safety planning and integration are weaknesses.

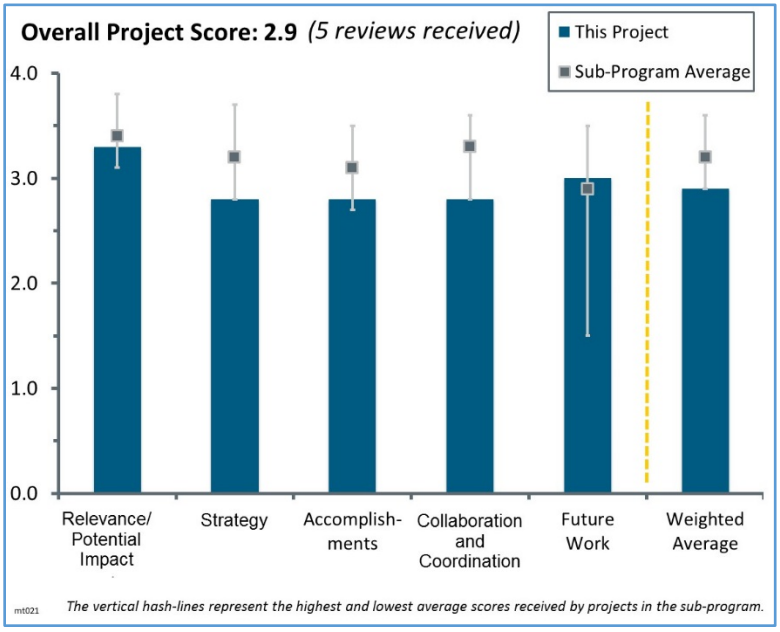
Recommendations for additions/deletions to project scope:

- The project team should discuss controls for two fuel cells working together to charge the battery. It is not clear how the system will operate if one fuel cell is operating at a different power point or with different efficiency. Next year, the project team should report on why this is not a weakness. There was no discussion of Phase II.
- It is important to keep focus on the key performance data. It is nice to have data from a large sample size, but the key here is to focus on metrics/data that are going to demonstrate the economics of building and operating the trucks in order to encourage private investment.
- Should the value proposition reflect good results, the project should identify expansion opportunities within FedEx.
- It might be helpful to have more detail on a performance and cost comparison of the project vehicle with the standard platform ICE hybrid vehicle.
- An immediate focus should be placed on safety planning and hazard assessment involving all team members.

Project #MT-021: Northeast Demonstration and Deployment of FCRx200

Abas Goodarzi; US Hybrid Corporation

Brief Summary of Project:



The project's objectives are to (1) design, develop, test, and demonstrate one fuel cell range-extended plug-in hybrid utility vehicle (FCRx200) at a commercial operator's site; (2) given the success of the initial prototype, receive approval to proceed with fleet development to deploy and operate a minimum of 20 FCRx200s for at least 5,000 hours or 30 months per vehicle, whichever occurs first, at the commercial operator's site; and (3) conduct an economic assessment, a payback analysis, a life-cycle cost analysis, an incremental capital cost per unit analysis, a fuel savings analysis, and a payback time analysis (concerning the use of hydrogen-fueled fuel cell range extenders in commercial fleets), as well as comments from the operator detailing the experience during operation. The economic assessment will be facilitated using data collected and submitted to the National Renewable Energy Laboratory on a quarterly basis. Upon project completion, the team will be able to make recommendations on the marketability of the FCRx200 vehicle.

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.

- The project looks into a new market segment, namely range extenders. One of the limitations of battery electric vehicles (BEVs) is range. By installing a small 5 kW stack, the range can be extended, and with that, a new application for fuel cells can be developed. Increased usage and sales volumes for stacks should lead to cost reductions and a more sustainable supply chain.
- The project supports the development of fuel cell system applications for vehicles. It addresses the development of fuel cell hybrid systems to increase the range of battery-powered delivery vans. The project advances fuel cells and hydrogen toward commercial systems.
- The project examines multiple possible uses of fuel cells, including transportation. This delivery van application further extends the scope of applications.
- This project seems to be more of an integration project than a technology demonstration/validation. Phase I involves the design, procurement, and integration of equipment for one prototype vehicle—which is fair enough, as this could provide some validation of the applicability of the balance between battery and fuel cell for the given size of vehicle and duty cycle. However, it does not seem that the further funding of 20 additional vehicles for demonstration breaks any new ground in terms of DOE goals.

Question 2: Strategy for technology validation and/or deployment

This project was rated **2.8** for its project design, approach to addressing barriers, feasibility, and integration with other efforts.

- The principle of using computer-aided design, simulation, and stack testing before putting it into a car is sound. Also, first building one car and then determining a go/no-go decision for the other 20 vehicles is good practice. However, doing the economic assessment at the end of the project is late; the assessment should happen earlier in the project, before going to 20-vehicle production. This technology is available in Europe, and there are more than a hundred BEVs with range extenders on the roads. The team should look at the experiences in Europe and try to reflect on those for the U.S. market. For example, Nissan and Symbio are working on the same technology for the eNV200. In Europe, this development with Nissan is not part of the Fuel Cells and Hydrogen Joint Undertaking funding. In the United States, Nissan works with US Hybrid to build the same system. It could be interesting to understand the differences in the economic models between the United States and Europe. During the presentation, it was mentioned that US Hybrid has no view yet on the road patterns and usage of the demonstration car. This is important information for designing the right stack performance. This is a very urgent action.
- Based on the project plan, the principal investigator (PI) has outlined a well-thought-out project. However, he should begin to consider economic issues quickly.
- The project is an evaluation of market viability (costs and meeting requirements) and acceptance (customer desire). The approach/project concept is to evaluate a light-duty fleet range extender for a BEV. Phase I is developing, building, and testing the prototype. Phase II is a two-year demonstration of 20 vehicles with fuel provided by the project (National Grid does not want to do it) for at least 5000 hours/vehicle. The specifications are 5–10 kW fuel cells with 2–3 kg hydrogen at 700 bar. The range is to increase from 100 miles (BEV only) to 250 miles. Also, since the project is in the Northeast, there is a significant cold weather component (heat recovery, freeze capable to -30ºC). The existing onboard charger will be used as an interface for the fuel cell system. It is unclear whether the project goals of determining cost viability and fuel cell durability require such a large fleet/funding. Other than any potential reliability problems that cause undue downtime/repair costs, the factors affecting cost viability will presumably be known at the outset. So while the goals of the project have some value, they do not seem to break any new ground in terms of DOE goals. The approach is simply to run 20 vehicles and see how much it costs and how long they last. This is not very novel and probably is not the most cost-effective way to get the information. It was stated in the question-and-answer (Q&A) session that DOE incentivized this project as a way of incentivizing (creating demand for) the 12 Northeast hydrogen stations. This may be an okay goal, but it was not stated directly in the project presentation.
- There is very little discussion of technology development in the objectives (Chart 7), yet Milestone 2 has fuel cell and balance-of-plant (BOP) design. Under accomplishments, the fuel cell stack and BOP were designed, but there was no discussion of that design.
- It is difficult to conclude that the project is well designed owing to the lack of information and the PI's response regarding safety planning and hazard assessment ("We have been operating [fuel cell electric vehicles] safely for 20 years"). Additionally, the inherent safety of the vehicle for operational and accident conditions can have an impact on market viability.

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.

- To the extent that one agrees that this is a valuable project, it is well organized and well planned, with clear milestones and deliverables. The go/no-go decision point works well as a process for managing projects of this size.
- The project has just begun, and progress is good so far; however, the tasks so far are easier than those in the future.
- Given that this project is just getting started, the accomplishments and progress appear appropriate.

- The project started just nine months ago. The project seems to progress well, although there is no Gantt chart available to judge that. Regarding the key performance indicators (KPIs), some were mentioned, but the discussion was very limited, and there was no mention of whether the prototype stack can meet the KPIs using simulations. Therefore, this point is not easy to judge objectively. It is recommended that the project team make a clearer plan and a more in-depth analysis of the state of play versus the KPIs that were set.
- There are very limited data and no discussion on fuel cell stack and BOP design. The stack result chart has no unit on the y-axis and legend. This is a very poor explanation of what was undertaken. It is not clear what the vehicle packaging boundaries are. There is no explanation of the thermal management system. This is a very poor discussion of accomplishments and progress.

Question 4: Collaboration and coordination with other institutions

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

- Collaborator roles are well defined except that of the fueling stations, which was mentioned only tangentially in the Q&A session. It seems like there is more opportunity there to obtain infrastructure data and interface detail, even though they are planning to use retail stations. Argonne National Laboratory (ANL) will perform modeling, US Hybrid will provide drive-cycle input, and Nissan and National Grid will perform testing. ANL will provide final technical assessment and economic assessment (lifetime emissions, fleet ownership costs). Risk is decoupled from Nissan and National Grid. Fueling is anticipated at the 12 Air Liquide Northeast stations. National Grid has operations in Connecticut and New Jersey, and National Grid team members hope to be able to use one of those. (Pete Devlin says that project is incentivized—perhaps by DOE—to support those stations.)
- Each project partner task is clearly defined. Since we are still early in the project, not much collaboration is required. However, it looks like each partner is contributing its share. However, once the prototype part is integrated in the car, bigger challenges will come, and good collaboration between partners will be crucial for project success. During the presentation, it was revealed that there is still no contract in place with Nissan. This step is crucial to project success.
- Collaboration with Nissan and National Grid is good; however, the interface with National Grid should extend beyond the vehicle operators to system-level utility individuals to determine whether a fleet of zero-emission vehicles would save money by offsetting the cost of compliance in the organization's generation assets.
- Regarding the project concept and teams, Nissan and ANL should be very good.
- The PI indicated that a failure mode effects analysis will be performed for the fuel cell and storage equipment. Hazards originating external to the project equipment should also be evaluated for their impact on project equipment and its safety operation/performance in off-normal conditions. The PI indicated that vehicle performance in an accident is Nissan's responsibility and will not be considered by the project. Such an approach may result in potential safety issues for operation of the vehicle and should be considered collaboratively.

Question 5: Proposed future work

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

- At a high level, the project appears to have clear milestones and well-defined deliverables. In the Q&A session, it was discussed that there may need to be more focus on clear deliverables from the cost analysis portion of the project for Phase II to make sure that the desired outcomes of fully understanding cost viability are met. The remainder of 2017 includes final design, initiating procurement, developing the vehicle model, hydrogen storage selection, and integration and hydrogen fill interface. Hydrogen safety system and sensors (Phase I) in 2018 involves complete construction of the prototype vehicle, validating performance, and demonstrations with the operator. More cost analysis is needed in the process of planning for Phase II.
- Only one go/no-go decision point by DOE is foreseen, and this is after the first prototype car is made and tested, a logical judgment point. Unfortunately, there is no evidence of risk assessment or a potential

mitigation plan in the documents provided to the evaluators, so it is hard to judge this. The challenge in the third and fourth quarters in 2017 looks very challenging, and more time might be required for this step. The target seems to be a validated and demonstrated vehicle by end-2018, which looks realistic; however, it is advisable to have a more detailed plan and identify better potential risk. During the presentation, it became clear that Nissan had not yet signed a contract; this is a serious risk.

- The future work plan is good, but more substance is needed for the plans for economic evaluation.
- The list of activities for the last two quarters of 2017 is very large. No economic assessment was presented.
- Future work should include all project partners working together for hazard evaluations and hydrogen safety planning.

Project strengths:

- The project looks for new business chances and thus an increase of fuel cell production for US Hybrid, which is a local industry. The project can thereby create jobs and growth. If BEVs with range extenders are acceptable in the United States and make economic sense, this project would be a good way to increase the usage rate of hydrogen stations in the United States and, thereby, their reliability. In a way, BEV drivers can experience driving and refueling with hydrogen; maybe in the future, they will become fuel cell vehicle buyers. The way the project looked to optimize the heat generation and give it some value is very interesting.
- The planned fleet of 21 vehicles should yield a large body of statistically significant data on durability, reliability, and fueling.
- The engineering plan is good. The project has a good partner in National Grid, a worldwide utility with potential emission issues that a fuel cell fleet could possibly offset.
- The project team is strong. The approach to implementation and evaluation of equipment performance and value is reasonable.
- No project strengths were apparent.

Project weaknesses:

- The economic assessment is at the end of the project. This has the risk of spending a good deal of money to make 20 prototype cars to conclude maybe that it does not make sense, so it is better to start earlier and have a first assessment ready after the first prototype build. There is no clear build plan or risk management plan. Integration in a car is a big challenge and might cause serious delays and will need good partnering, especially as the Nissan e-NV200 will probably not be built in the United States but will instead include vehicles modified through aftermarket installation. It is noted that no U.S. automaker is part of the project and a contract is not yet signed with Nissan. Another weakness is that the design of stack performance is performed without knowing the customer profile in terms of daily routes, route profiles, and weight carried. In that sense, it looks like a 5 kW stack is too low and very risky. During the presentation, it was mentioned that a 10 kW stack might be possible. It is important to have a careful look into the right requirements; this will also have an impact on the economic model.
- There does not seem to be a well-developed up-front cost analysis/estimations, particularly for estimated maintenance costs. It seems like this could jeopardize project completion if those costs are high. Also, the project refers to learning about the duty cycle, but that needs to be understood beforehand to ensure vehicles get enough usage to accumulate 5000 hours of operation for the durability goals to be met. For the planned two-year demonstration, the vehicles would have to run eight hours per day, six days per week, to reach 5000 hours.
- The US Hybrid presentations were not very informative. Incomplete data were presented, and there was no discussion on thermal management. No economic assessment plans were presented.
- Hazard assessment and safety planning does not appear to be an integrated team approach.
- A weakness is the lack of economics.

Recommendations for additions/deletions to project scope:

- There should be an intermediate KPI check. A clearer and more detailed development schedule is needed that includes risk-mitigating measures (e.g., the lack of a signed contract with Nissan). The project should check experiences in Europe. The economic assessment should be started earlier; it should be part of the go/no-go decision. There is an urgent need to check the customer profile and route profile to define the right stack performance.
- This is an expensive project that has a high risk of not reaching the project objectives. The prototype phase should be expanded to obtain the reliability, customer acceptance, and durability data envisioned before building such a large fleet. It seems like those questions can be answered with perhaps three vehicles, greatly reducing the risk associated with building the large fleet and consuming a large amount of funding just running so many vehicles. If the prototype phase yields satisfactory information, then the second phase could be done later with much less risk and with much greater cost share from the non-DOE partners.
- The project should evaluate and analyze the safety of the system in an accident or off-normal condition.
- The project should be restructured with better organization and management.