

2012 — American Recovery and Reinvestment Act

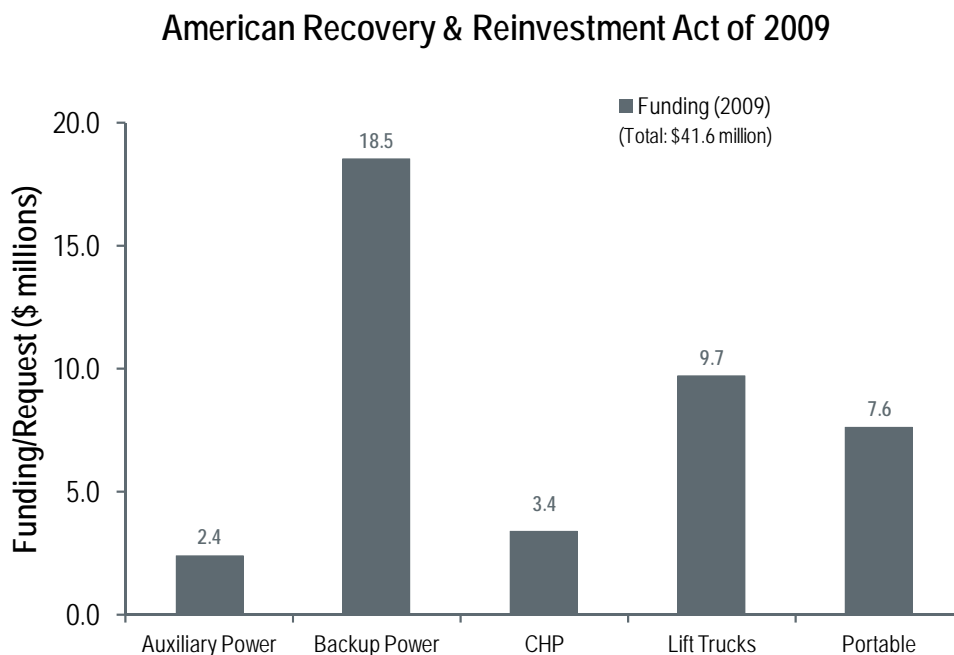
Summary of Annual Merit Review of American Recovery and Reinvestment Act Activities

Summary of Reviewer Comments on the Recovery Act Activities:

This review session evaluated the projects funded under the American Recovery and Reinvestment Act of 2009 (Recovery Act) for enabling fuel cell market transformation. The Recovery Act projects included the development and deployment of a variety of fuel cell technologies including polymer electrolyte, solid oxide, and direct-methanol fuel cells in auxiliary power, back-up power, combined heat and power (CHP), lift truck, and portable-power applications. The Recovery Act projects are considered by reviewers to be well aligned with the goals and objectives of the Recovery Act and the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program. In general, the projects were judged to be making significant progress toward fuel cell development and deployment, especially considering the additional industry-funded (i.e., without DOE funds) deployments completed or planned.

Recovery Act Funding by Technology:

In April 2009, DOE announced the investment of \$41.6 million in Recovery Act 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 Recovery Act 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 approximately \$54 million, more than 56% of the total cost of the projects.



Majority of Reviewer Comments and Recommendations:

Seven of the 12 deployment projects and one data collection and analysis project in the Recovery Act activities had oral presentations; two projects had poster presentations. Of these, only five of the projects were reviewed, because

the remaining projects were either completed or nearly complete (see fiscal year [FY] 2011 and FY 2010 proceedings for prior year reviews). In general, the reviewer scores for the Recovery Act projects were good, with scores of 3.7, 3.0, and 2.1 for the highest, average, and lowest scores, respectively. Three of the five 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 FY 2009 or early FY 2010.

Auxiliary Power: One project in this area, involving the development of a diesel auxiliary power unit to power hotel amenities for use on Class 8 sleeper trucks, was reviewed, receiving a score of 3.0. The project was seen as being on a clear path to commercialization and addressing a huge potential market for fuel cells, especially with the anti-idling regulations in many states. The reviewers felt the delays in the project and having only one test unit were hindering progress. It was also recommended that the project team investigate additional market applications.

Backup Power: Two projects addressing 72-hour backup power for cellular communication towers and U.S. Department of Defense sites were reviewed, with an average score of 3.1. Overall, the reviewers thought the deployment of a large number of fuel cells into the market was a significant contribution from these projects. It was recommended that the project with deployments at cellular towers look into reformer-based, on-site hydrogen production technologies as a potential way to open up additional deployment sites.

Combined Heat and Power (CHP): One project in this area, addressing residential and light commercial applications, was reviewed, receiving a score of 2.1. The project was seen as a good potential avenue for reducing energy use in homes. The reviewers were concerned with the membrane electrode assembly failures and recent no-go business decision by the project lead on commercial deployment of these units, but recognized the company's efforts in salvaging the project by transferring deployment responsibilities to another company. It was recommended that more cost/benefit analyses be done for this market.

Data Collection and Analysis: One project in data collection and analysis was reviewed, receiving a score of 3.7. The reviewers thought the project provides valuable data on a number of fuel cell deployment sites and partners through an easily understood set of products. It was recommended that this analysis effort continue, because it is seen as a huge benefit to the fuel cell industry. The reviewers also recommended data collection and analysis be performed for internal combustion engine and battery applications.

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

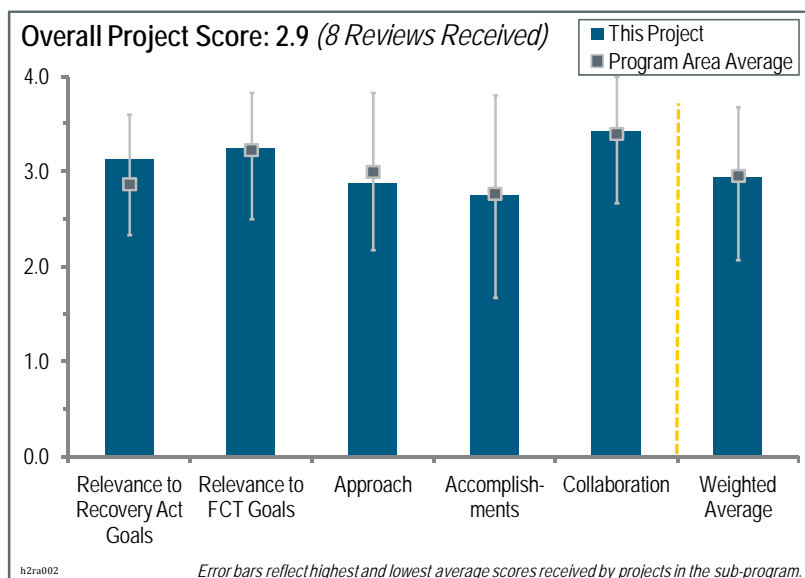
Dan Hennessy; Delphi Automotive

Brief Summary of Project:

The objectives of this project are to: (1) define system specifications and commercial requirements for a solid oxide fuel cell (SOFC) auxiliary power unit (APU) to be used with a diesel engine; (2) design, build, and test the diesel APU system; (3) demonstrate a vehicle using the system for one year; and (4) analyze the data from the demonstration.

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

This project was rated **3.1** for its relevance to overall Recovery Act goals.



- This project can significantly affect the trucking industry and create a new aftermarket manufacturing product.
- The project is relevant and will make contributions to Recovery Act goals.
- This could get fuel cells and some companies into a new market.
- This project states that it will create/retain nine jobs. Because of a no-cost extension, these jobs are being retained longer than the original duration. The project is making relevant contributions to Recovery Act goals.
- Delphi claims a 40%–50% fuel efficiency improvement as compared to conventional diesel APUs. If true, and if life-cycle costs can be held comparable or better than conventional APUs, this should be attractive to tractor trailer owners and provide environmental benefits that would make it attractive outside the United States as well as domestically (which would benefit net U.S. job creation).
- The project’s relevance to Recovery Act goals is fair. This is less of a “shovel-ready” project than a new product engineering effort. On the plus side, the retention of engineering/technical jobs is a worthy thing, particularly through stimulating \$2.4 million of in-house investment. The highly structured, and very professional, approach seems to give it a good chance of creating some manufacturing jobs in the future—if the market accepts the product.
- The commercialization of SOFC APUs for long-haul Class 8 sleeper trucks would add a significant number of jobs because there are many of these vehicles on the road. This is not just a potential small niche product being addressed with Recovery Act funding. Long-haul vehicles are a principal means of moving goods in this country. There are also 30 states with anti-idling legislation that do not allow the drivers to leave their diesel engine on. The Technology Readiness Level of SOFC APUs was and still is too low to expect significant economic activity and job growth in this industry any time soon.
- Delphi went from 18 jobs created/saved in 2011 to nine jobs created/saved in 2012 for this project. With the significant economic potential that was orally described by the presenter (expected cost competitiveness with internal combustion engine [ICE] APUs due to system simplification and newly approved regulations, 2014–2018 National Highway Traffic Safety Administration/U.S. Environmental Protection Agency standards that basically guarantee a market), the number of jobs created/saved is small. The potential is there, but it was not presented or emphasized in the presentation.

Question 1b: Relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's Recovery Act project goals

This project was rated **3.3** for its relevance to the FCT Program's Recovery Act project goals.

- The project is relevant and will make moderate but significant contributions to FCT Program Recovery Act project goals.
- The project has laid out a reasonable execution plan to achieve the stated goals. The project is behind schedule due to desulfurization capabilities limiting the implementation of the product.
- The DOE FCT Program has both Technology Validation and Market Transformation sub-programs, both of which assist emerging markets through demonstration and business case validation. This is a large potential market that could jump start the SOFC industry and provide environmental benefits as well. The risk to industry is still too great to invest solely in this technology—especially given the need to desulfurize the diesel fuel and the lack of data on how a fuel cell APU could stand up to the rigors of real-world road conditions.
- The project is clearly relevant to FCT Program goals and is squarely aimed at commercialization. This is an interesting niche market, and the presenter provided a very clear development and deployment plan. This reviewer believes that truckers and truck manufacturers will accept the unit. Sales could become quite significant as “anti-idling” regulations take full force in the next few years.
- DOE's Recovery Act seed money has induced Delphi to invest beyond its obligation to develop and demonstrate this technology. Without that seed, it was not apparent at what rate (or if) this technology would have been developed. Demonstration testing and follow-on life-cycle cost estimates will provide insight into the timing and market potential of the product and, ultimately, jobs that might be created/saved. It appears, at this point, that Recovery Act funding did accelerate development.
- SOFC APUs have the potential for significant market penetration, far beyond truck APUs; so this project is critical to help advance the technology beyond the research and development stage and into a marketable product that Delphi can sell or license.

Question 2: Development and deployment approach

This project was rated **2.9** for its development and deployment approach.

- The appropriate milestones and schedule were identified, and barriers and risks were addressed. The effort is likely to achieve project goals, but the approach could be improved.
- The project approach is good, but there was no “Plan B” for handling supplier issues and delays. Good project management has contingency plans for this type of issue, such as alternate suppliers or technical paths.
- The timeline laid out for the project is reasonable but has been readjusted due to desulfurization issues that are delaying deployment of the technology.
- The desulfurizer risk probably should have been recognized earlier, but this reviewer liked the solution of removing the desulfurizer and going with reduced performance.
- The project has well-defined milestones; however, it has encountered technical difficulties that have created substantial delays. Current progress appears to follow the updated schedule fairly well. The project has an approach to resolving the current delay due to desulfurization, which provides some confidence that the project will be completed in the second quarter of calendar year 2013.
- Expanding the project to more than one unit for demonstration testing would be desirable because of the risk associated with unit failure, which will delay the project significantly. Two to five units would give better data and provide an average, plus speed up lessons learned if failures of specific components are common or incidental. Barriers and risks were adequately addressed; although, due to the delay, the presenter was not completely clear what the potential new barriers and risks are because it will fall outside the time frame for Recovery Act/DOE input. In addition, this reviewer suggests giving consideration to testing the unit in (hybrid) transit buses, which are at a similar weight class as Class 8. These buses have a 16–20 hour/day operational cycle in large cities; return to the same base at the end of the day; and have significant APU load for inside lighting, air conditioning, heating, etc.
- The approach of building the APU based on PACCAR-generated requirements and testing it at various levels with an ultimate year-long road test demonstrates the seriousness with which Delphi wants to commercialize this technology. The fact that overcoming barriers and risk management are a consideration, coupled with the fact

that this project has had significant delays, shows that perhaps the risk of balance-of-plant component issues—in particular the desulfurization problem—were not managed as well as they could have been. Teaming with PACCAR—one of the top four original equipment manufacturers (OEMs) for Class 8 sleeper trucks—was a great approach that will provide a chance for the truck OEM to understand and witness the performance of a SOFC APU. The fact that it will be a Wal-Mart truck testing this APU gives a major user of long-haul trucks a chance to evaluate the technology. Should the demonstration be successful, Wal-Mart could use its market power to insist on clean APUs for the trucks that carry their products.

- The technical development plan seems well thought out; the reformer-solid oxide approach is now mature enough that a product development effort such as this one should have a high probability of success in the hands of a highly professional organization such as Delphi. However, the significant schedule slippage causes great concern. Better planning might have identified the potential for problems with the desulfurizer and reduced the slippage caused by this and other “balance of plant” problems. Commercial competition with combustor-based APUs is a big concern. These could be less costly (depending on scrubber technology) and probably would have comparable or better fuel efficiency. This reviewer felt that answers to questions on this regard could have been better answered. Perhaps a slide explicitly comparing the total life-cycle costs of both approaches side-by-side could be included next year.

Question 3: Technical accomplishments and progress

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

- Overall progress is acceptable.
- The project has experienced significant delays but appears to be on track to complete the last 12 months. Delays and job creation have been quantified.
- The project made significant progress toward objectives and overcoming some barriers. The issues of desulfurization and start-up need more attention.
- Progress toward achieving the project’s objectives and milestones was clearly demonstrated. It was not completely clear to this reviewer how fuel economy is improved compared to running on a comparable, commercially available ICE solution. Also, the number of jobs projected could have been explained better.
- This project was a good demonstration of 28% efficiency. One reviewer believes this is probably due to operation on low-sulfur diesel, and wants to know how much the efficiency will drop once the desulfurizer is included into the system. This reviewer also wondered, if the functional life of the desulfurizer is only six months, what the expected cost is to replace it.
- Inordinate delays have been experienced. This was supposed to be a 30-month project that would have been completed in February 2011 and include a one-year road test. As of the DOE Hydrogen and Fuel Cells Program Annual Merit Review briefing, the road test had yet to commence. The project has performed well in other areas. Efficiency tests are complete, with 28% efficiency measurements validated. The load cycle test is complete. Operations instructions, service plans, and safety plans are all in place. The problems with mean time between replacement of sulfur absorbent beds should have been noticed earlier, and TDA Research, Inc. should have put a solution in place in a timely manner. Delphi is still committed to seeing the road test through. Delphi is also addressing the desulfurization and start-up issues in their next work plan.
- Impressive technical material was presented, but looking at the milestone chart, the project seems to have encountered considerable delays. It is not clear that simply pulling the desulfurizer out of the system and counting on the reformer to do the job will actually work. Thus, there still seems to be significant technical risk in the project, even at this late date.

Question 4: Collaboration with other institutions

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

- It appears that there is great collaboration and support from the end-user community.
- The project has effective collaboration with other institutions that will enhance the probability of success of the effort.
- Signing PACCAR onto the project was an excellent choice and will prove to be a tremendous asset if the APU actually can be fielded. TDA Research, Inc.’s contribution seems to have been marginal.

- PACCAR and TDA Research, Inc. were identified as partners. Some comments were made regarding Wal-Mart's relationship for demonstration.
- It appears that partners PACCAR, TDA Research, Inc., and Wal-Mart are good choices; all are driven to improve fuel use by Class 8 trucks to be increasingly competitive.
- This project had a key collaboration with PACCAR, one of four Class 8 sleeper truck OEMs with significant market share. Having PACCAR develop requirements to include operator interface ensures the ultimate fuel cell APU product will have fewer customer-related problems as it moves toward commercialization. There is no collaboration with other entities beyond TDA Research, Inc. and PACCAR. This is understandable to a degree in the sense that Delphi wants to be first to market with this technology, but Delphi might have considered more than just one company (Wal-Mart) for testing the SOFC APU.
- The collaboration with PACCAR appears to be strong. Because (according to the slides) PACCAR has only 24% of the market, the principal investigator (PI) should explain the business plan going forward and whether PACCAR has an exclusive right to sell on this or if the other 76% of the market will also be able to buy this APU as an option.

Project strengths:

- A strength of the project is the expertise in the manufacturability of fuel cells.
- This project has good commercial focus and its path to deployment is clear.
- The fuel cell product has market potential and there is a reduction in the number of components. Progress has been made, lessons have been learned, and decisions have been made on a new direction. The timeline appears to match the newly adopted emission regulations timeline.
- A strength is the size of the potential market that this project will address. The cost share from Delphi was significant (\$2.4 million), which shows commitment. The methodical, disciplined approach shows a desire to go through commercialization steps. The team of Delphi, PACCAR, and TDA Research, Inc. covers all the major areas needed.
- The heavy-duty truck and aircraft APUs have been identified as high-potential applications/markets for fuel cells; this project significantly advances developing a product for and testing such potential.
- The SOFC technology is a good area to pursue a real-world market and provide leverage to get the technology pushed forward. The involvement of the user community is also notable.
- There is a clear market that is ready and (should be) willing to accept this product when it is introduced into the market. The project has a clearly laid out plan for bringing this to market.

Project weaknesses:

- The issue with fuel desulfurization is a weakness.
- A weakness was the 1.5-year slippage on a 3-year schedule. Also, there is still no clear solution to the sulfide removal problem.
- The project's weakness is risk management.
- There is a low number of test units and the project is missing job creation projections. Another weakness is the comparable APU ICE unit performance numbers (fuel economy, emissions, etc.) to the SOFC APU.
- Schedule slip continues to be a problem. Managing risk of desulfurization issues with diesel could have been done better, sooner. There are still no road test results more than three years after award of this "30 month" project. DOE needs this data to share with the public, regulators, the U.S. Department of Transportation, and other stakeholders. This could enable even more impactful anti-idling efforts because it would have been demonstrated that clean APUs are available or will soon be available. Everyone benefits from cleaner air—the sooner the better.
- Significant delays (1.5 years) have caused the energy-saving and jobs impact of this potential product to be delayed into the future. The project needs to be working with other suppliers or developers on a desulfurizer because this is such a critical technology. It is unfortunate that at this point the project should have already had 6 months of field experience with the prototype, but instead it is still not yet in the customer's hands.

Specific recommendations:

- Desulfurization created problems, but the environmental problem was not an issue because the total sulfur content was less than 10 ppm.
- Commercial competition with combustor-based APUs is a big concern. These could be less costly (depending on scrubber technology) and probably would have comparable or better fuel efficiency. Perhaps a slide explicitly comparing the total life-cycle costs of both approaches side-by-side could be included next year.
- The PI should acquire real-world test data even if it means compromising on the first system's design and start providing more detail on component failures once testing starts.
- A recommendation is to compare fuel economy and emission improvements when presenting the product. In addition, the PI should consider additional units for demonstration/testing, consider evaluating other markets based on emissions regulations in the United States, and consider additional market applications and the potential to scale up the fuel cell to become the main power source for Class 8 or similar-sized vehicles.
- The team should work to incorporate the APU more fully with the truck electrical and thermal system in the future. There are many integration synergies that are missing due to the "aftermarket" approach currently being pursued. The team should evaluate whether this same system (or a variant of it) could be used on refrigerated trucks, recreational vehicles, emergency field hospitals, etc.

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

Donald Rohr; Plug Power Inc.

Brief Summary of Project:

The objectives of this project are to: (1) substantiate the durability of 5-kW combined heat and power (CHP) fuel cells through system design and modeling; (2) verify the technology and commercial readiness of 5-kW CHP fuel cells through reliable fleet operation; (3) develop engineering models and train graduate students to use them; and (4) create new products, jobs, and markets.

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

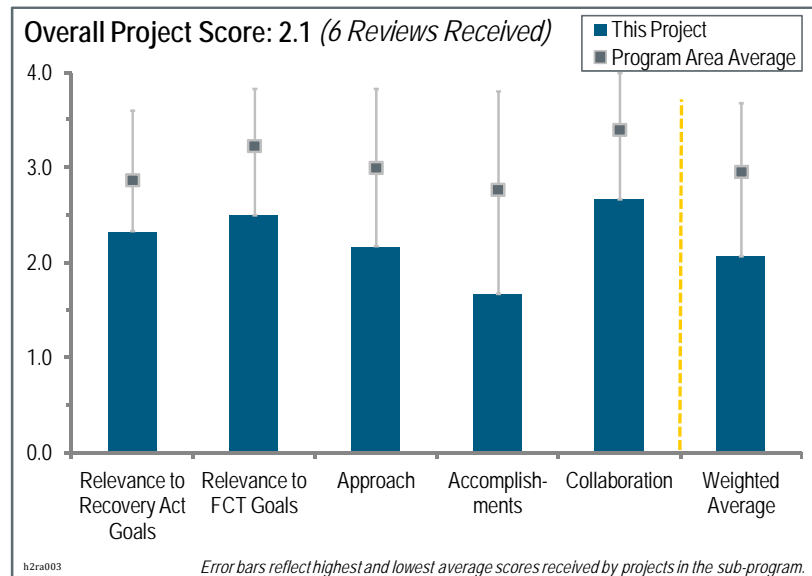
This project was rated **2.3** for its relevance to overall Recovery Act goals.

- On the face of it, CHP is a good application for the technology and there should be a market in the future.
- The project, as originally configured, is relevant to saving and creating jobs.
- The project's basic (original) concept was relevant to the Recovery Act; however, its execution has decreased its likely contribution to Recovery Act goals.
- The project area was discontinued by Plug Power due to its focus on material handling only. An attempt has been made to transfer project learnings to ClearEdge Power, but this has not yet been completed. So, within the short term, it is unlikely to contribute to Recovery Act goals, unless University of California, Irvine (UC-Irvine), has gained enough knowledge to turn this into a researcher job position to support the project. It is good that project-related jobs at Plug Power could be absorbed within the Plug Power organization.
- This project preserved some jobs at Plug Power as it refocused on the material handling (forklift) market. It supported a number of postdoctoral and graduate students at UC-Irvine. It may lead to manufacturing jobs, but the path appears to be arduous.

Question 1b: Relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's Recovery Act project goals

This project was rated **2.5** for its relevance to the FCT Program's Recovery Act project goals.

- This project is directly targeted at manufacturing and deployment.
- This project clearly addresses the goal of accelerating deployment (installation/maintenance/support) of fixed-site fuel cell power units.
- An attempt has been made to transfer lessons learned, but it is unlikely that related intellectual property (IP) will be transferred to ClearEdge Power without negotiation/terms of use. In addition, the membrane electrode assembly (MEA) used in a few units appeared to have short life/durability. Units in operation and lessons learned could help ClearEdge Power (if contracts between parties can successfully be agreed upon) accelerate the learning process.
- While the presentation discussed improvements (efficiency improvements and cost reductions), it did not give the status quo to compare them (e.g., costs decrease from \$90,000 to \$53,000, but what would a



conventional diesel unit would cost in comparison?). One slide compared CO₂ savings to various vehicles, but it was unclear why it compared stationary use to transportation.

- Development issues have reduced the project’s likely contributions to Recovery Act goals. Plans in response to those issues have had limited success in resolving those issues and fulfilling project and FCT Program Recovery Act goals.
- The plan appears good, but it was unclear why the plan did not catch the MEA issues and get control of them earlier. It is also unclear if there was a risk management plan in place.

Question 2: Development and deployment approach

This project was rated **2.2** for its development and deployment approach.

- It does not look like the risks were adequately addressed, but overall the plan was sound.
- The barriers are all related to resolving the MEA issue and funding the process to achieve this.
- The project’s technical and business risks were not adequately identified early in the project, and plans to resolve them have been ad hoc.
- The approach is on balance and well thought out. The issue is transitioning the program to ClearEdge Power. That does not seem to have happened up to now, and it represents a risk. Plug Power should certainly be commended for taking that step of working to transition the program. The question is whether it will reflect a program delay.
- It is not clear how realistic the vision is for replacing conventional electric power and gas-fired heating systems with fuel cell clusters. The project plan—a staged gate approach to managing risk—is a good one, and resulted in a rational decision being made at the third go/no-go point.

Question 3: Technical accomplishments and progress

This project was rated **1.7** for its technical accomplishments and progress.

- Progress is slow due to Plug Power’s lack of business interest.
- Progress has been severely hampered by technical issues (especially with the MEAs), resulting in only one of six deployed units operated in CHP mode. There was no apparent report of jobs.
- Slide 13 discussed that failures dropped from 10%–20% to 1%–2%, but this reviewer did not understand why improvements occurred (in slides or presentation). It appears stack reliability will be the key to CHP success. However, the continued assertion that a fuel cell CHP market is real is difficult to believe at this point, with project results as they are.
- Plug Power’s fuel cell unit design had problems—hence the “no-go” decision on the large-scale deployment in the fourth quarter of 2011. The very “workman-like” job done in installing, monitoring, data logging, analysis, and modeling at the UC-Irvine installation saved this project from being a total loss.
- On one hand, the progress is poor due to MEA issues. On the other hand, there is some good data on the rest of the system. There is a hint of failure analysis in the presentation. It would be good to go further and provide more detail on key component failures. Also, the stack degradation mechanisms were not adequately addressed in the presentation. Mechanical problems, as identified by the presenter, do not seem to explain the chemistry difference between laboratory gas and reformat output.

Question 4: Collaboration with other institutions

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

- The collaboration between Plug Power and BASF, ClearEdge Power, and UC-Irvine appears effective, but it is not conclusive until current negotiations to transfer the project result in an actual contractual transfer.
- The project appears to have a good partner list. It is unclear if the struggles were due to the inability to achieve the goals or if a partner change would lead to success.
- It is a good idea to salvage the program with ClearEdge Power, but it is not yet done, which slows things down.
- Collaboration with UC-Irvine seems to have been excellent, and quite productive. Handing the project to ClearEdge Power may be the right thing to do, but it was unclear how rigorous a selection process was used to

select this company, among all fuel cell makers, to take over. The project has several partners and collaborators with well-defined roles and participation. The project has brought in additional participants (ClearEdge Power) to compensate for deficiencies that have appeared.

Project strengths:

- The project successfully uses the go/no-go decision process.
- This project has a good concept. It has the potential to reduce energy in homes. It includes the involvement of knowledgeable partners.
- This is a good idea for a program; it has a reasonable approach and is originally defined. This was a good concept for salvaging after Plug Power declared its lack of interest.
- Good fundamental modeling work arose out of the collaboration with UC-Irvine. This project has provided useful data on problems using the BASF stacks in the Plug Power design.
- Building systems and testing real hardware to determine real issues is the most difficult bridge to market. This project certainly helps build that bridge.

Project weaknesses:

- The transition status with ClearEdge Power is a risk.
- Plug Power did not “go the distance.”
- Project weaknesses include IP transfer, funding shortage, and Plug Power refocus (including investment commitments).
- It appears that materials qualification, supplier issues, and the project’s inability to identify and resolve technical issues with MEAs have seriously delayed this project. The possibility of other internal design and quality issues exist.
- This project’s weakness is the way it manages risks. Even if there were no membrane and stack issues, it is unclear that there is currently an economic value.
- This was a very difficult project to review due to the recent no-go decision. It is difficult to ascertain if the struggles were due to the failure of MEAs from one company’s product or if the application itself will not work (not enough information was given to make that decision). Some of the comparisons were inappropriate (e.g., comparing stationary to transportation applications) and the information was incomplete (e.g., conventional application information).

Specific recommendations:

- The project team should try to save what can be saved (knowledge) and help ClearEdge Power and BASF learn from it.
- The team should move forward quickly with the transition, or simply terminate the program.
- There is a data set on component reliability that needs to be mined and reported. Also, this needs more market assessment information. It is unclear if this is really a viable market and at what fuel price it would be viable.
- This reviewer wants to believe that this CHP application makes sense, and it appeared last year to be on track. The setback at this point should be reviewed and reconsidered. If it can be argued that a different partner has a different approach or reason to show success where the first failed, then a continuation may make sense. But this continuation would need additional go/no-go milestones and heavy review (this reviewer suggests more than annual) to ensure it is a worthwhile endeavor.
- Turning the project over to another company is a good idea. When ClearEdge Power presents at the next DOE Hydrogen and Fuel Cells Program Annual Merit Review, a good justification should be made, “up-front,” as to why this particular company was the best choice. A cost/benefit analysis justifying the entire model (replacing conventional electric/heating services with local fuel cell installations) should be performed. It would be very instructive to see just how much the market must change before this vision can become a reality.

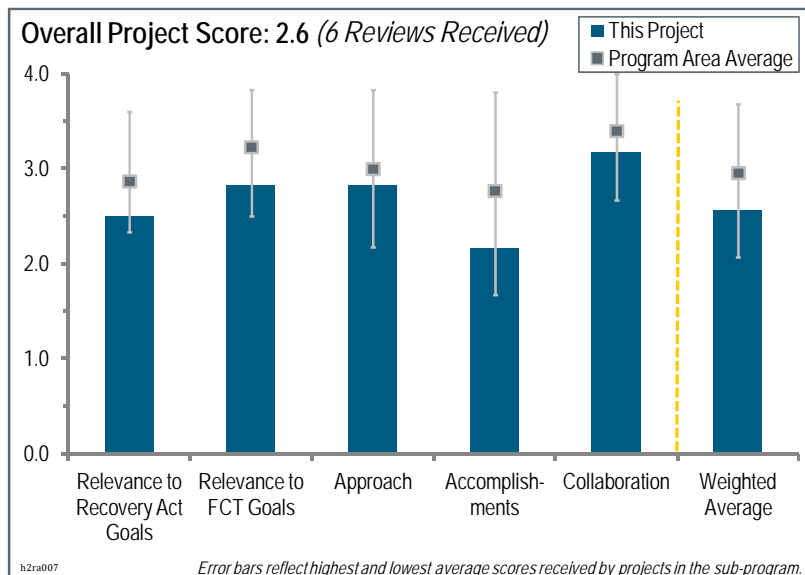
Project # H2RA-007: Accelerating Acceptance of Fuel Cell Backup Power Systems

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 within our 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 liquefied petroleum gas units (GenSys LT) that provide economically viable backup power in excess of 72 hours.

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



This project was rated **2.5** for its relevance to overall Recovery Act goals.

- The program as planned is well aligned with Recovery Act goals.
- This project's impact on jobs is not clear. It is further obfuscated by the subsequent involvement of IdaTech.
- This project is relevant to creating new jobs both within Plug Power and outside through collaborations with the supply base.
- This project preserved some jobs at Plug Power while it got out of the fixed-site business. It provided jobs for local contractors in California and Georgia.
- The original concept of the project supported Recovery Act goals; however, its execution and lack of technical and business risk analysis and mitigation planning have greatly reduced and hampered its contributions.
- The technical success seems doubtful, and relevance relative to employment is weak.

Question 1b: Relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's Recovery Act project goals

This project was rated **2.8** for its relevance to the FCT Program's Recovery Act project goals.

- This project is very relevant and will make substantial contributions to the FCT Program's Recovery Act project goals.
- The program's objectives are well aligned with the FCT Program's Recovery Act goals and objectives.
- Backup power that requires continuous operation does not appear to be a strong value proposition. This reviewer believes that the plan is flawed.
- This project has the potential (if successfully completed) to further the Recovery Act goals of bringing additional fuel cells into the marketplace. This should compete favorably with diesel systems.
- Acceptance of fuel cell backup power at these locations could lead to wider U.S. Department of Defense (DOD) acceptance and increased sales/deployment/jobs in the fuel cell industry.
- The project's original concepts address the FCT Program's Recovery Act project goals to accelerate commercialization and deployment of fuel cell and fuel cell manufacture, installation, maintenance, and support services. Inadequate planning, preparation, and execution have greatly reduced its contribution to the FCT Program's Recovery Act goals.

Question 2: Development and deployment approach

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

- This project has a well-planned approach; however, provisions for “risk mitigation” could have been better.
- The project managed to deploy 20 GenSys LT units that provided economically viable backup power in excess of 72 hours, but the main barrier was cost, partly due to market volume.
- The original approach was well considered, and the transition to IdaTech makes a lot of sense. It is encouraging that IdaTech seems to have picked the program up. Plug Power should be commended for working to find a partner to absorb the work in the program.
- The project’s presentation provided only a list of tasks that give little insight into the appropriateness or existence of technical and deployment schedule and milestones. Technical and commercial risks appear to have been addressed on an ad hoc basis, which has led to delays in systems deployments.
- The project’s definitions of milestones and schedules are adequate. Barriers are understood, but they need to be better defined. It is not clear whether the project is near or far from commercialization.
- It is a good approach to take the best of the two different backup systems (instant on and extended runtime) and put them together into one system.

Question 3: Technical accomplishments and progress

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

- The transition of the program has slowed things down a little bit.
- The rate of technical progress is slow because of software issues, manifold leaks, welding cracks, and other related problems. The approach to overcoming the barriers is in progress, which will help in a better future design.
- This project appears to have been a success, at least in producing very useful information about a real-world deployment. However, many of the fuel cell units seemed to have serious problems in living up to their specifications.
- The project has been delayed in achieving technical objectives by encountering a series of technical issues that have detracted from achieving Recovery Act objectives. The presentation reported the number of systems installed at Warner Robins Air Force Base and Ft. Irwin (none yet), but it provided no insight into jobs created/saved.
- The technical progress appears weak. Mean time between failures is poorly documented and a more quantitative assessment (not just a list) of components’ reliability is needed.
- The net electrical efficiency and availability was disappointing. There appear to be many issues with design and implementation. In retrospect, this project appears to be much more of a development project than a Recovery Act or market transformation project. There appear to be some missing Recovery Act reporting requirements, such as jobs.

Question 4: Collaboration with other institutions

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

- It was a good choice to have IdaTech absorb the program.
- The collaboration with IdaTech as a subcontractor with site supports (Fort Irwin, Warner Robins Air Force Base) is good.
- The relationship with the DOD demonstration sites appears to have been excellent, and the actual installation (e.g., interfacing with contractors) also looks to have been well managed.
- Working with a couple different facilities is good. More than one site and its various issues provide a broader range of user issues to discover.
- Glad to see that IdaTech has been brought in to help save this project, but perhaps other collaborations earlier in the project could have mitigated some of the issues that were discovered along the way.
- In general, this project has made excellent use of its partners and collaborators—especially to overcome planning and technical deficiencies that existed originally and that have appeared during the course of this project. It has

recently introduced IdaTech to provide site support, spare parts, and data analysis capabilities. One past project weakness was placing systems at Ft. Irwin in a bowling alley, but it has recovered, to some extent, by placing them in an engineering building.

Project strengths:

- This project's strength was its fuel cell expertise.
- This project focuses on a valuable market segment of extended-run-time instant-on backup power systems.
- This project's strength was working dutifully to find a way to continue the program despite Plug Power's business shift.
- The project provided a good demonstration of what it takes to install and maintain a fuel cell "farm" for backup power. It displayed well-managed collaboration and contracting. This was very professionally done.
- The project explores one approach to backup power. This reviewer is not sure the approach can be successful, but it is getting hardware out there to provide evaluation.

Project weaknesses:

- The project's weaknesses include software and welding technology.
- The project's weaknesses are its delays associated with the transition to IdaTech.
- This reviewer does not think this approach is going to hit the market needs. The useful data on durability and reliability were not adequately presented.
- This was a rather strange presentation, because Plug Power is getting out of the fixed-site market. It is not clear where this will lead in the future, and whether IdaTech will take over the sites and attendant business leads if the Plug Power units are decommissioned and removed.
- With the company's focus away from this product and toward material handling equipment, it appears they have let this product slide. The project has so far had disappointing results from the first field demonstration. This product does not yet appear ready for the marketplace, and the hydrogen community cannot afford to have a black eye from premature market introduction of any fuel cell technologies.

Specific recommendations:

- The data set on component reliability needs to be mined and reported.
- The final report should contain a business case analysis for fixed sites such as this one. It would also be interesting to have insight into why Plug Power is getting out of this market.
- A recommendation is to use the remaining time and budget of this project to determine if this system makes sense to continue developing. The project should allow IdaTech to use the best aspects of this system for inclusion in their future products and avoid some of the problematic areas. The team should not try to bring this product to market if it is not yet technically mature enough to provide customers a favorable experience.

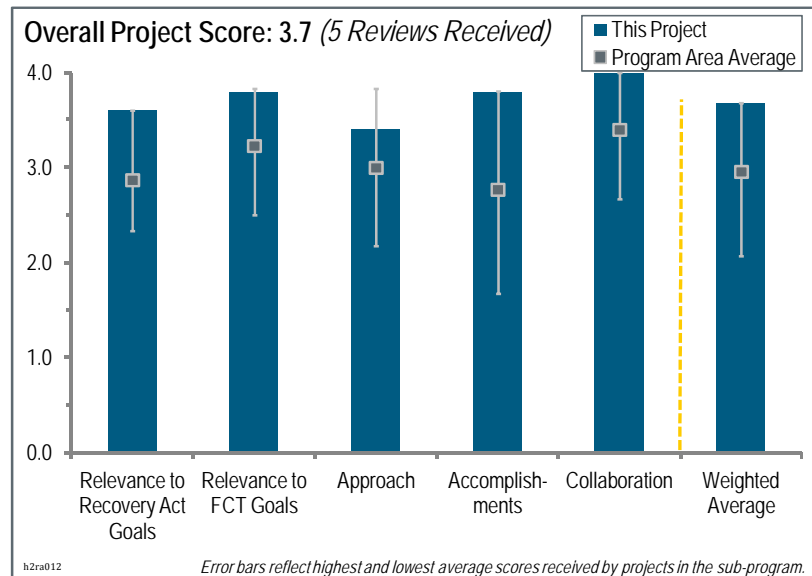
Project # H2RA-012: Use of 72-Hour Hydrogen PEM Fuel Cell Systems to Support Emergency Communications

Kevin Kenny; Sprint

Brief Summary of Project:

The objective of this project is to support job retention and creation by introducing hydrogen fuel cell technologies to new regions in the United States. The project is organized into three phases: (1) Site Survey: identify potential for a fueling station and negotiate with candidates; (2) Pre-Construction: acquire site, permits, approvals, and materials for construction; and (3) Installation/Commissioning/Project Closure: build and begin operation of the station, and collect and report the data.

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



This project was rated **3.6** for its relevance to overall Recovery Act goals.

- This project is an excellent example of the positive impact that Recovery Act projects can have on jobs, economic activity, and building relevant business relationships between companies for the future.
- This project supported building trades and electrical worker jobs in multiple states. Also, it produced employment in a number of collaborators' firms. Success by Sprint-Nextel will lead other cell phone services to follow suit.
- Utilizing a high-visibility customer in Sprint is critical in terms of customer acceptance of this new product and technology.
- Backup power production is an opportunity for fuel cells; cell tower applications are especially attractive. A successful demonstration of fuel cell capability and comparable or lower life-cycle costs in cell phone tower backup power could stimulate further (post-project) sales/deployments and industry expansion, thereby supporting Recovery Act goals.

Question 1b: Relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's Recovery Act project goals

This project was rated **3.8** for its relevance to the FCT Program's Recovery Act project goals.

- This project has done an excellent job of actually getting fuel cells deployed into the field. While it has taken longer than the project team originally anticipated, there has been significant learning about site selection in the process.
- This appears to be an excellent application for fuel cells from a technical and use perspective. The product appears to be able to compete directly with the diesel status quo. It will be interesting to see if the economics make sense as well.
- This project is an excellent correlation with DOE Hydrogen and Fuel Cells Program goals. The large proportion of cost sharing is abundant evidence of the project's role in stimulating commercial deployment.

- This project would be outstanding, except for the fact that several sites have been found to be unsuitable for hydrogen (H₂) due to siting and codes. In this sense, it has helped to inform the relevant stakeholders (fire marshals, safety officials, etc.) of the importance of mitigating this non-technical barrier.
- Unlike some FCT Program Recovery Act projects that have become fuel cell research projects as much as deployment projects, this project has had few technical development issues, so it has focused on practical technical and commercial deployment issues in rolling out cell phone tower fuel cell backup power. This project has encountered and identified many practical issues and some solutions to issues associated with deploying fuel cells in this application. These solutions can provide guidance on implementation and significant risk reduction to others who would consider deploying fuel cells in such applications. This learning and risk reduction can “smooth the path” for others considering similar fuel cell applications and, thereby, accelerate commercialization and deployment in support of the FCT Program’s Recovery Act goals.

Question 2: Development and deployment approach

This project was rated **3.4** for its development and deployment approach.

- This project has an excellent approach (e.g., using desktop review first, then phased site review) to limit risks and narrow the opportunity list to the best site opportunities. The lessons learned appear to be well documented, which will improve the future process (e.g., identifying acceptable sites for footprint, setbacks, and the ability of truck access).
- This project has a very logical approach and is well thought out. The plan could have been slightly improved by paying attention to generic siting problems (e.g., setback, truck access) at the start.
- Other than the overall project time frame, the presentation provided no detailed set of project milestones and schedule. However, the presentation gave an efficient, detailed protocol for identifying appropriate sites and installing fuel cells, which is being pursued vigorously.
- This project has taken a very methodical approach to identifying sites, preparing for installation, and ultimately deploying units. The approach has been modified and improved during the project based on the initial experiences and setbacks.

Question 3: Technical accomplishments and progress

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

- This project appears to be doing very well, making progress and improvements along the way. Most issues appear to be logistical rather than technical.
- This project, despite some unforeseen barriers, still seems to be on track. The diligence, commitment, and professionalism in working around the high attrition rate from the potential site to the Phase II candidate has paid off.
- The progress of this project has been well reported and quantified in terms of the number of sites in different phases of evaluation and installation. Specific numbers of jobs by job types were also presented.
- This project has deployed a large number of fuel cell units and employed many local tradesmen in the process, as well as jobs at both Alteryg and ReliOn, which manufactured the fuel cell systems.

Question 4: Collaboration with other institutions

This project was rated **4.0** for its collaboration.

- The project features a group of top-notch collaborators, and it is well coordinated.
- This project has a diverse group of stakeholders and partners. Lessons learned should be shared widely to support greater competition and other stakeholders into the application.
- This project includes more than a dozen partners and collaborators whose responsibilities appear to be well defined and coordinated.
- The connection with the fuel cell suppliers appears to be very strong. The collaboration with Air Products has developed a new rapid on-site refueling system that is very valuable for the H₂ community to have.

Project strengths:

- This project has brought H₂ and backup power fuel cells into important new jurisdictions.
- This project has strong private industry support (cost share, commitment) and a business approach to success (go/no-go). It also has a strong process to limit unnecessary risks and weed out inappropriate sites early. Lessons learned appear to have been well used in this project, and should be useful in follow-on projects of same nature.
- This project represents a significant effort by a major “customer” for H₂ power. It has uncovered, and solved, several real-world problems that can be encountered in the large-scale deployment of fuel cells. The final report for this project, particularly the “lessons learned,” will be extremely useful to others. The fuel-cell-powered transmitters that are being installed will be an enduring legacy of this project.
- This project has successfully deployed a large number of fuel cell systems. It has developed good relationships with fuel cell suppliers as well as a key H₂ supplier. This project has provided a shining example of operating fuel cells in the field for future executives to examine when evaluating whether fuel cells will actually work when placed in the field.

Project weaknesses:

- No obvious weaknesses were identified from this project.
- It would be interesting to see additional partners (or similar projects using different technology partners) to focus on more cost reductions and competitiveness, as well as additional approaches to implementation.

Specific recommendations:

- The project team should keep up the good work.
- It was a good idea to explore reformer-based technologies for sites that would be difficult for H₂-based systems.
- This was a very good project that should be followed through. It is unclear if the economics will make sense (although it appears the technology does), which could result in follow-on projects open to additional competitive partners to encourage cost reductions, new approaches, and/or other improvements to a good project. The project team should complete and “advertise” benefits and opportunities.
- It would be good to document the learning obtained from the site selection (using Google Earth, etc.) to enable more rapid deployment by other H₂ developers and demonstrators in the future. The reviewer questioned if this could be produced as a fact sheet that is posted online and given out by DOE at future conferences. Another recommendation is to continue to operate these systems as long as possible to provide a rich data set to document the technical status and progress of the technology.

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

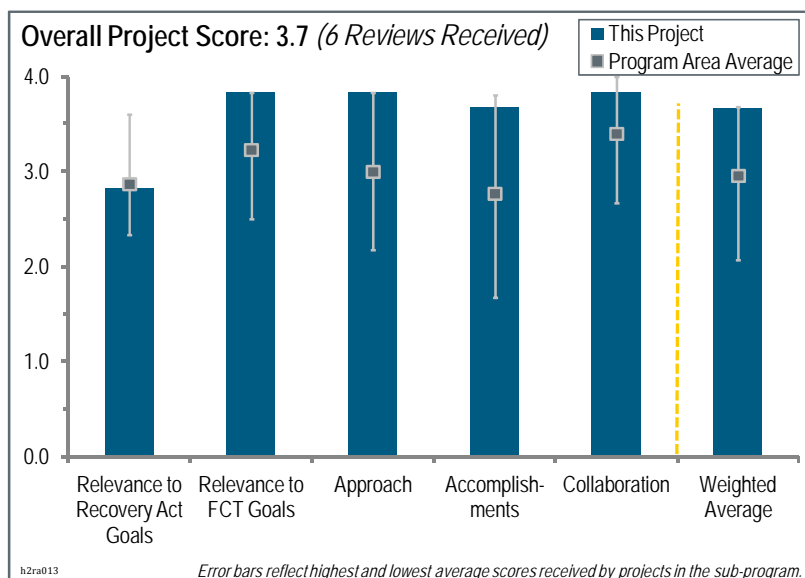
Jennifer Kurtz; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) assess the technology status of fuel cells in real-world operations, (2) establish performance baselines, (3) report on fuel cell and hydrogen (H₂) technology, and (4) support market growth by evaluating performance relevant to the markets' value proposition.

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

This project was rated **2.8** for its relevance to overall Recovery Act goals.



- This project is good—more detail is needed on the safety aspects.
- There was no reference to job creation based on data collection or resulting economical impact from data collection. Under the definition of the Recovery Act goals, there was a very limited explanation about how this project meets these goals, although reviewers can guess that it does have an impact because there were a number of people involved performing the data collection and analysis.
- Even though the project assessed the technology status in real-world operations, there was no indication of creating new jobs or saving existing ones.
- It is not clear how this contributed to the rapid generation of new jobs—other than paying the folks who worked on the project. It may contribute to the long-term goal of creating a true H₂ power industry, which will eventually create jobs.
- This project documented the value proposition for material handling equipment (MHE) fuel cells on a cost-of-ownership basis. This has been a substantial benefit in validating the value proposition for MHE. The data helped improve the performance, quality, and reliability of MHE and backup power fuel cells. Codes and standards support greatly assisted the penetration into niche early markets.

Question 1b: Relevance to the U.S. Department of Energy (DOE) Fuel Cell Technologies (FCT) Program's Recovery Act project goals

This project was rated **3.8** for its relevance to the FCT Program's Recovery Act project goals.

- This is a great way to compile the data and not just rely on each company to “market” its product.
- This is one of the most important and successful projects within the DOE Hydrogen and Fuel Cells Program (the Program) Annual Merit Review (AMR), because it supports all of the fuel cell activities by providing a neutral assessment and evaluation and a readily digestible review of the various projects. It helps not only to understand what is happening within the projects, it allows for comparisons and contrasts in various applications so that each can learn from the others.
- The subsequent boost in commercial sales for MHE and backup power fuel cells, without DOE investment, validates the relevance of the plan to the fuel cell industry.
- This project is relevant, but it is not overly clear how this data will be used besides that the project is an independent technology assessment.

- This project addresses the technology development plan of the FCT Program's Recovery Act project goals of accelerating the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services.
- This type of data collection and analysis is indeed relevant to the mission of the Program at DOE and will be useful to a number of groups that study market readiness and maturity of fuel cell products. Given the overlap of graphic material between this and some of the other National Renewable Energy Laboratory (NREL) presentations at the AMR, however, there is some question as to what, exactly, this contributed to the whole effort.

Question 2: Development and deployment approach

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

- The presentation of data is very good. More data can be extracted to guide suppliers' feedback on how to optimize operation to maximize operating life.
- This project was an excellent addition to the "Hydrogen Safety Panel Final Report" (compared to the 2011 AMR project presentation). This will certainly increase the value of the assessment, especially during the adoption phase of the evaluated technology.
- This project always has clearly defined milestones, presents complex information and analysis in an easily digestible manner, and highlights significant challenges or successes. This works for multiple applications and areas using similar templates to increase familiarity.
- The development and deployment approach are impressive, as evidenced by the deployment of 1,111 fuel cell units throughout the United States by the end of 2011. Systems are operating reliably in 15 states with 99.7% successful starts. The unsuccessful starts included an emergency stop signal and system failures.
- This project has a very good approach—expanding tools developed for fuel cell electric vehicle market analysis was the right thing to do. However, there was a lot of commonality between the slides in this presentation and some others from NREL. This made it a little difficult to understand precisely how much was contributed by this specifically funded effort and how much was already in place from other projects.

Question 3: Technical accomplishments and progress

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

- This project appears to have met all the timelines and milestones and does a very good job of identifying obstacles and progress/success.
- The Hydrogen Secure Database has gained the kind of acceptance needed to make this a very useful study. Continuing to collect and publish this kind of data is a very important way to help foster the acceptance of H₂ power.
- This is a great package so far, but this reviewer hopes to see more detail that leads to insight and customer comfort (and that cost and safety are clearly understood).
- The approach to establish capabilities under other technology validation activities (NREL Fleet Analysis Toolkit) and industry collaborations are helpful, as is the concise reporting of large data sets from multiple project partners. There is good progress compared to last year, but data and information need to be pushed out to industries more. As mentioned before, companies and entities might find this useful, but they do not know that it exists or that it could be relevant.
- It appears that 2011 presented projected 2012 "units in operation" but did not have sufficient information about the number of "backup power" units for 2012, which made the total number of projected units slightly off compared with 2012 operational units (in a positive way). Also, because no more Recovery Act funding is used to support 2012 fuel cells (MHE and backup power units), the 2012 projection was not necessary (a mention of the numbers of units purchased by private industry beyond Recovery-Act-funded units suggests a positive effect of the data collection and may strengthen the final NREL report). The number of operational hours/kg for backup power systems (slide 10) has increased significantly (from 6.6 hours/kg in 2011 to 8.4 hours/kg in 2012). It may be worth mentioning or giving an explanation as to why this is the case. Continuous run time for fuel cell backup systems (slide 11) would have been good to see, and compared with previous years. On slide 13, the numbers of MHE units in operation do not add up correctly based on the numbers provided per class; it may also be worth

mentioning the total average operational time per day. This reviewer questioned if NREL looked at the correlation between the number of hours of operation per day and degradation (including the number of start/stops of the fuel cell). This could be a good metric to share with industry regarding preferred operational mode to extend the durability of the fuel cell unit. It would also be useful to see comparable averages for battery MHEs from industry (fuel cell MHE safety report, slides 18–19). This reviewer would also like to know if the fact that H₂ compressors have a significant share of total H₂ leaks has been shared with others in industry.

Question 4: Collaboration with other institutions

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

- Collaboration activities, including site visits, are impressive.
- There are high-quality partners on all of the MHE and backup power projects and partners that put in substantial resources, both financial and human, into the projects.
- It looks like the project has good collaboration from all parties. This reviewer suggests providing a slide overview on how the project team obtains good collaboration and data.
- This project is a little different from other projects in regard to collaboration (i.e., it appears that the project team ends up working with most of the various partners in other projects to conduct analysis and products). There is less direct understanding of how and when they interact, but it appears to be succeeding.
- This project has excellent coordination with other contractors and other parts of DOE. There is widespread acknowledgement of NREL, and of this group specifically, as the “place to go” to obtain data and to report successes (and maybe more importantly, problems); this project demonstrates the outstanding and successful effort to collaborate with customers, too.

Project strengths:

- This project displays good collaboration activities.
- This project shows impressive work, considering that it was funded with \$0.00.
- The MHE and backup power projects were well executed with high-quality partners.
- This is a great way to put all the data together and get information back to the industry and potential customers. It needs to continue even when the Recovery Act projects wind down.
- This project produces a lot of valuable data and includes a wide variety of partners and application sites. The secure data center adds value for both partners and strengthens NREL’s position globally.
- This research takes complex projects, conducts detailed analysis, and produces easily digestible products. It is by far one of the most exciting things within the Program, as it allows stakeholders, industry, and the public to understand what is happening across various projects. This work successfully protects private and confidential information, yet it provides significant value to industry. It highlights where future focus and challenges need to be addressed as well as progress and success.

Project weaknesses:

- This work could be used in more applications as a template for review in other areas.
- This project’s weakness is its lack of comparable data for the incumbent technologies.
- The project’s weakness is its future funding. The project could add more safety panel site visits to strengthen the Safety Report.
- This project includes a lot of data, both raw and “reduced,” but it would be useful to see a bit more in the way of analysis. This reviewer would like to know what this means for the future and the competitiveness of H₂ power.
- Another reviewer would like to know where all these data are reported, so people can use the data as a reference in planning and developing new products and markets.

Specific recommendations:

- Keep this work going!
- This project really needs a cost-of-ownership analysis for backup power.

- Continue this work and look into expanding this type of review, analysis, and summarization products to other industries and areas.
- The project did not address the Recovery Act goals related to job creation or saving existing ones.
- NREL should consider developing a measurement tool to show the benefit of their data collection work and analysis to industry and on job creation. DOE should continue the data collection for the benefit of industry and build on Recovery Act project data. The reviewer suggests collecting data on internal combustion engine and battery applications, both for backup power and MHE.
- A relative risk assessment delineating the safety of H₂-powered versus battery-powered forklifts would be very useful. This should also be put into perspective by comparing it to the relative risk of all power-related incidents with risks (e.g., “crashes” or load collapse).