

## 2011 — American Recovery and Reinvestment Act

### Summary of Annual Merit Review of American Recovery and Reinvestment Act Activities

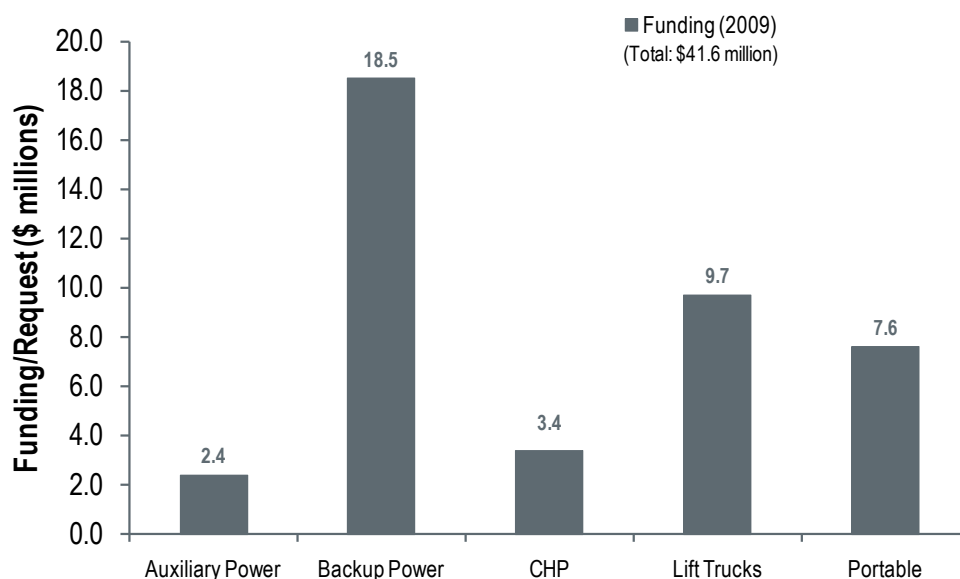
#### Summary of Reviewer Comments on Recovery Act Activities:

This review session evaluated the enabling of fuel cell market transformation projects funded under the American Recovery and Reinvestment Act of 2009 (ARRA). The ARRA projects include the development and deployment of a variety of fuel cell technologies including polymer electrolyte, solid oxide, and direct-methanol fuel cells (DMFCs) in auxiliary power, backup power, combined heat and power, lift truck, and portable-power applications. The ARRA projects are generally considered by reviewers to be well aligned with the goals and objectives of ARRA and the Fuel Cell Technologies Program. Overall, the projects were judged to have made significant progress toward fuel cell development and deployment.

#### Recovery Act Funding by Technology:

In April 2009, the U.S. Department of Energy (DOE) announced the investment of \$41.6 million in ARRA funding for fuel cell technology to accelerate the commercialization and deployment of fuel cells and to build a robust fuel cell manufacturing industry in the United States with accompanying jobs in fuel cell manufacturing, installation, maintenance, and support services. Twelve grants were competitively selected and awarded to develop and deploy a variety of fuel cell technologies. These projects (denoted at the Annual Merit Review by the label “H2RA”) are addressing the aforementioned objectives as well as the overall ARRA goals of creating and saving jobs, spurring economic activity, and investing in long-term economic growth. The cost share provided by the project teams is about \$54 million, more than 56% of the total cost of the projects.

#### American Recovery and Reinvestment Act of 2009



#### Majority of Reviewer Comments and Recommendations:

All 12 deployment projects and one data collection and analysis project in the ARRA activities gave oral presentations. Four of the projects were not reviewed because the projects were nearly complete. The remaining projects were reviewed. In general, the reviewer scores for the ARRA projects were good, with scores of 3.4, 3.0,

and 2.5 for the highest, average, and lowest scores, respectively. Six of the nine projects had a score of 3.0 or higher. The scores are indicative of the technical progress that has been made since the project grants were awarded in late fiscal year (FY) 2009 or early FY 2010.

**Auxiliary Power:** One project in this area, involving the development of a diesel auxiliary power unit (APU) to power hotel amenities for use on Class 8 sleeper trucks, was reviewed, receiving a score of 3.1. The project was seen as a viable solution to the anti-idling regulations in many states. Reviewers recommended that this project should look into additional opportunities to use the APU, such as heat recovery for cabin heating and cooling. The reviewers also recommended development of a commercialization plan, should the APU reach its performance targets.

**Backup Power:** Three projects addressing 72-hour backup power for cellular communication towers and U.S. Department of Defense (DOD) sites were reviewed, with an average score of 2.9. The reviewers noted the huge potential market addressed by these projects. It was recommended that the projects involving cellular towers should identify the lessons learned from these installations, and prepare case studies and fact sheets to advertise successful demonstration sites and help inform and plan future installations. Reviewers observed that these projects have highlighted the importance of the permitting process to the cost of deploying backup systems. The project with DOD was advised to collaborate more with partners to assist with product placement and the project timeline.

**Combined Heat and Power (CHP):** One project in this area, addressing residential and light commercial applications, was reviewed, receiving a score of 3.1. Reviewers noted that the project demonstrates impressive greenhouse gas reduction potential and efficiency gains, and that using natural gas opens up a wide range of application sites. The reviewers expressed some concern over the fact that the fuel cell company that is implementing the project dropped its CHP product line as the project was commencing. However, they recognized that the project was currently on track for completion. It was recommended that this project continue with long-term testing and economic analysis.

**Fuel-Cell-Powered Lift Trucks:** The project in this area was rated higher than the average for ARRA projects, receiving a score of 3.3. The reviewers thought that this was a solid demonstration project, with the ability to make a value proposition to a large number of companies due to the implementing company's extensive market penetration. With the hundreds of fuel cells being deployed through ARRA funding, the reviewers felt the project was accelerating the fuel-cell-powered lift truck market. It was recommended that those involved in the project identify improvement metrics to make their fuel-cell-powered lift trucks economically sustainable.

**Portable Power:** Two portable power projects were reviewed, receiving an average score of 2.9. Reviewers felt that one project, involving the development of a DMFC for mobile computing, has the potential to result in a new and useful product for the electronics market, and that the research involved will help advance fuel cell technology in general. The reviewers recommended collaborating with other DMFC developers worldwide to help address the project's degradation issues. The reviewers also recommended collaborating with an electronic equipment manufacturer over the next year to identify market needs for the technology. The other project, involving development of a one-kilowatt portable generator, was seen as having the potential for high visibility once the units are ready for use in a NASCAR season, but the reviewers felt that there needs to be a stronger business case for the product.

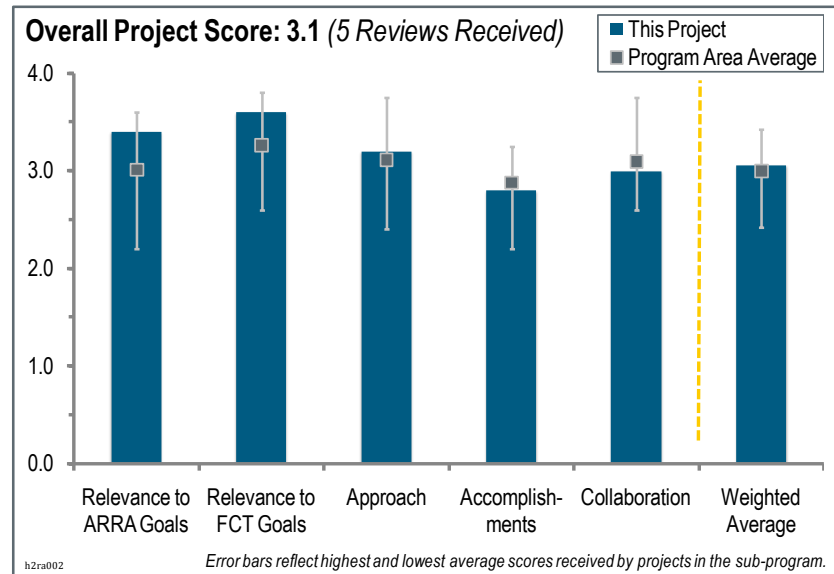
**Data Collection and Analysis:** One project in data collection and analysis was reviewed, receiving a score of 3.4. The reviews found the project to be extremely valuable to the DOE Hydrogen and Fuel Cells Program portfolio, providing key information on the other ARRA projects that cannot be found elsewhere. It was recommended that this project identify other pathways to sharing information with industry stakeholders, who may find this information useful. It was also recommended that fuel cell performance be compared with that of incumbent technologies in the data products being produced.

## Project # H2RA-002: Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration

Dan Hennessy; Delphi Automotive

### Brief Summary of Project:

The overall objective of this project is to dramatically increase the technical and commercial viability of fuel cell auxiliary power unit (APU) technology. Objectives are to: (1) define system specifications and commercial requirements, including subsystem requirements, and develop a subsystem requirements document; (2) design, build, and test the diesel solid oxide fuel cell (SOFC) APU system, including verification testing of APU subsystems, form and packaging redesign, and APU system vibration analysis; and (3) perform a one-year demonstration on a Class 8 sleeper truck, including data collection and analysis.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.4** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- This project created 18 jobs. This is an example of what the President means when he talks about creating jobs with clean energy.
- The amount of jobs created now is unremarkable. However, if this could become a product, there might be a lot of jobs created.
- For the foreseeable future, the project will involve technology development and technology demonstration. Thus, significant job creation is not anticipated in the near future. However, the project has the potential of creating and sustaining a moderate level of jobs.
- While it was not clear from the presentation, it seems like this project would support about three or four full-time people for three years.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.6** for its relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies Program's ARRA project goals.

- Anti-idling legislation could create a huge commercialization market for Class 8 sleeper truck APUs using fuel cells. This shows relevance to the large investment in the DOE Solid State Energy Conversion Alliance program and the potential for a commercial product being spun out of that investment.
- This work is key to advancing SOFC technology toward commercialization of a product.
- This is a potential market, but it is not any more efficient than a small diesel and battery system. The requirement to run 24 hours for days at 30% efficiency seems like it would be less fuel efficient than a small generator and battery system.

- The project's focus on developing truck APUs is very relevant to accelerating the commercialization and deployment of fuel cells. The project supports long-term testing for durability and also vibration testing to simulate a realistic operating environment for truck APUs. Additionally, the work deals with using diesel as a fuel.
- This project is one of the few activities to seriously address solutions to anti-idling regulations in 30 states, as this SOFC APU meets 2012 U.S. Environmental Protection Agency emissions regulations and has a fuel efficiency that is 40%–50% higher than current technologies. It appropriately focuses on the Class 8 sleeper trucks, which have almost 1,500 hours per year of idling time on average with a power requirement of 2.5–4.0 kilowatts.

### **Question 2: Development and deployment approach**

This project was rated **3.2** for its development and deployment approach.

- Teaming with PACCAR is critical, as there needs to be a fleet test with a major Class 8 truck original equipment manufacturer (OEM) in order to have this effort lead to commercialization. Targeting the Class 8 sleeper truck is a very good approach, as exemplified by the number of APU hours (1,456 hours per year) that are used compared to other truck classes. Delphi is building a system around the fuel cell, rather than just a retrofit.
- It seems like a more robust development effort would have mitigated the delays.
- The market seems to be understood and there are some advantages, but the presenter needs to address the complete energy picture, including how the emissions over the entire 24 hour period (idle during the day and some level of power required while parked) compares to a system that only runs while the truck is parked.
- The project team is results-oriented and has demonstrated good project management skills. Risks are identified early and are being addressed adequately.
- The approach is reasonable to increase both the technical and commercial viability of fuel cell APU technology. Once successful in the truck APU market, this same technology could be more broadly applied to many other applications. The principal investigator is keeping this project appropriately focused only on this one single application to ensure success, which is a robust approach. The approach of a simple bolt-on solution, without additional integration redesign, is an excellent approach to start the market.

### **Question 3: Technical accomplishments and progress**

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

- Delphi is behind on the long-term fleet test. Delphi is having issues with system vibration robustness, form factor, weight, cost target, and manufacturability. The efficiency is 40%–50% with no emission after-treatment required, as with internal combustion engine APUs. Delphi has indicated that it may need an additional desulfurizer. Field failures to date have been mostly balance of plant, not the SOFC technology itself. There seem to be issues with the sorbent bed for hydrogen sulfide removal related to thermal cycles.
- This project has taken on delays due to unforeseen development issues.
- It is great to see a system being developed. From what was presented and discussed, it is uncertain whether the system reported actually met performance requirements. Only slide 11 mentioned a test, but it did not report anything that stated whether performance targets (power, operating time, etc.) were achieved. There were no defined metrics in this area.
- The technical approach to use larger surface area cells is sound. The progress made in heat exchanger and reformer developments are noteworthy. However, the project is behind schedule for completing durability tests and supplying the APU for demonstration.
- The project has achieved tremendous success in a very short amount of time. In-house testing has been almost completed, and the researchers are about to deliver the APU to the demonstration site, which is on a Class 8 vehicle as part of a controlled vehicle fleet. There has been significant development on the desulfurizer, compact heat exchanger, and reformer.

#### Question 4: Collaboration and coordination with other institutions

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

- This is a commercial development project, so while they do not have much collaboration to date, this type of project does not lend itself to collaborations until the product is ready to be introduced to the market. To the extent collaborating with the fuel cell supplier base is being evaluated, Delphi is working within the existing SOFC fuel cell supply chain. Collaboration with PACCAR is also key, as they make the Class 8 sleeper trucks.
- This project has a good partner in PACCAR; however, it may have been helpful to the development timetable if the collaboration included a partner skillful in system design. It is also unclear how sophisticated the sales and marketing expertise is when the product is ready for sale in order to develop and promote an attractive business case for the product.
- The implications of the collaboration are not clear, nor is it clear how the collaboration is helping to get this technology to market.
- This project shows very good use of its partners' strengths in increasing the probability of its success.
- The level of teaming and collaboration seems sufficient to complete the project. After the project concludes, it would be good if this product is offered to all truck OEMs, not just one.

#### Project strengths:

- This project shows major potential for job creation in a clean technology market. Fleet field testing will validate the potential of SOFC APUs on Class 8 trucks. The teaming arrangement with PACCAR increases the likelihood of success. This project has a strong Delphi cost share.
- This project's strength is Delphi's experience with SOFC technology.
- This project's approach to complete systems in real applications is great.
- Following are four key strengths: (1) good teamwork among partners, (2) a sound technical approach, (3) a rigorous test plan, and (4) safety awareness.
- This project targets a key problem for goods movement: truck idling. It focuses on decreasing fuel usage, lowering emissions, and reducing unwanted background noise into the environment. The team has done an excellent job in designing this system to be a bolt-on addition of power to an existing 12-volt voltage bus.

#### Project weaknesses:

- A weakness of the project is the progress it has made toward its objectives. Also, the balance of plant needs work in order to be ready for the fleet test.
- While the technical development appears top-notch, the product development could have been more robust.
- There is no benchmarking against the incumbent approach, and there is no assessment of what is needed (cost and performance) to get it to market.
- No cost information was presented.
- System degradation cannot be determined from the data presented.
- It would be good to see some future work discussed beyond the end of this project, such as commercialization plans if the technology meets targets. It would also be good to see some cost analysis showing the glide path from current (research and development stage) prices to future market prices that are competitive with alternatives, including fuel savings costs.

#### Specific recommendations:

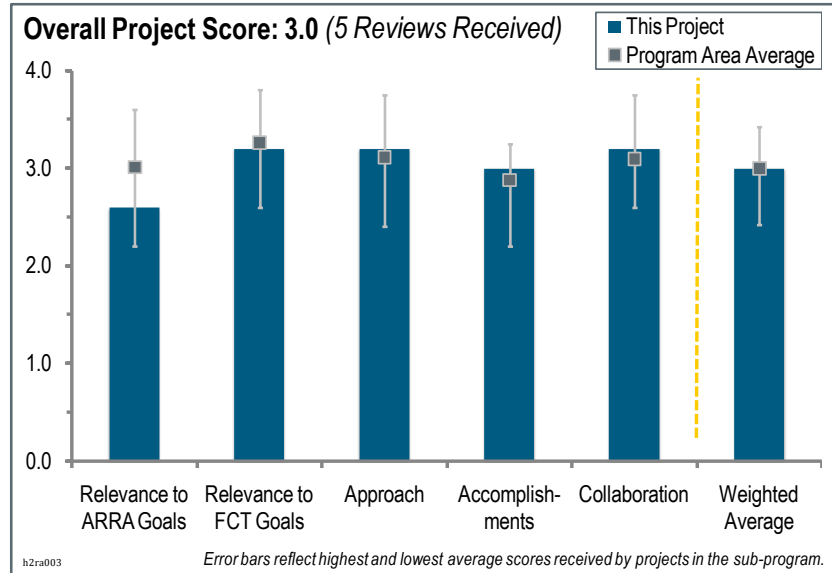
- It would be good to see more discussion of a business case that would be the foundation of a sales and marketing strategy.
- Two recommendations are to: (1) assess the capability of this technology to be commercialized and assess what metrics need to be achieved and (2) report on system performance.
- As the DOE project concludes, the researchers should look for opportunities to include some of the system integration with the truck and energy optimization, such as heat recovery for cabin heating and cooling, refrigeration units, etc.

## Project # H2RA-003: Highly Efficient, 5 kW Combined Heat and Power Fuel Cells Demonstrating Durability and Economic Value in Residential and Light Commercial Applications

Donald Rohr; Plug Power Inc.

### Brief Summary of Project:

The objective of this demonstration project is to substantiate the durability and economic value of the GenSys Blue fuel cell and verify its technology and commercial readiness for the marketplace. The goal is for the GenSys Blue fuel cell to have the following characteristics: (1) an electrical efficiency of 40% at rated power; (2) a combined heat and power (CHP) efficiency of 90% at rated power; (3) a cost of \$10,000 per kilowatt-electric; (4) durability of 10,000 hours at 10% of rated power degradation; (5) a noise level of less than 55 A-weighted decibels at 10 meters; and (6) emissions of combined nitrogen oxides, carbon monoxide, sulfur oxides, hydrocarbon, and particulates of less than 1.5 grams per megawatt hour.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **2.6** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- While the project falls significantly outside of the company's current business focus, it seems to be on track (after some delay) and about to make real progress. The project manager has done a good job against significant odds in garnering sufficient internal resources to move this project ahead. If the project is successful, it will have a significant positive impact and open new markets for the technology.
- Plug Power dropped the CHP product line just as this project was being awarded. There was a net job loss in its CHP workforce during the period that this effort was being undertaken. Given that Plug Power may have had no choice in the short term to maintain viability as a company, this project will help it launch a better CHP product if it achieves profitability and restarts the GenSys Blue production line.
- This project involved many partners (especially from the private sector), which can result in additional jobs and business opportunities. The project was designed with cost and manufacturing in mind; however, it was not clear on specific jobs generated via the ARRA/U.S. Department of Energy (DOE) reporting criteria (which seem limited in scope).
- The opportunities appear to be weak and secondary to forklifts and backup power.
- It appears that most of the jobs saved are in supplier companies. This is unfortunate. It might be better if one or two employees from the project's company were dedicated to the project.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.2** for its relevance to the DOE Fuel Cell Technologies Program's ARRA project goals.

- This project appears to have relevance toward accelerating deployment through a combination of data analysis and modeling that will be useful for product development. It appears that more work is needed with respect to modeling the deployment of a CHP system in residential and other locales, as there is a huge variability among timing and needs for power and heat in many applications. The balancing act is one of right-sizing the fuel cell and storage (both heat and electric) to maximize efficiency and minimize both system and installation cost. The presentation could have expanded on this aspect of the program. Overall, once the project is complete, it will advance the state of knowledge and experience in CHP.
- Fuel cell residential CHP is clearly something that U.S. industry should pursue, given the success already experienced abroad, particularly in Japan. Greenhouse gas (GHG) reduction is very important to DOE goals, and residential fuel cell CHP saves more GHG on average than even a fuel cell electric vehicle. Commercialization and deployment goals will likely not be met here, as the original equipment manufacturer (OEM) has suspended operations in this area.
- This project is well focused on developing and accelerating commercialization and manufacturing of a fuel cell product. It has great commercial opportunity. Multiple test users—especially the heating, ventilation, and air conditioning (HVAC) business owner—will provide excellent real-life feedback.
- The fact that Plug Power cannot put resources toward this is indicative of the market potential. Compromises just to get costs down are indicative of the very large market versus the capability gap. It does help keep the technology alive at Plug Power, but the resources may be better spent to advance the technology in other segments.
- Residential and light commercial CHP is an important market sector for fuel cell power plants for a number of reasons. Demonstration of these technologies is essential to their commercialization.

### Question 2: Development and deployment approach

This project was rated **3.2** for its development and deployment approach.

- The project manager has done a good job getting the project back on track for completion, but it is clear that getting this far was not easy or a priority for the company. Real progress is being made and the project goals remain relevant and achievable.
- DOE funding of \$3.3 million is an awful lot in order to only field six CHP systems that will eventually sell for \$30,000–\$50,000 each. Plug Power's decision to proceed with 100 layoffs—many in the CHP area—and to drop the product line just as this project was commencing does not bode well for commercialization. However, the project approach is still sound for the objectives being pursued. The use of go/no-go criteria in two critical parts of the project with specific metrics to inform the decisions is appropriate.
- The project has well defined milestones and checkpoints along the way.
- The project has well defined technical goals and a good summary of its status. The reason for some delays appears to be resources and not technical. There needs to be additional clarification on stack testing (continuous versus duty cycle) and more explanation on the reliability metrics presented on slide 12. Slide 13 did not identify any stack failures.
- The project is nearing a crucial area where the systems will be deployed. This might be later than initially planned and additional schedule delays might jeopardize the success of the project.

### Question 3: Technical accomplishments and progress

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

- It appears that a significant slippage in the schedule occurred. Still, the project appears to be back on track.
- The presentation could have provided more detail on the overall system modeling and optimization with respect to energy storage (heat and electric).

- The work had a number of failures in testing, but most were not fuel cell stack related. The new principal investigator (since March 2011) is still going through a learning curve. The work met go/no-go criteria in both instances. The availability of the reliability fleet CHP systems tested at Plug Power was reported to be only 94%. Most targets were met or came close to being met and did very well on the durability test.
- The project's objectives and milestones are very clear.
- The technical goals are well quantified, and there is good progress given some of the resource and staffing issues. The quantified number of jobs is vague.
- Although the project shows 70% completion, the most difficult area may remain—that is, when the systems are actually deployed.

#### **Question 4: Collaboration and coordination with other institutions**

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

- Collaborations are taking place. The project's relationship with the University of California, Irvine (UCI) appears solid and productive. Sempra sites look good. It would be worthwhile for the team to reach out to other potential sites that could be better testbeds for a system of this size.
- Collaborations with both an energy company user (for site selection) and community residential user (for trial) are good. Collaborations with the supply chain will not occur until the OEM (Plug Power) drives toward a product launch date. UCI's work on a system model for reliability will be useful to Plug Power and hopefully to other CHP OEMs as well.
- Many collaborators were only mentioned during the oral presentation. The suppliers and test sites discussed have great value and should be more clearly detailed in written documentation.
- This work touches a lot of vendors. There is not enough user interaction and not enough work on applying the FC1 standards to the design.
- Collaborations appear to be adequate to support the project.

#### **Project strengths:**

- This project has good technology depth and a capable team. It has a sound plan with some additional attention to siting for demonstrations.
- This project has a good teaming arrangement with UCI, Sempra, and the local community. It met go/no-go criteria and vastly exceeded them in durability. The project demonstrates impressive GHG reduction potential and impressive 80%+ efficiency gains.
- The project has clear goals and objectives, well defined milestones, and strong partnerships and collaboration.
- This project is getting good data on systems under testing and determining and fixing failure modes.
- This is a good market area and has good potential for additional products. Using natural gas fuel opens a wide range of application sites. Using high-temperature membranes makes CHP more viable for polymer electrolyte membrane technologies.

#### **Project weaknesses:**

- This project lost time on the schedule. There is a lack of technical detail on system design and balance, and the project showed little indication of impact on current jobs or future impact.
- It is difficult to assess the cost target because Plug Power is not selling CHP units anytime soon and just put its CHP line in "mothballs."
- All of the collaborators were not clearly defined (written), and jobs were not fully defined (could be better understood and quantified).
- The modeling may not add real value. By the time the model is paid for and validated, it might be just as good to test the systems.
- The current project status might indicate that schedule delays could jeopardize the project's completion. The project team will need to dedicate sufficient resources to this project in order to achieve the project's goals.

**Specific recommendations:**

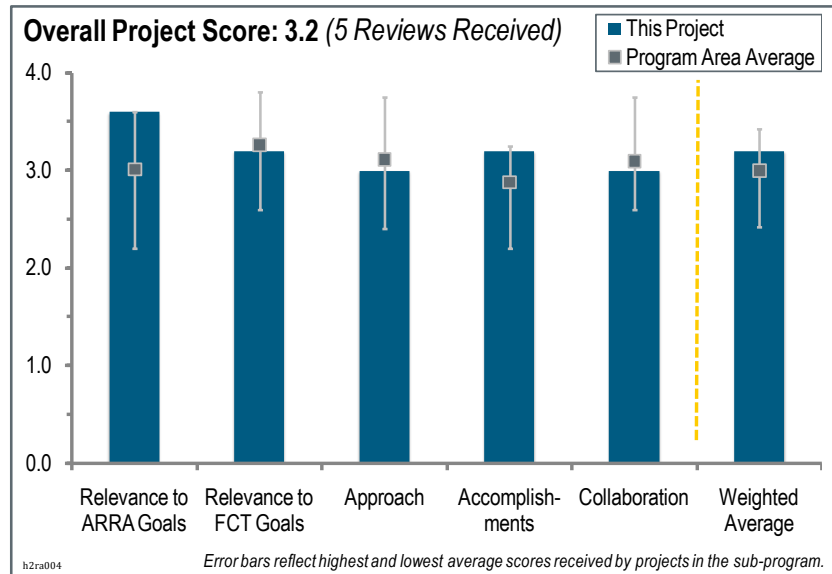
- One recommendation is to discuss the challenges and approaches with respect to system design and balance of components issues, which is a central issue to CHP systems for cost, installation, complexity, and overall efficiency. This project appears well managed and executed.
- This is a good project making good progress. It is a worthwhile effort that should continue through economic analysis and long-term testing.
- One recommendation is to explain the value of the modeling.
- It might be helpful to dedicate additional resources to the project in order to meet the project's goals in a timely manner.

## Project # H2RA-004: Advanced Direct Methanol Fuel Cell for Mobile Computing

Jim Fletcher; University of North Florida

### Brief Summary of Project:

This project's objective is to develop a direct methanol fuel cell (DMFC) power supply for mobile computing using the novel passive water recycling technology acquired by the University of North Florida (UNF) from PolyFuel, Inc., which enables significant simplification of DMFC systems. The 2011 objective is to perform system engineering and extensive brassboard (unpackaged) testing to move toward the 2010 technical targets. The remainder of the project will focus on optimizing the performance of the packaged system.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.6** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- This project had a positive impact on jobs, supporting both university leads and the now defunct company Polyfuel, and a positive impact on economic activity. With continued private company development of the product, and further advancement through redesign and testing, this project has the potential of resulting in a new product for market. This work also has the potential to develop into a long-term useful product, assuming the product continues to reach commercialization.
- This program has saved jobs that would have otherwise been lost, and preserved a suite of technologies that could subsequently add value.
- This technology is needed to advance the fuel cell industry.
- This project exhibits good job production compared to the project's budget.
- This project has a stated impact of more than 5 direct jobs with 10–12 indirect jobs, which is good, based on the project's budget. The electronics field is strategically important to this country, so if this project leads to U.S. leadership for battery chargers, it will have achieved a significant goal of ARRA in leading to long-term economic growth.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.2** for its relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies Program's ARRA project goals.

- This project demonstrates very strong manufacturing and commercialization potential, as it supports a strong and growing market area (mobile computing). Multiple fuel storage sizes provide more versatility (local use, meeting on flight limitations, etc.).
- This project focuses on making a useful product that would spur economic growth and show commercial products in the field. It is believed that the mere existence of the products will accelerate commercialization.
- This research will help reduce the complexity and possibly the costs of the fuel cell technology, which will accelerate commercialization.

- The project's goals seem appropriate for accelerating commercial deployment of fuel cells and fuel cell manufacturing, assuming that the product is commercially successful.
- This is a good application of fuel cell technology (supplementing small batteries to allow longer run times when away from the grid) where significant market penetration is possible with a successful product. UNF proposed a 20-watt (W) design, which may not achieve DOE's 2010 targets (halfway for specific power, power density, and lifetime). This project should aim higher.

### Question 2: Development and deployment approach

This project was rated **3.0** for its development and deployment approach.

- Most goals and barriers are well outlined, but the schedule is not as detailed. However, the project appears to be on schedule, according to the presentation. The mention of the possible optimization (or elimination) of the methanol sensor is very positive.
- Despite the fact that the work is being done at a university, the development approach is straightforward and focused.
- This project has developed a brassboard unit and is moving forward.
- This project has made good progress, although degradation issues remain.
- One of the stated goals of this project is to spin this off into a successful startup company, which is an excellent goal. The approach of simplifying the balance of plant to decrease cost, size, and complexity is good. The concept of using the stack as a methanol sensor is intriguing.

### Question 3: Technical accomplishments and progress

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

- The project's progress appears to be reasonable and on target.
- This work has a good mix of design, durability testing, and component performance testing.
- This work is approximately 75% complete and seems to be meeting its milestones.
- This project has demonstrated good job production for the budget. Also, the mock-up demonstrates good product engineering. Some degradation issues remain to be solved.
- This work has taken a thorough approach to evaluating cooling fans, electric motors, and pumps, exceeding the expectations of this type of work. Creating and operating three brassboard systems with at least 500 hours each is a significant accomplishment. Creating an engineered and packaged system is also a significant accomplishment. It is good to see that the dynamic model has been validated.

### Question 4: Collaboration and coordination with other institutions

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

- Existing collaborations appear very strong. This project has a direct tie between the university lead and the former manufacturer company, as well as other universities. Similarly, this work has strong ties to component suppliers.
- It may have been more efficient to involve a design firm than doing everything at the university.
- The project seems to have the technical experts it needs to complete its goals.
- Additional collaboration could help solve the remaining degradation issues.
- To date, most of the project's collaborations have been academic. It would be beneficial to have more industrial collaborations in the future.

### Project strengths:

- This project appears to have identified a good product potential, a market area, and strong collaboration ties.
- The work shows good progress and milestone achievement, and has identified existing challenges and next steps.
- This project is a well focused development program.

- The product has fewer parts than a traditional DMFC, which should help reduce the costs. The passive water technology should help simplify the overall system.
- This project shows evidence of good engineering, thorough design reviews, good brassboarding practices, good packaging mock-ups, and generally good engineering work. The novel ideas for DMFC are obviously helping to meet the design goals, providing that they are not the source of the degradation issue and that the degradation issue can be solved.
- It is good to see hard data on stack current degradation under different modes of operation (continuous versus stop/start). This project has also performed lots of testing and has analyzed the data.

### Project weaknesses:

- This project could do a better job of clarifying jobs-related goals and outcomes.
- This project could have more partnerships.
- The cost targets will be difficult to meet.
- Degradation with intermittent use may prevent commercialization entirely.
- This project needs to work harder for a high specific power and a more power-dense system if it has any chance of meeting DOE's 2010 targets in the future. The project has proposed some technical improvements for the 20 W system as compared to the 15 W 2008 system, but the improvements are only incremental, not revolutionary.

### Specific recommendations:

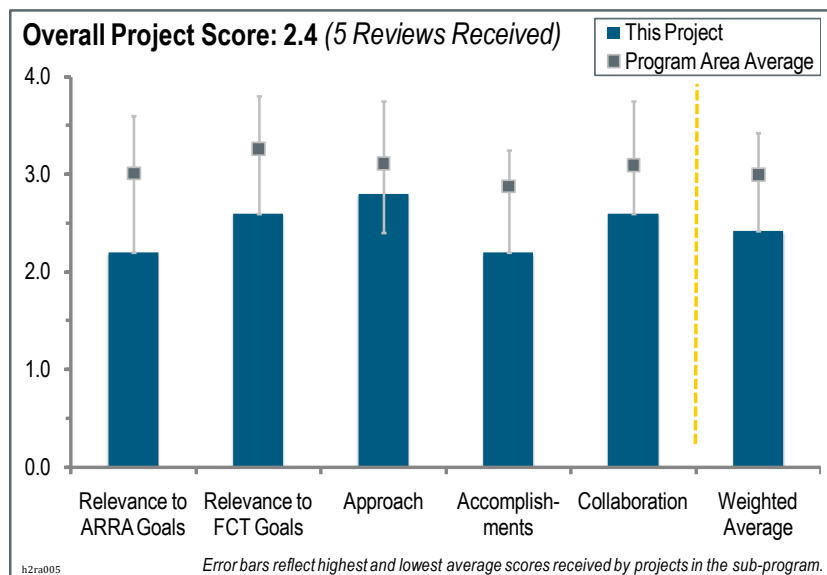
- After review of the final report, it is clear that this project has positive potential to be pursued further, per recommendations and the identified challenges.
- Additional collaboration with DMFC developers worldwide might help to solve the degradation issue that remains to be solved.
- As stated in the presentation, the difference in performance between durability with start/stop versus continuous operation is significant and the most important issue that this project should address and resolve over the next year. One recommendation is to establish a strong collaboration in the next year with an electronics original equipment manufacturer (OEM) such as Toshiba, Dell, or Apple to identify real market needs for the technology. However, the researchers should not give up intellectual property to the electronics OEM if the goal is to have a stand-alone startup; instead, the researchers should have the OEM license their current technology and fund future improvements of it.

## Project # H2RA-005: Jadoo Power Fuel Cell Demonstration

Ken Vaughn; Jadoo Power

### Brief Summary of Project:

The objectives of this project are to: (1) develop two portable electrical generators in the 1–3 kilowatt (kW) range utilizing solid oxide fuel cells (SOFC) as the power element and propane as the fuel; (2) develop and demonstrate a proof-of-concept electromechanical propane fuel interface that provides a user-friendly capability for managing propane fuel; (3) deploy and use the fuel cell portable generators to power media production equipment over the course of several months at multiple NASCAR automobile racing events staged in locations throughout the United States; (4) deploy and use the fuel cell portable generators at scheduled events by first responders (e.g., police, fire) of the city of Folsom, California, to power equipment in emergency or off-grid situations; and (5) capture data with regard to the systems' ability to meet U.S. Department of Energy (DOE) technical targets and evaluate the ease of use and potential barriers to further adoption of the systems.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **2.2** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- A portable 1 kW fuel cell generator running on propane will not likely result in large job growth over the short- to mid-term timeframe. The NASCAR market is limited in its potential for volume manufacturing of this product. However, demonstrating this technology over the course of a NASCAR season will provide plenty of visibility and may grow new markets.
- This project is relevant in that it spurs economic growth, is very supportive of both Jadoo and Delphi, and is supportive of a market that is poised for growth.
- It is unclear if there has been the necessary market analysis for this type of product, even if the product development is successful. The business case for buying the product is not highlighted.
- This project does not appear to offer many benefits for this market. The 1 kW system, however, does have some applications. It appears that this fuel cell unit cannot beat existing technology in either size or carbon footprint. This work does support Jadoo, which is making contributions to advancing the technology.
- It is not clear if this project will be successful, as many important tasks are still to be completed. Consequently, it is difficult to predict how many jobs will be created. It is stated that some jobs have been created in New York, California, and Michigan.

**Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals**

This project was rated **2.6** for its relevance to the DOE Fuel Cell Technologies (FCT) Program's ARRA project goals.

- Portable fuel cell commercialization is clearly one of the goals of ARRA projects in the FCT Program. The project's technology development plan had many targets, but the deployment plan did not, other than to get two units in place for the NASCAR season and talk to the Folsom, California, police and fire departments.
- This project demonstrates a good early market application that is relevant to accelerating the deployment of fuel cell technology.
- It is important to develop early markets for SOFC technology; however, it is unclear if this is a well thought-out market for a SOFC product.
- This may be the wrong path to go down. A user assessment is needed to determine the market for this product.
- This is a good niche application for SOFCs. However, cost data is not presented. While an SOFC-based portable generator presents significant advantages, if it is cost-prohibitive, then the application will only have a limited market.

**Question 2: Development and deployment approach**

This project was rated **2.8** for its development and deployment approach.

- Working with NASCAR provides maximum visibility. This project has good teaming arrangements with Delphi to modify its auxiliary power unit. The hot swap of propane is a pragmatic fueling strategy. The principal investigator (PI) should have had other markets identified beyond the limited NASCAR market and the local police and fire station.
- This work is focused on key barriers to deployment.
- The presentation did not inspire confidence that the team understands the potential market for this product to the level of sophistication that would support development of a strong business case.
- High-level technical goals were established on slide six; however, no information was provided about the schedule or the status of the schedule. There was minimal discussion of technical barriers and a point-by-point assessment of solutions.
- This project adequately identified milestones, go/no-go dates, and risks. The test duration is short and the number of systems tested is small.

**Question 3: Technical accomplishments and progress**

This project was rated **2.2** for its technical accomplishments and progress.

- Missing the NASCAR season in 2011 was a major setback. The PI indicated that there is still a need to reduce costs. Meeting the form factor to NASCAR requirements has proven difficult. This project has completed a detailed analysis of NASCAR camera equipment power needs and has almost completed reformer development and fuel interface work. There may be a problem with the inability to see fuel levels in tanks.
- The mechanical design seems sound and the progress made on the details to enable the application, such as the fuel gauge, is also useful.
- It is not clear whether Jadoo is making the sort of progress that would result in a strong business case for this product.
- Technical progress seems insufficient compared to the funds that have been spent to date to reach the end-of-program goals. This work needs to show actual power output versus time, not just a stack heat-up rate. The project also needs to present a milestone status or a schedule on slide seven.
- This project is behind schedule. Many important tasks remain to be completed.

#### Question 4: Collaboration and coordination with other institutions

This project was rated **2.6** for its collaboration and coordination.

- Collaborating with NASCAR is a plus, as many people will see this proof-of-concept. The focus group with local and state first responder officials (e.g., Folsom, Federal Emergency Management Agency) will help get this through the permitting process faster. There is no collaboration with other markets for a product such as this beyond NASCAR.
- This project demonstrates excellent leverage with Delphi's core program. It is good to see companies collaborate in ways that others might see as competition.
- While it appears collaboration exists, it is not certain that there is a strong coalition in place.
- Using the Delphi system takes advantage of existing work for a parallel application.
- There is not much evidence of collaboration. NASCAR's role at this point is only consultation.

#### Project strengths:

- This project has the potential for high visibility if units are fielded for an entire NASCAR season. The potential for emission and noise reduction is very good compared to diesel generators.
- A strength of this project is the collaboration between Jadoo and Delphi.
- A strength of this project is its niche application of SOFCs.

#### Project weaknesses:

- A weakness of this project is the limited market for large-scale production of fuel cells. Not many jobs are created as a result of this ARRA project. In addition, this work missed a major milestone by failing to have the two units ready for 2011 NASCAR season.
- This work needs a stronger level of collaboration and a business case for the product. When compared to what Sandia National Laboratories has accomplished with the mobile light tower project, it falls short.
- There does not seem to be a good fit for the technology. The advantages that came from the unique logistics are not particularly associated with the SOFCs.
- Following are three weaknesses: (1) no cost data was provided, (2) the test duration is short, and (3) progress is slow relative to the schedule.

#### Specific recommendations:

- This project should be given a no-cost extension to allow the fuel cell to be a part of the 2012 NASCAR season.
- It is important to ensure that some validation in the field gets completed in the program.

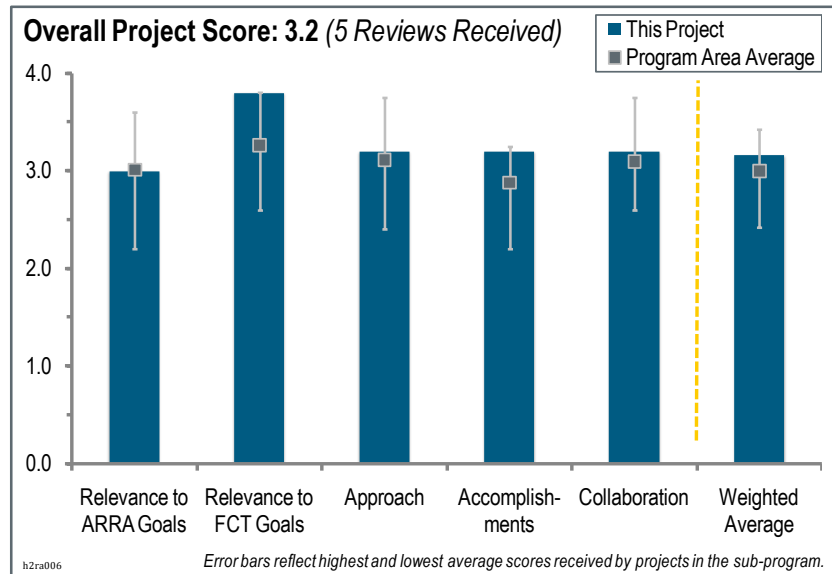
## Project # H2RA-006: PEM Fuel Cell Systems Providing Backup Power to Commercial Cellular Towers and an Electric Utility Communications Network

Mike Maxwell; ReliOn Inc.

### Brief Summary of Project:

The goal of this project is to install and operate hydrogen polymer electrolyte membrane fuel cells as critical emergency reserve power for cell sites operated by AT&T and as backup power equipment for communications sites used by Pacific Gas & Electric (PG&E), a California utility. Up to 189 sites will be served. Goals for 2010 were to ramp up site acquisition, accelerate deployments, begin bulk refueling, and collect operating data. This project's relevance to the goals of the American Recovery and Reinvestment Act of 2009 (ARRA) are: (1) the manufacture and installation of up to 189 fuel

cell systems, which creates and retains direct and indirect jobs at ReliOn and indirect jobs through the service supply chain, as well as develops growth in new service industries to install and refuel these systems; (2) Air Products and Chemicals, Inc. has developed a new fueling vehicle and a new hydrogen storage module, allowing access to more sites and expanding the potential market served for compressed hydrogen; and (3) multiple subcontractors have gained experience installing fuel cells, increasing their product offerings.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.0** for its relevance to overall ARRA goals.

- There is tremendous job potential for backup power for cell towers. The Katrina Commission recommended eight hours of minimum backup, which is in a fuel cell's "sweet spot." Working with a major carrier such as AT&T could lead to big orders and accompanying jobs. ReliOn only reported two jobs having been created.
- This project has developed some new jobs (e.g., a fuel provider) and retained jobs. It will spur some economic growth if industry begins to use this approach; however, it is unclear how big this potential is or what its impact will be.
- This is an impressively broad project and is touching a lot of people and market segments.
- Although the project can only take credit for two jobs, many more jobs are affected.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.8** for its relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies Program's ARRA project goals.

- The Battelle Memorial Institute study in 2008 cited the fuel cell emergency backup power as an emerging market, particularly for the commercial cell tower market. This effort focuses on that market. By partnering with AT&T and PG&E, ReliOn maximizes its chance to see this market grow if the units perform well, given the tremendous reliability expectations on mobile phone infrastructure. In short, there are many cell towers to be backed up, which could result in a lot of jobs created and a success story for DOE fuel cell team.

- If successful, this work will foster additional fuel cell commercialization efforts by increasing production, demand, and capacity.
- This appears to be one of the more promising efforts. It is potentially economically justifiable, but the contractor should make that case. The reviewer asks what the economics are now, and what they will be as broader market adoption occurs.
- Using hydrogen fuel cells for backup power supply is a viable niche market for hydrogen fuel cells. Deploying hydrogen fuel cells will help showcase the opportunities and attributes of hydrogen fuel cell backup power systems. In addition, this project has prompted hydrogen suppliers to put in place new and innovative fueling systems to better serve the systems and the customers.

## Question 2: Development and deployment approach

This project was rated **3.2** for its development and deployment approach.

- The technical approach addresses the barriers to site selection, site acquisition, and fueling infrastructure. Serving 189 sites represents a “critical mass” that could lead to further adoption. Partnering with PG&E could be very positive for commercial customers in the future. This approach will help energize the supply chain for using backup power fuel cells. Deploying this technology across 10 states will maximize its visibility.
- Milestones are shown in phases, but they do not have dates or deadlines. The milestones and schedule could be better quantified in this way.
- This project does not present much technical information. The power and other specifications were unclear from the presentation. However, it does appear that the technology is capable of meeting the market needs.
- Although approvals took longer than expected, the project appears very likely to be achieving all of its goals.

## Question 3: Technical accomplishments and progress

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

- Lessons learned from this effort are being incorporated into a next-generation product. Permitting took three times longer than anticipated (six months versus two months). The site selection process was very thorough. This project began with 740 sites, ultimately selecting 189 sites. This information could be useful to educate future customers on ideal locations for fuel cell backup power.
- As described, the project is learning from and working on overcoming the barriers of site selection and permitting. This is very valuable information; however, there is little on the operational data collection or technical information (this may be yet to come, but it is not clear in the goals or reporting).
- The project’s objectives appear to be adequately reported and quantified, although it would be interesting to know the specification of the power system.
- Although approvals took longer than expected, the project appears very likely to achieve all of its goals.

## Question 4: Collaboration and coordination with other institutions

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

- Collaboration with Air Products and Chemicals, Inc. for the “fill in place” bulk fuel resupply strategy will lower the costs for hydrogen at these locations (cheaper than bottles). Input on this ARRA project provided by a Safety Panel member indicates that there is still not enough training being done with the cell company and cell tower personnel to accurately answer questions from permitting officials. Deployment in multiple states, with more permitting officials involved, will help speed future installations, as this would provide more collaboration than if sites were concentrated in a single jurisdiction.
- This project appears to have good collaboration and will be very interesting to compare to a similar, parallel project.
- This project exposed major issues in the codes, standards, and permitting. It is unclear who the “right” collaborator is, but there needs to be a more efficient process in place.
- This project showed great collaboration.

- Collaborations were limited to the participants and the fuel provider. This may have been sufficient and possibly all that could have been achieved; however, some collaborations with installers, siting consultants, and other industry professionals might have been helpful in overcoming approval barriers and providing information to other stakeholders that could benefit future projects.

### Project strengths:

- Following are several project strengths: (1) the large number of deployments in a market sector that is ripe for fuel cells; (2) the teaming of a major fuel cell backup power original equipment manufacturer with a major cell phone company and major utility; (3) the use of a new hydrogen delivery approach that can reduce costs; (4) the significant data on reliability that will emerge from this effort; and (5) the development of a 72-hour hydrogen storage solution.
- This project is developing a very promising technology and is learning a great deal about the challenges in site selection and acquisition. This can help many other industries encountering similar issues and help educate officials. A parallel project is very good to compare differences that will be encountered within different industries and applications.
- This project overcame barriers in codes, standards, and permitting.
- The project includes broad involvement from the user and the supplier community, and thus appears to be one of the better fuel cell opportunities.
- It appears that the engineering applied to the project was successful in meeting the many challenges of the project. The fuel supplier has developed a new, improved refueling system to support this project and similar projects to meet the needs of the technology and the needs of the customer.

### Project weaknesses:

- Permitting delays resulted in moderate schedule slippage.
- The schedule and timeline are not clear. Progress does not appear to be on time (although lessons learned in the challenge are valuable). Job impacts could be more clearly presented.
- This project needs to describe a typical installation quantitatively: volume, dimensions, fuel amount, and power level.
- Obtaining permits and approvals took longer than expected, but this appears to have been overcome through persistence and good engineering.

### Specific recommendations:

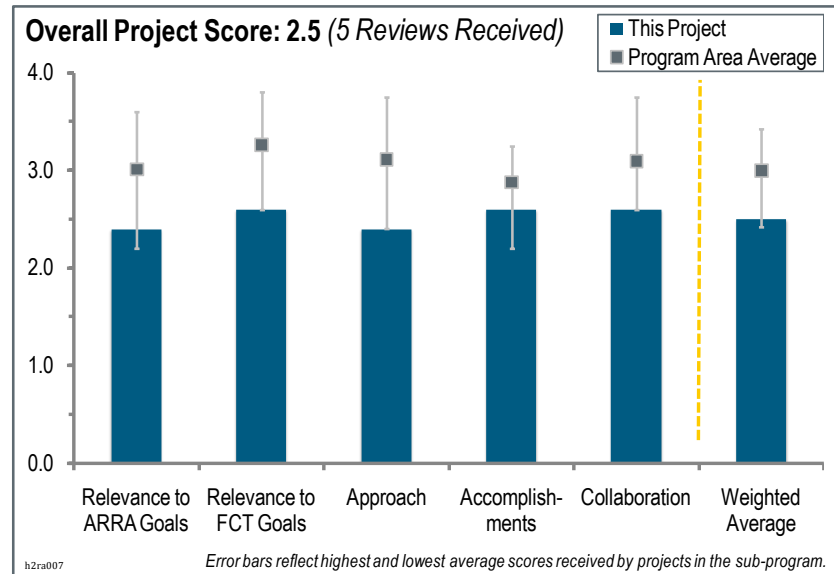
- This is a very promising project that should be followed through. Two recommendations are to review this work against similar projects to determine next steps and consider conducting greater technical data collection and review.
- This shows how important—and how considerable the barrier—local codes, standards, and permitting are to the cost of deploying backup power systems.
- One recommendation is to describe a typical duty cycle and usage profile.
- More partnerships with siting consultants might have shortened the time needed for approval.

## Project # H2RA-007: Accelerating Acceptance of Fuel Cell Backup Power Systems

Donald Rohr; Plug Power Inc.

### Brief Summary of Project:

The objectives of this project are to (1) demonstrate market viability and increase market pull of fuel cell systems with government customers and partners; (2) maintain U.S. jobs both within Plug Power and outside through collaborations with the supply base; and (3) deploy 20 GenSys low-temperature polymer electrolyte membrane, liquid petroleum gas units that provide economically viable backup power for at least 72 hours to increase distributed power generation, improve reliability and efficiency of mission critical backup power, and decrease fossil fuel dependencies for power generation.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **2.4** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- This project has demonstrated solid progress and has a good work plan and capable team. It appears that this project has resulted in improved technology and an increased knowledge base, and it is reasonable to expect the upcoming deployments to provide significant data. It appears that the team has done well on many aspects of the plan and will continue to do so. Once complete, this project should result in increased sales and jobs.
- Many partners (especially outside of the U.S. Department of Defense and other government partners) should lead to job opportunities, but this could be better defined.
- This application is a good use of the U.S. Department of Energy's (DOE) developed fuel cell technology, and deployment projects are well aligned with ARRA goals.
- Plug Power has limited the resources available to this project due to company priorities—this is a project weakness.
- The project's contribution to creating new jobs and saving existing jobs is uncertain. The project appears to promote substitution of fuel cell technology for diesel technology versus expanding the job market—how the project provides a net increase in jobs is not apparent. The project's objective, "Demonstrate market viability and increase market pull of fuel cell systems within our government customers/partners," focusing on government sales is of questionable value. That is, unless the technology provides environmental or other benefits, the federal government paying a contractor to improve its sales to the federal government is questionable. This project refurbished previously manufactured units—it is not apparent where long-term investment to expand production capacity was made.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **2.6** for its relevance to the DOE Fuel Cell Technologies Program's ARRA project goals.

- This project has made real progress toward ARRA's goals. More progress in this direction will come with deployment.
- The project and the product have the potential to support deployment and commercialization opportunities, but it is difficult to assess this potential at this time.
- This work is appropriately focused on efficiency and reliability metrics. It would be beneficial to understand why maintenance is so high and how it can be reduced. Also, it would be helpful to know the target for system efficiency and how that is derived.
- Backup power is an important market for fuel cell power systems. Using liquefied petroleum gas (LPG) fuel opens up a wide variety of potential applications in remote areas.
- Fuel cells deployed in this project were refurbished cells from India—it is unknown to what extent this will accelerate fuel cell manufacturing. Installing backup power for bowling alley lighting is not a strong demonstration of the value of fuel cells in a mission-critical application.

### Question 2: Development and deployment approach

This project was rated **2.4** for its development and deployment approach.

- Delay in the product should have permitted more time for coordination with sites. It appears that there was little communication with Fort Irwin, resulting in a scramble to find an appropriate load. Still, the plan looks solid and, based on the company's experience, will likely result in significant progress and new information.
- Goals and milestones are not well defined, and those listed are not being met.
- This project is a traditional build/test program. It would be useful see a systemic analysis of the cause of reliability trouble.
- Several project changes have affected the work. Resources have been applied elsewhere due to company priorities. Some delays have resulted from shipping damage or aging units.
- This project has clearly defined technical stages and a go/no-go decision milestone that appears appropriate and feasible. The presentation only provided a schedule for future activities. This project must be behind schedule, given that it is 35% complete, but more than 80% of the project time has elapsed. The presentation described addressing technical barriers, but not commercial ones.

### Question 3: Technical accomplishments and progress

This project was rated **2.6** for its technical accomplishments and progress.

- The development and testing activities have yielded real progress on efficiency improvements. This project has a good work plan that is well executed.
- This project has admitted difficulties and slow progress. It is difficult to judge the project due to this. The assessment to move toward LPG when hydrogen did not work is good.
- The testing progress appears good. It would be useful to have more field data, including quantitative analysis of reliability problems and failure analysis as it becomes available.
- Much work remains to be done, and the project has asked for a time extension due to delays.
- The progress on each project step was well quantified, but the overall work is behind schedule.
- The presentation did not provide objective results concerning job numbers; however, an anecdotal estimate was provided after the presentation. Because the technology was presented as a replacement for diesel technology, the net job numbers would reduce that estimate.

#### Question 4: Collaboration and coordination with other institutions

This project was rated **2.6** for its collaboration and coordination.

- It appears that better coordination with the shipping of units and site selection could have saved time and resulted in further progress. Still, the team has recovered well and laid the appropriate groundwork for further progress.
- This work has demonstrated good collaboration of partners; however, the site selection of the bowling alley should be reconsidered. This reviewer wonders how much information will come from this, and if it would be better to spend more time finding a more productive partner.
- This project demonstrates good collaborations with end customers, and it appears that good collaborations with suppliers are underway.
- Collaborations appear to be adequate for the project.
- The placement of a unit at a bowling alley (versus a mission-critical situation such as an ALC Distribution Depot) indicates a lack of coordination.

#### Project strengths:

- One strength of this work is its solid technical achievements with reference to efficiency gains.
- The project's concept shows potential, which could result in a good outcome.
- This work is aligned with ARRA goals and is an interesting application.
- This project has a good potential market and a good choice of fuel for wide application.

#### Project weaknesses:

- Two project weaknesses include the project's coordination with partners and its timeline slip.
- The project's milestones are not well defined or being met, causing a review of the project to be difficult to evaluate on merit of potential. This project has made some questionable decisions and actions (e.g., partnering with a bowling alley and the lack of durability or foresight in shipping units/damage).
- This project has displayed a limited analysis of reliability problems.
- Product and project changes appear to have delayed the work. Efficiency appears to be lower than expected.

#### Specific recommendations:

- The team should continue with the plan as is.
- If this project does not show significant progress soon, it may lose its ability to deliver at all. This work does show potential, but if funding is not already spent or delivered, then decision-makers should reconsider how to make improvements or discontinue this work.
- The researchers should consider using a pareto analysis of the reliability issues as a priority for field testing and include the results in the DOE report.
- Additional collaboration with technology partners might improve the project progress rate.

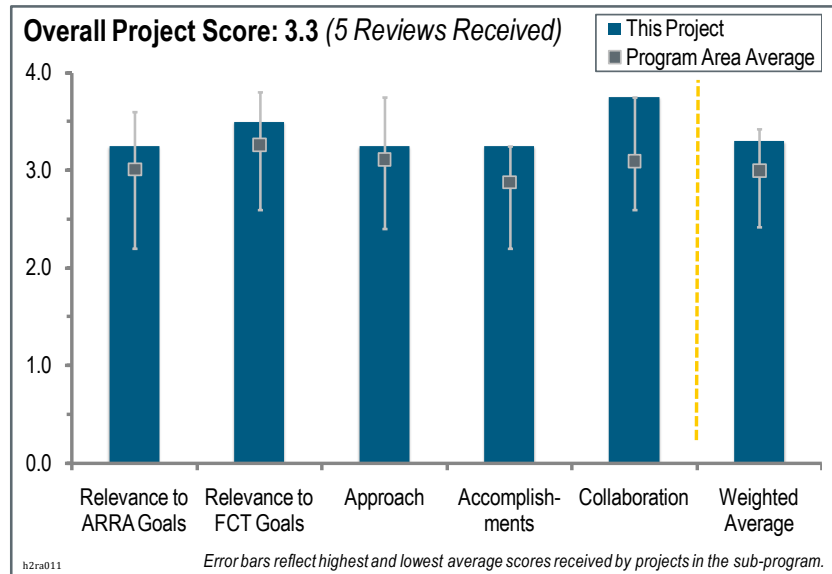
## Project # H2RA-011: GENCO Fuel Cell Powered Lift Truck Fleet Deployment

Jim Klingler; GENCO

### Brief Summary of Project:

The objectives of this project are to: (1) support an American Recovery and Reinvestment Act of 2009 (ARRA) goal of long-term economic growth by successfully demonstrating a new technology and (2) promote the economic and environmental benefits of hydrogen fuel cell technology. The goals for this project are to: (1) demonstrate the economic benefits of converting large fleets of battery-powered lift trucks to fuel cell power units by measuring; analyzing; and reporting the performance, operability, and safety of the systems; (2) convert electric drive forklift truck fleets to fuel cell use in five large

distribution centers and manufacturing facilities; (3) provide affordable and reliable hydrogen; and (4) establish a proving ground for hydrogen fueling technology that will promote the future adoption of fuel cells in other applications, such as cars, and help drive fuel cell technology use in the United States.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.3** for its relevance to overall ARRA goals.

- This is a solid demonstration program with sufficient details in its execution plan to indicate a good chance of survival of the product, post-incentives. Feedback on projected economics looks positive and meaningful.
- GENCO is a third-party warehouse distributor and therefore can make a value proposition to many companies to which it provides support. This could lead to the product's adoption across a wide range of material handling equipment (MHE) sites.
- This project is one step closer to creating new jobs and may create economic activity, but it would be useful to address lowering costs and safety concerns.
- This work is relevant to ARRA objectives of initiating the use of fuel cells in a new application, which promises to grow jobs.
- This is one of the better projects. There is enough market opportunity to really create jobs.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.5** for its relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies Program's ARRA project goals.

- This project appears to be on target to deliver meaningful results and a positive impact in a live "production" environment. Given the ultimate size of the potential market, this bodes well for meeting ARRA goals for commercialization and deployment.
- The polymer electrolyte membrane fuel cell market has been given a tremendous boost in commercialization as a result of forklift deployments sponsored by the U.S. Department of Defense and DOE. This effort will accelerate this commercialization even further.

- This project addresses the technology development plan of accelerating the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services.
- The GENCO project deals with key issues of implementing hydrogen forklifts and the real issues encountered in that process.
- This is building user advocacy, a supply infrastructure, and production capability.

### Question 2: Development and deployment approach

This project was rated **3.3** for its development and deployment approach.

- This was a well run and executed program. This project demonstrates good partnerships, strong delivery of the solution set, and good follow through. As more data on performance is acquired, more specific guidance on costs and savings will likely help the ultimate commercialization plan.
- The principal investigator's proposal to convert five different facilities with five different companies (Wegmans, Whole Foods, Coca Cola, Sysco, and Kimberly Clark) is an approach that could lead to widespread adoption if successful. The Kimberly Clark location provides for shared utilization of the hydrogen infrastructure. This may be the first "public" MHE hydrogen station in the United States.
- Go/no-go decision points have been established with deployment to each of the five sites. Utilization of two hydrogen providers (Linde and Air Products) reduces the risk and increases the competition for affordable hydrogen. All classes of forklifts will be deployed as part of this effort. This can demonstrate the possibility for eliminating battery infrastructure.
- The repair frequency is not clearly defined. It would be useful to understand which class of GenDrive has more problems than the other.
- This project demonstrates the traditional approach to build and test hardware.
- Goals are well defined and reasonable. The issues of market price tolerance and the need to sustain incentives were glossed over in the presentation, but addressed in the discussions. The presentation could have provided a better economic analysis showing what it will take on the cost side to enter this market.

### Question 3: Technical accomplishments and progress

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

- This project demonstrates excellent technical progress and reporting on the number and types of installations, but it would have been beneficial to see a chart or two summarizing or estimating the jobs impacted and created by the project.
- Three out of the five go/no-gos were achieved and the remaining two appear to be coming along. Follow-up orders announced by Sysco demonstrate the achievements already made, even though this project has more than two years left. GENCO stated that the biggest challenge was maintaining a relationship with the customer and lease holder. GENCO reports that there is a lot of customer interest in these deployments.
- Progress toward objectives and overcoming barriers seem slow.
- This project is a little behind, but the planned fleet deployment is significant, and a lot of work has gone into site planning.
- The progress is very encouraging, and it is one area where there could really be a breakthrough for fuel cells.

### Question 4: Collaboration and coordination with other institutions

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

- This project has outstanding collaborations with product original equipment manufacturers (OEMs) that may order more conversions of MHE to fuel cells within their respective companies. The project worked closely with Kimberly Clark to determine savings of \$105,000 over three years. This work is continuing to communicate savings to customers. It is also collaborating with Plug Power, Linde, and Air Products to give valuable feedback on ways to further satisfy this customer market.
- This project has provided an excellent demonstration of site collaborations. It would have been useful to have more clarity on the interactions with the fuel cell provider.

- This work involves all of the right players and has the right project lead.

**Project strengths:**

- This project is creating jobs by accelerating the fuel cell forklift market. Its deployment activities involve a diverse range of companies and locations. This is a win-win proposition, as GENCO wants to be the most effective third-party distributor to grow its business and believes fuel cell forklifts can help it do that. This effort may tip the market to the point that forklift OEMs do a bottoms-up design of lift trucks using fuel cells.
- The development of safe hydrogen material handling operations to demonstrate economic benefits and spur more distribution and manufacturing centers to convert to fuel-cell-powered MHE is important to create new jobs and create economic activity.
- This work is very relevant to ARRA goals. This project is a good application, has a good program plan, is well managed, and engages the end customer.
- This is a real-world test of the fuel cell MHE economics.

**Project weaknesses:**

- One weakness of concern is the uncertain power unit reliability due to the lack of widespread performance data. Another concern is the safety and expense of hydrogen and fueling equipment.
- This work could focus more on what would be necessary to make these projects sustainable from a financial point of view, e.g., fuel cells need to be reduced in cost by “x,” be more efficient by “y,” and be more reliable by “z.”

**Specific recommendations:**

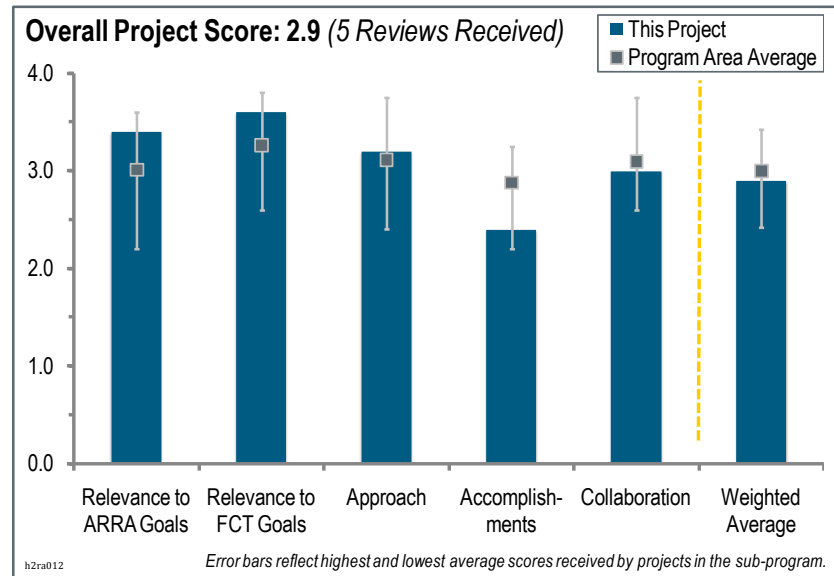
- It would be beneficial to establish quantitative improvement metrics to make fuel cell forklifts sustainable economically.
- The researchers should provide the economics and be specific about what is needed to get to the market.

## Project # H2RA-012: Use of 72-Hour Hydrogen PEM Fuel Cell Systems to Support Emergency Communications

Kevin Kenny; Sprint

### Brief Summary of Project:

The overall objective for this project is to demonstrate the technical and economic viability of polymer electrolyte membrane (PEM) hydrogen fuel cells to provide backup power for critical Sprint code-division multiple access cell sites. The scope of the project is to deploy 260 new and 70 retrofitted fuel cells using a new, on-site, refillable, medium-pressure storage solution. New sites are slated to be installed in California (100), Connecticut (30), New Jersey (65), and New York (65). The project will retrofit 70 PEM fuel cells currently deployed in Louisiana and Texas.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.4** for its relevance to overall American Recovery and Reinvestment Act of 2009 (ARRA) goals.

- This is a big potential market, and the project addresses the goal of creating jobs in a way that is likely to be sustainable and beneficial.
- This project is an investment in long-term opportunities and is helping to jump start the fuel cell industry. By cost-sharing these field trials, the program is getting hundreds of fuel cells in the field that may not have been installed if this program was not available. This project has both created and saved existing jobs. This work has reportedly created 18.5 jobs.
- This project has multiple partners. It is at the information gathering and securing permits stage. As it moves toward maturity, it has the potential to create additional jobs.
- The number of jobs created (18) seems low compared to the cost of the project (\$24 million).
- This project states that it is supporting 18.5 jobs this quarter.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.6** for its relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's ARRA project goals.

- This work is exceptionally well aligned with the goals of the FCT Program's ARRA objectives.
- This project is installing fuel cells in the field and increasing the knowledge of fuel cells of workers across the country, including municipality employees, safety and fire workers, and telecom industry personnel. This funding accelerated the deployment of fuel cells into the telecom industry.
- This is a niche application that will provide a good testbed and increase the experience base for PEM fuel cells.

- Backup power is a viable hydrogen fuel cell niche market, as demonstrated by numerous installations worldwide. Installation of hydrogen fuel cell backup power systems can support the hydrogen fuel cell market and showcase capabilities, accomplishments, and opportunities.
- Replacing the need for diesel generators or short-life lead-acid batteries with long-running, high-durability hydrogen fuel cells for cell tower backup is an excellent application of this technology, and will further DOE commercialization and deployment goals.
- It is good that this project is working with a fuel provider to improve the delivery of fuel, as that seemed like a weak link with standard bottle replacement.
- This project doubles the number of fuel cells deployed compared to Sprint's original field trial.

### **Question 2: Development and deployment approach**

This project was rated **3.2** for its development and deployment approach.

- This is a logical, well laid-out program.
- This project is well laid-out and its milestones are achievable. Progress has been made to install the equipment and barriers are being overcome, such as permitting issues, environmental and safety approvals, and basic education issues.
- This is a straightforward project using available fuel cells from two vendors and using experienced architecture and engineering firms. While deployment milestones have been identified, they have not been quantified (i.e., it is unclear when a specific milestone is scheduled for completion).
- The project appears to be working hard to make site selection, design, and installation a routine matter by using a regularized screening approach with go/no-go decisions based on appropriate criteria.
- The approach seems reasonable, although it is disappointing that so much effort has to be spent on site screening and evaluation. A recommendation for the future is to identify a streamlined method for selecting appropriate installation sites.

### **Question 3: Technical accomplishments and progress**

This project was rated **2.4** for its technical accomplishments and progress.

- This project has had some delays, but overall has made good progress.
- This project is meeting the goals of installing the fuel cells and solving the barriers that have slowed installation.
- Considering that this work is nearing the halfway point (September 2011) and is only 15% complete raises a red flag. It is not clear from the presentation whether this is how the project was laid out. Most of the work completed at this point is paperwork.
- Fewer than 10% of the initial sites considered for installation were finally approved for construction. This is not a good result. Although this may not be the fault of the project, something could have been done to realize a better percentage of sites approved for construction. The Sprint lease cost limit may have been set too low, and because Sprint was the proposer, this would seem to be within its control.
- Many barriers have been overcome to get to the point of selecting suitable sites for pre-construction preparation. It is disappointing that phase three (installation/commissioning) is 0% complete, implying that no sites currently have construction underway. Most of the indirect jobs from this project come from the actual construction and installation by local tradesmen, so the sooner the project can move to phase three, the sooner jobs will be largely impacted.

### **Question 4: Collaboration and coordination with other institutions**

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

- The project could have done more to highlight the fuel cell manufacturers' role and what learning they have taken into their design activity.
- The project team has the technical expertise to meet the goals of the project and is making progress on the installation of the equipment.

- This project has multiple partners with well defined roles. No issues among partners have been identified. However, because the project is only 15% complete, it will not receive an “outstanding” rating.
- This project demonstrated good collaboration with industry members.
- It is good that the project is working with both Altergy and ReliOn, and not just one vendor. It is excellent to have Air Products demonstrating a refillable approach for fueling to avoid bottle change outs.

**Project strengths:**

- The project’s focus on rolling out a product in a high-value market is excellent.
- The project is meeting its milestones. At each installation site, the project team has educated the public on fuel cells and fuel cell safety, which will help fuel cells penetrate the market. The project also is purchasing units from the manufacturer, which will improve the industry.
- This work is straightforward. This is a niche application that increases the experience base.
- This project has ambitious goals and a broad scope.
- This project has good objectives and a good approach to getting a large number of fuel cells deployed in a mission-critical application with high visibility for other industries that require backup power.
- The work has established good partners that will be able to sustain this work beyond the end of the DOE ARRA project.

**Project weaknesses:**

- The project’s interaction with fuel cell companies is somewhat unclear.
- The project seems to be making progress toward its milestones.
- One of the project’s objectives is economic viability; however, no cost information is provided.
- There may have been ways to site systems by using “Alternate Means Request” methods when siting issues became troublesome. The number of sites that were deemed unsuitable seems high. It would seem that additional engineering could have been fruitful in resolving these issues. With Sprint being both the proposer and putting restrictions on the lease cost, increases could have resulted in some sites not being selected that were suitable, other than lease cost. Some of the DOE funding could have been used to offset the lease cost increase. Likewise, the cost share could have been used to offset the lease cost increases.
- It does not appear that the systems have been installed yet. The project needs to get going on this. The reviewer asks why the project team failed to start installing some systems immediately at the “low-hanging fruit” sites that were obviously suitable for the technology.

**Specific recommendations:**

- One recommendation is to set up goals to identify what was learned from the installations so that the fuel cell providers can use this information in their redesign.
- Following are several recommendations: (1) accelerate the timing for installing the product into the sites; (2) prepare a few case studies and fact sheets that can be used by DOE and industry to advertise successful demonstration sites; and (3) before the project concludes, establish a list of “lessons learned” that can be published at an appropriate conference.

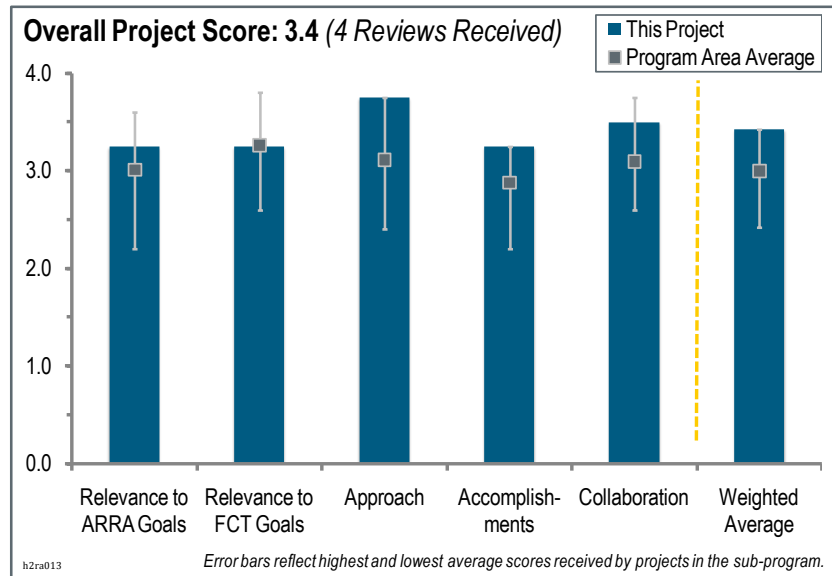
## Project # H2RA-013: Analysis Results for ARRA Projects: Enabling Fuel Cell Market Transformation

Jennifer Kurtz; National Renewable Energy Laboratory

### Brief Summary of Project:

The overall objective for this project is to assess technology statuses in real-world operations, establish performance baselines, report on fuel cell and hydrogen technology, and support market growth by evaluating performance relevant to the markets' value proposition for early fuel cell markets. The objectives are to: (1) conduct independent technology assessments in real-world operating conditions; (2) assess technology focused on fuel cell systems and hydrogen infrastructure in terms of performance, operation, and safety; (3) leverage data processing and analysis capabilities developed

under the fuel cell vehicle learning demonstration project; (4) support market growth with analyses and results relevant to the markets' value proposition; (5) support market growth by reporting on technology statuses to fuel cell and hydrogen communities and other key stakeholders such as end users; (6) support early fuel cell markets for material-handling equipment, backup power, portable power, and stationary power; and (7) conduct analysis of up to 1,000 fuel cell systems that were deployed with American Recovery and Reinvestment Act of 2009 (ARRA) funds.



### Question 1a: Relevance to overall American Recovery and Reinvestment Act of 2009 goals

This project was rated **3.3** for its relevance to overall ARRA goals.

- This project enables numerous other activities—within existing U.S. Department of Energy (DOE) and ARRA projects and spin offs—to develop and prosper, which will enable new job creation. This work supports long-term growth by tracking and reporting progress, challenges, and development in these many areas (i.e., various applications).
- Analysis of the operation of fuel cell technology can be used as feedback to the manufacturers and the public. It will increase the general knowledge of the industry, and can be used to make improvements on fuel cells.
- This project is relevant to ARRA goals if the analyses are credible. The results are compelling; product reports in the hands of potential end users will persuade them to consider investing in these technologies.
- The analyses appear to be credible.
- The results describe performance, reliability, and safety, but they do not appear to provide a value proposition or compare existing technologies. It is unclear if the reports reach potential end users and, if they do, if they provide adequate information to motivate end users to contact fuel cell manufacturers.

### Question 1b: Relevance to the U.S. Department of Energy Fuel Cell Technologies Program's ARRA project goals

This project was rated **3.3** for its relevance to the DOE Fuel Cell Technologies Program's ARRA project goals.

- This is one of the best projects within the DOE Hydrogen and Fuel Cells Program. It enables others to succeed in many ways and provides one of the best measurement and tracking processes. This work enables private industry to understand where it can enter markets (anywhere along the curve).
- This research can improve the support services of the fuel cell industry and accelerate commercialization by feeding valuable information back to the industry and out to the public.
- The project's results describe performance, reliability, and safety, but they do not provide a value proposition or compare existing technologies—both of which are required for end-user acceptance.

### Question 2: Development and deployment approach

This project was rated **3.8** for its development and deployment approach.

- This work is very clearly defined, tracked, and measured.
- The team has shown significant amounts of data in very useful formats and seems to have made consistent progress with no visible barriers to the research. The team has laid out achievable goals and schedules and seems to be meeting these goals.
- The project plan is well defined with clear and achievable milestones. The project provides credible information about technology performance, reliability, and safety that reduces technical uncertainty and quantifies risk for fuel cell manufacturers and potential end users. Such uncertainties and risk are barriers to commercial adoption.

### Question 3: Technical accomplishments and progress

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

- While this project is a little different than other projects, it accomplishes what it sets out to do and reports it well.
- This project is meeting its goals and milestones and is producing significant data reports.
- The project's milestone chart indicates that project deliverables are up-to-date. The technical analyses appear to be credible and complete. By its nature, this project is not expected to be able to report progress in ARRA metrics; however, it would have been useful to provide some metrics as to the effects the reports have had on, for example, manufacturing design changes, operational or safety changes, and customer contacts.

### Question 4: Collaboration and coordination with other institutions

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

- Collaborations for this work are numerous and applicable.
- The team seems to have the technical skills needed to accomplish the goals, and has collaborated with numerous industry partners to compile data on the fuel cell technology.
- One recommendation is to develop a process to present comparable data for incumbent technologies. It is difficult to assess performance without something to compare it to.
- This work has a very good representation of fuel cell manufacturers and users and excellent coordination with them.

### Project strengths:

- This project provides one of the best quantifiable tools and processes, resulting in an enormous amount of data (both public and private). This is one of the best projects within the DOE Program.
- This project demonstrates thorough data collection and very usable report formats with significant amounts of data. The amount of data being presented is hard to find anywhere else.

- The project's strength is the National Renewable Energy Laboratory's expertise in collecting and reporting data.

### Project weaknesses:

- While much data and information is made available, it would be worth brainstorming how it could be "pushed" out to industry more. Many companies and entities might find this useful, but they do not know that it exists or that it could be relevant.
- There is a lack of comparable data for the incumbent technologies.

### Specific recommendations:

- Two recommendations are to: (1) definitely continue this activity and (2) consider ways to proactively disseminate the information to those who do not know (or seek out) the value of this technology.
- One recommendation is to continue compiling and creating reports on these topics to showcase the growth of the industry.
- There need to be processes to compare the fuel cell products with incumbent technologies.