2011 — Market Transformation
Summary of Annual Merit Review of the Market Transformation Sub-Program

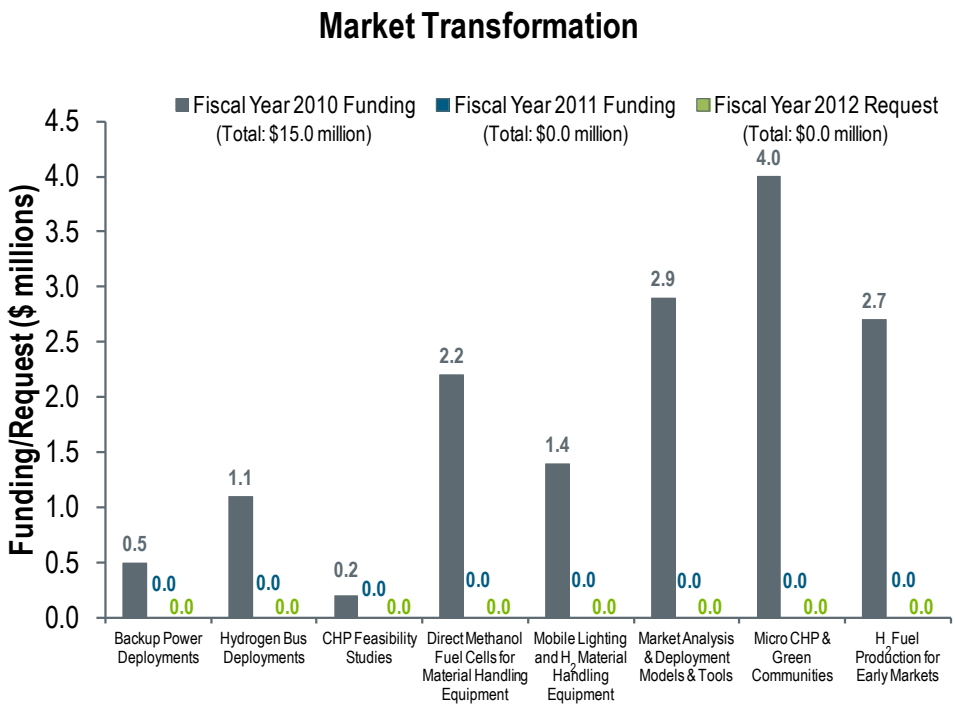
Summary of Reviewer Comments on the Market Transformation Sub-Program:

The purpose of the Market Transformation sub-program is to continue to spur market growth for domestically produced hydrogen and fuel cell systems. By supporting increased sales in key early markets, this sub-program aims to help identify and overcome non-technical barriers to commercial deployment and to reduce the life-cycle costs of fuel cell power by helping to achieve economies of scale. The current focus of Market Transformation is to build on past successes in lift truck and emergency backup power applications (part of the U.S. Department of Energy's [DOE] Recovery Act efforts) by exploring the market viability of other potential and emerging applications. In keeping with this focus, a diverse set of 10 projects were started and reviewed this year. These projects are highly leveraged, with more than half of the funds provided by DOE's partners. This substantial commitment of external resources shows the high level of interest in exploring applications and markets where the hydrogen and fuel cell industry can expand and where the technologies can play a valuable role.

This is the first year that Market Transformation projects have been reviewed at the Annual Merit Review. Generally, reviewer comments on the sub-program were positive, and its activities were considered to be important for enabling the commercialization of hydrogen and fuel cells. Reviewers considered the sub-program to be well-managed, well-organized, and focused on addressing promising applications. Several reviewers noted the extensive collaboration involved in the projects and the substantial leveraging of federal funds through cost-sharing. However, a number of reviewers felt that the Program lacks an overall market transformation strategy and that the current projects do not seem to be part of an integrated plan. Reviewers noted that the next update of the Office of Energy Efficiency and Renewable Energy (EERE), Fuel Cell Technologies Program's *Multi-Year Research, Development, and Demonstration Plan* will provide an opportunity to clarify priorities and sub-program metrics.

Summary of Market Transformation Funding:

With the market successes that have been achieved by fuel cells in lift trucks and backup power applications as a result of fiscal year (FY) 2009 and Recovery Act funding, the focus of FY 2010 funds was on new applications, such as micro combined heat and power (CHP) and mobile lighting applications. A chart showing sub-program funding for FY 2010, 2011, and 2012 (requested) is included on the next page.



Majority of Reviewer Comments and Recommendations:

Market Transformation projects were rated average to high, with seven individual projects rated 3.0 or higher. Overall ratings ranged from 2.7 to 3.6, with an average score of 3.1. All projects were judged to be relevant to the Program's activities, with good or adequate technical approaches used. Reviewers recommended that future data collected and analyzed from all deployment activities be used to develop business case reports that can be used to support further market expansion. These projects were fully funded, and many of them have one-year durations; therefore, some of these projects are complete.

Transportation and other Mobile Applications (Hydrogen Buses, Direct Methanol Fuel Cells for Material Handling Equipment, Hydrogen Production for Early Markets, and Mobile Lighting): Four projects in this area were reviewed, with an average score of 3.2. In general, the reviewers were complimentary of the work being performed and with the progress being made. The combined use of fuel cells along with other energy-efficiency technologies being developed by EERE was lauded by reviewers. While reviewers were encouraged by the relatively low cost to DOE and the high partner cost shares, they noted that the lack of economic data on several of the projects needs to be addressed immediately in order to achieve an effective comparison of fuel cells with other technologies.

Stationary Applications (Backup Power, Micro CHP, and Green Communities): Three projects were reviewed, with an average score of 3.1. Reviewers commented that all three projects were relevant and could help build significant markets for hydrogen and fuel cells in the near term. They also observed that these projects could serve as good guidelines for future efforts. However, concern was expressed that the execution of these projects could be improved, including by staying on schedule and providing more detailed status information.

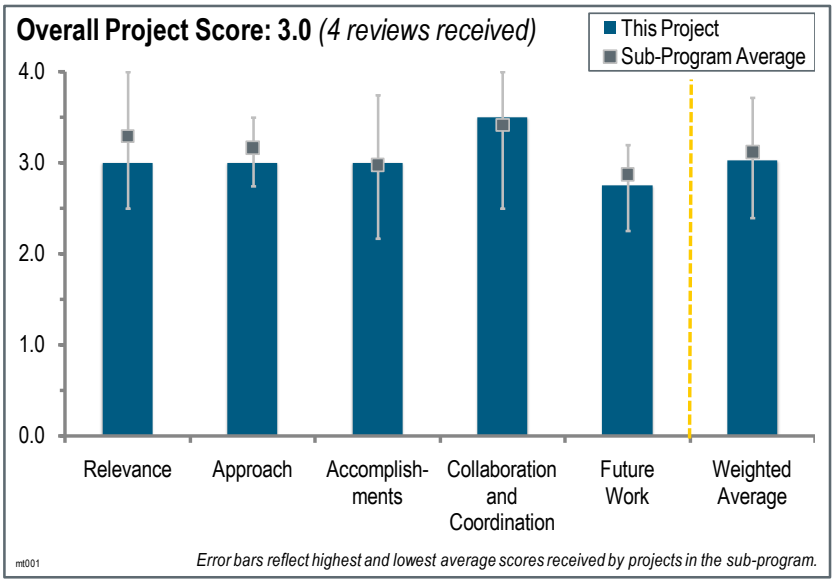
Studies (CHP Feasibility, Market Analysis, and Deployment Models & Tools): Three projects were reviewed, with an average score of 3.1. Generally, reviewers' comments were positive, with several noting that the use of models to analyze new applications provides valuable results, which help to make application-specific deployment decisions. However, some reviewers felt that there is a need for more transparency in the models, including concise descriptions of the assumptions and factors used.

Project # MT-001: Assessment of Solid Oxide Fuel Cell Power System for Greener Commercial Aircraft

Larry Chick; Pacific Northwest National Laboratory

Brief Summary of Project:

The project objectives are to: (1) assess approaches to provide electrical power from solid oxide fuel cells (SOFCs) on board commercial aircraft; (2) focus on more-electric airplanes, with the Boeing 787 as a case study for comparison; (3) assess optimum sizing, location, and configuration of the SOFC power system; and (4) identify and quantify barriers to deployment of fuel cell power systems on commercial aircraft.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.0** for its relevance to U.S. Department of Energy (DOE) objectives.

- The project explores the use of SOFCs on aircraft and is consistent with the DOE objectives of fuel cell deployment.
- The total fuel savings for aircraft fleets would be a helpful number to support the DOE Hydrogen and Fuel Cells Program.
- One of the key strengths of fuel cells is that they can be applied to a very diverse range of applications. While this feature also causes complexities, it is worthwhile to explore all potential applications to see where benefits are and what market shares can be gained. Thus, an investigation into the use of fuel cells for aircraft is a worthwhile study.
- Aircrafts use lots of petroleum. A DOE Office of Energy Efficiency and Renewable Energy (EERE) strategic goal addressed by the Fuel Cell Technologies Program is to "dramatically reduce dependence on foreign oil" (from the *Multi-Year Research, Development, and Demonstration Plan*). While auxiliary power for aircraft is among the applications addressed in the draft *DOE Hydrogen and Fuel Cells Program Plan*, generating aircraft electric power accounts for a small portion of fuel use. Based in part on the results of this project, it seems that little petroleum reduction can potentially be achieved by SOFC auxiliary power units (APUs) for aircraft. This seems to be more of an analysis project than a market transformation project. It is providing information that can help determine whether aircraft APUs should be a target of opportunity for the Program.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- Pacific Northwest National Laboratory (PNNL) worked with Boeing to develop an understanding of the aircraft power needs and looked at methods for power saving. The project developed a system model to estimate the efficiency and weight of the fuel cell system.
- This project follows an effective approach of first understanding the current aircraft structure, developing models for analysis, and then testing via demonstrations. Industry input should be a key component in all of these steps.
- The approach to this relatively small project seems logical. PNNL's modeling expertise is applied to assess alternative SOFC system configurations. The "optimum" fuel cell system is then compared to the baseline

aircraft electrical system to determine benefits. The use of fuel cell waste heat for aircraft heating requirements was not addressed in the presentation. The reviewer wonders if there is a potential contribution from the selected fuel cell power system. The reviewer also wonders if all the heat from the SOFC stack exhaust is used for the fuel reformer. The decision to include a desulfurizer in the analysis was not made until after the initial assessment. It would have been better to take this into account earlier in the process, rather than starting with an assumption that low sulfur fuel will be available at airports. When given an opportunity, the presenter did not provide evidence to support the assumption about the availability of low sulfur fuel at airports. While it is expected that fuel cells for aircraft auxiliary power generation are not cost-competitive, some cursory analysis of, or statements about, the cost differential between the baseline electric power system and the SOFC system would result in a more complete project.

- This is a good analytical study, but it does not identify some key barriers as promised, including the impact of frequent airplane start/stop cycles on SOFCs, as well as the impact of vibration on lifetime.

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

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

- The project has identified a power generation strategy that could save approximately 100 kilowatts. The weight estimate indicates that the fuel cell system is feasible.
- The information generated with a limited budget is fairly impressive. If the objective of the project is to better understand the merits of fuel cell APUs for aircraft, this is being accomplished. Analysis results in a conclusion that the overall weight of fuel and electrical systems could be reduced, given the right operating conditions. However, there does not seem to be much of a difference in parameters of interest, e.g., fuel requirements and total weight, between the baseline design and the fuel cell scenario. No clear statement was made about projected changes in fuel consumption and greenhouse gas emissions for the fuel cell option, compared to the baseline aircraft design. Such a statement needs to be in the final report.
- This project features good first strike analysis, but it does not identify barriers.

Question 4: Collaboration and coordination with other institutions

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

- The partnership with Boeing is a very positive step, providing a two-way learning process of needs and capabilities. The project team is continuing discussions with other relevant organizations.
- Collaboration with a major aircraft carrier helps obtain real-world data, insights, and feedback on assumptions.
- This project features good cooperation with Boeing.
- The collaboration with and inputs from Boeing and other members of the Aviation Working Group are key to the project's success. PNNL should seek and acquire feedback from members of the Aviation Working Group, particularly Boeing and Airbus, on the draft final project report. That feedback should be included in the final report.

Question 5: Proposed future work

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

- It is good that considerations are being expanded to include more factors, such as onboard desulfurization, alternatives to providing peaking power, and use of water from fuel cells. Investing in as many factors and applications or benefits as possible allows for a better understanding and possibly better value propositions.
- The desulfurization system is very important—both in terms of weight and the effectiveness of the removal strategy. Continuing to refine the weight estimates is good. Experimental determination of the effect of pressure on SOFC performance should be deferred to other studies.
- Specific project tasks to be accomplished prior to September 30 are well defined, and their successful completion will enhance the final project content and value. On slide 11, there is no indication that near-term demonstration projects will be identified. This is an activity included in slide 5. There are no recommendations regarding appropriate project follow-on work. Given the current state of SOFC technology and the results of this analysis,

the merit of using scarce resources to fund additional work on aircraft SOFC APUs is questionable, at least in the near term.
- The project team needs to identify real technical barriers.

Project strengths:

- The collaboration, information exchange, and exploration of possibilities with the commercial aircraft industry are very useful. The system has been designed for high thermal integration and high-pressure operation. High anode gas recycle eliminates the need for a steam-reformer burner. The weight estimates are a good starting point. The project team identified a power savings strategy.
- The project objective is to improve understanding about the implications of using SOFCs for aircraft electric power generation. A logical approach was developed and implemented for planning and conducting the project's analysis. Collaboration with Boeing and other members of the Aviation Working Group is a key strength of the project.
- This project features a very good first strike analysis that shows the idea is feasible from a weight standpoint.
- This project has an effective approach and good collaboration with a major industry partner.

Project weaknesses:

- Thermal integration may increase efficiency, but it adds to the complexity, cost, and weight. It is surprising how the weight is still within feasible range, perhaps because of the high efficiency numbers, which may be difficult to realize. The polarization curve is probably too optimistic. A high-temperature, high-pressure system makes it more challenging to implement. If the system's success hinges on high-pressure operation of the SOFC, which most developers have steered clear of, the prospects of getting such a system becomes weak. High anode gas recycle will reduce the power densities of the stack. It would be good to see a more quantitative breakdown of the heat loads of the various components in the fuel cell system.
- The project has a relatively small target of opportunity in terms of potential for petroleum use and greenhouse gas reduction. (This is not a project weakness, but more of a weakness in the case for devoting scarce government resources to this particular fuel cell application.) Creating a ballpark cost estimate for an aircraft SOFC APU option (relative to the baseline) was evidently not considered. This could be an important factor in determining the merits and content of any follow-on activity, such as a demonstration project.
- The project team needs to identify real technical barriers.
- The project is currently based on major assumptions, such as the availability of low-sulfur fuel.
- Assumptions should be widened more and sensitivities should be investigated.

Recommendations for additions/deletions to project scope:

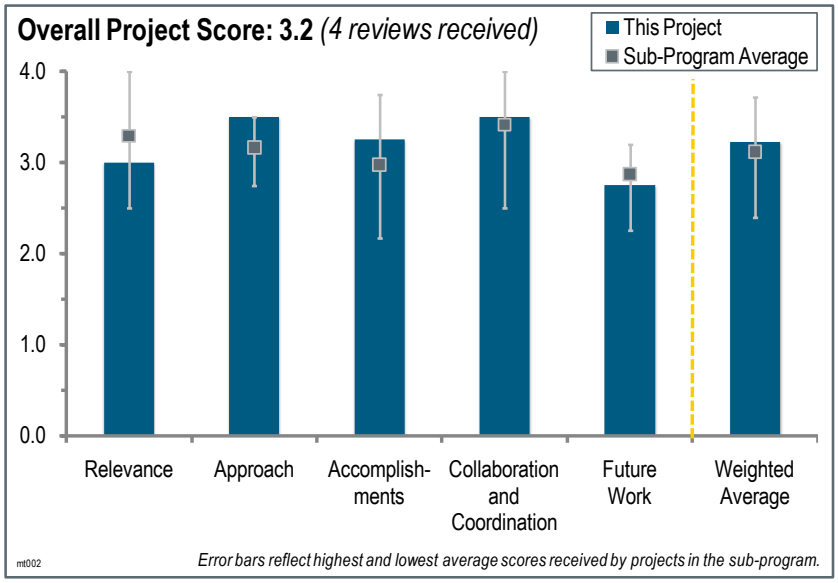
- Recommendations include providing more quantitative data on the fuel cell system and evaluating system feasibility for low-pressure operation. The reviewer questions the feasibility of a traditional APU based on ambient pressure without the compressor-expander. The project team should defer experimental studies on pressurized operation of SOFCs to other (separate) projects.
- A project such as this one, using limited resources to assess the potential merits of fuel cells, is justified. Given what has been learned from this project, there is no need for follow-ons or additions (such as demonstrations) at this time. With further advancement in SOFC technology, resulting from research and development (R&D) and experience with other applications, perhaps funding an aircraft demonstration project can be considered after fiscal year 2013. Such a demonstration should be preceded by a life-cycle cost/value proposition analysis. DOE should continue to support R&D of technologies that can result in more electric aircrafts and significant reductions in aircraft petroleum use. Fuel cells and renewable biomass are important technologies of interest.
- The project team should understand thermal cycles and vibrations and their impacts, as well as fuel variability from airport to airport around the world.
- Estimates were done using state-of-the-art SOFC systems, but it might be worthwhile to look at estimates using future projected characteristics of SOFCs to see the magnitude of difference and technology development needs. Future analyses could also look at project findings more in context of surrounding conditions, such as the airport environment, available fuel type, infrastructure needs, and synergies with other applications.

Project # MT-002: PEM Fuel Cell Systems for Commercial Airplane Systems Power

Lennie Klebanoff; Sandia National Laboratories

Brief Summary of Project:

The U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy is broadening the application scope of its Fuel Cell Technologies (FCT) Program to include commercial aircraft and airport ground support equipment. This project assesses: (1) the feasibility of using polymer electrolyte membrane (PEM) fuel cell systems on commercial airplanes and (2) the impact of such a system on other airplane systems and overall flight performance.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.0** for its relevance to DOE objectives.

- One of the key strengths of fuel cells is that they can be applied to a very diverse range of applications. While this feature also causes complexities, it is worthwhile to explore all potential applications to see where benefits are and what market shares can be gained. Thus, an investigation into the use of fuel cells for aircraft is a worthwhile study.
- It is important to have air transport included in the DOE Hydrogen and Fuel Cells Program.
- Aircrafts use lots of petroleum. A strategic goal of the FCT Program is to "dramatically reduce dependence on foreign oil" (from the *Multi-Year Research, Development, and Demonstration Plan*). While auxiliary power for aircraft is among the applications in the draft *DOE Hydrogen and Fuel Cells Program Plan*, generating aircraft electric power accounts for a small portion of fuel use. Based in part on the results of this project, it seems that little petroleum reduction can potentially be achieved by PEM fuel cell auxiliary power units (APUs) for aircraft. This seems to be more of an analysis project than a market transformation project. It provides information that can help determine whether aircraft APUs should be a target of opportunity for the Program.
- If critical airplane systems such as air conditioning are not included (and this reviewer understands why they are not), then one needs to ask whether this application should even be investigated at this time. Once the Federal Transit Administration and airline operators are convinced that fuel cells are fully reliable, then this could be a promising application. However, if fuel cells are limited to non-critical functions such as in-flight entertainment and in-flight cooking, then one has to question the point of investigating this application at this time.

Question 2: Approach to performing the work

This project was rated **3.5** for its approach.

- The investigators looked at several configurations and seemed to leave "no stones unturned."
- The approach to planning and executing this relatively small project seems logical, and the modeling approach seems sophisticated. The PEM fuel cell system was compared to the baseline aircraft electrical system to determine benefits. Scenarios and system designs involving use of fuel cell waste heat were extensively assessed. Mass contributions for PEM fuel cell scenarios were calculated using both current and projected (DOE target) fuel cell characteristics. While it is expected that fuel cells for aircraft auxiliary power generation are not cost-

competitive, some cursory analysis of, or statements about, the cost differential between the baseline electric power system and the PEM fuel cell system would result in a more complete project.
- The approach could be more integrated regarding hydrogen storage and the use of the by-products' water, nitrogen, and heat. Ground operation at airports was not mentioned.
- The project team based its evaluations on commercially available components, but it might have also been worthwhile to look at estimates based on projected future technology improvements to see what magnitude of effects there might be.

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

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

- The information generated with a limited budget is impressive. Sandia National Laboratories' (SNL's) modeling expertise was applied well to assess the merits of PEM fuel cells. The objective of the project—to better understand the implications of fuel cell APUs for aircraft—was achieved. Simulation results were clearly displayed and presented. The charts provided lots of data (including the technical backup slides). The data support a useful conclusion—use of a fuel cell for the applications addressed will not make much difference in aircraft fuel use. It would have been helpful to quantify the petroleum use impacts and greenhouse gas (GHG) reductions for the current fuel cell technology case, not just the DOE target case for fuel cells and hydrogen.
- The presentation of the results, which were certainly good, could be clearer and easier to understand.
- In many ways, this project seems to indicate that this application should not be considered until critical in-flight power can be included. The 30% electricity reduction hardly seems worth the logistics of delivering and storing hydrogen fuel for each flight.

Question 4: Collaboration and coordination with other institutions

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

- It is good that the project is collaborating with both aircraft and hydrogen providers.
- The collaboration with and inputs from Boeing and Hydrogenics were key to the project's success. Because the project is completed, there is presumably no opportunity for more collaboration at this stage. It would have been good for SNL to seek and acquire feedback from members of the Aviation Working Group, particularly Boeing and Airbus, on the draft final project report.

Question 5: Proposed future work

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

- No future work is proposed, which is fine. This project was successful, and led to a conclusion that further advancement in fuel cell technology is needed before conducting follow-on work related to the aircraft APU application.
- The project is complete, but there could be some valuable follow-on studies.
- It is not clear that the findings of this project warrant continued developmental work for this application.

Project strengths:

- One strength was the project's objective to improve understanding about the implications of using PEM fuel cells for aircraft electric power generation. The project team took a logical approach to the analysis, based on specific non-critical electrical loads and scenarios for use of waste heat. The outstanding modeling capability of the SNL team provided extensive results for the funds provided. The results were clearly communicated, and the collaboration with Boeing and Hydrogenics was positive.
- The extension of a PEM fuel cell application to aircraft and multiple scenarios for system integration were strengths of this project.
- This project featured excellent analytical work.

- The partnerships with major aircraft and hydrogen providers and the investigation into the use of waste heat from fuel cells were strengths of this project.

Project weaknesses:

- This project had a relatively small target of opportunity in terms of potential for petroleum use and GHG reduction. (This is not a project weakness, but rather a weakness in the case for devoting scarce government resources to this particular fuel cell application.) Creating a ballpark cost estimate for an aircraft PEM fuel cell APU option (relative to the baseline) was evidently not considered. This could be an important factor in determining the merits and content of any follow-on activity, such as a demonstration project.
- There may be more aspects in the use of fuel cells on an aircraft (e.g., use of by-products, ground operation, or regulation at airports).
- This is a questionable application for a fuel cell given the constraints placed upon how the electricity could be used for in-flight power needs.
- It would have been worthwhile to also explore PEM fuel cells for APU use, as well as potential synergies with ground support applications at the airport.

Recommendations for additions/deletions to project scope:

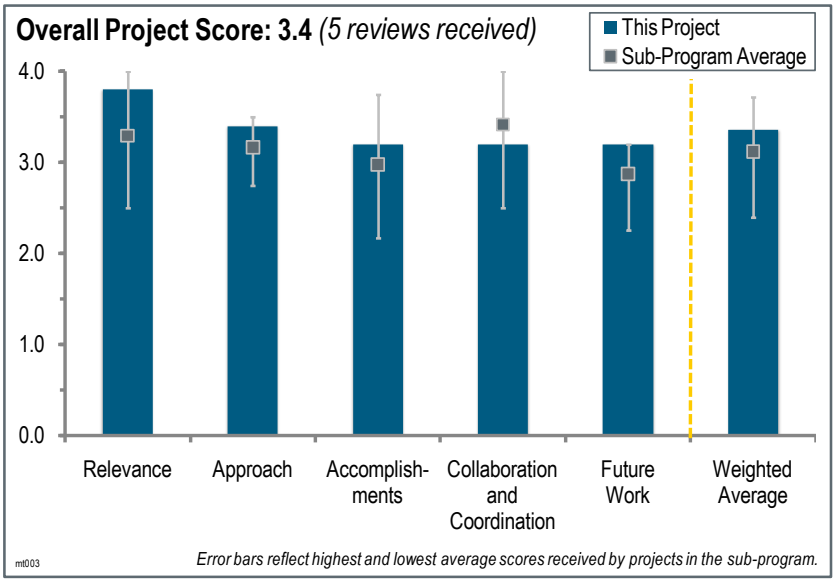
- A project such as this one, using limited resources to assess the potential merits of fuel cells, was justified. Given what has been learned from this project, there is no need for follow-on or additions (such as demonstrations) at this time. (The presenter's response to a question indicated agreement with this observation.) With further advancement of PEM fuel cell technology, resulting from research and development (R&D) and experience with other applications, perhaps funding for an aircraft demonstration project can be considered after fiscal year 2013. Such a demonstration should be preceded by a life-cycle cost/value proposition analysis. DOE should continue to support R&D of technologies that can result in more electric aircrafts and significant reductions in aircraft petroleum use. Fuel cells and renewable biomass are important technologies of interest. Also, at a later date, aircraft designs incorporating fuel cells could be investigated.
- One recommendation would be to add taxi operation from the gate to the runway.
- This project is complete, but a valuable follow-on study could include further investigation regarding the magnitude of benefits expected with designing the fuel cell specifically for the airplane, and vice versa.
- This reviewer does not see a need for continued work in this area unless the project scope is broadened to include in-flight air conditioning and other larger scale power applications.

Project # MT-003: Green Communities

John Lewis; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives for this project are to: (1) develop methods and techniques for identifying and evaluating candidate communities for suitable hydrogen and fuel cell technology projects; (2) assist communities in deploying and using hydrogen and fuel cell technologies in innovative integration projects with existing energy efficiency, conservation, and renewable energy investments; (3) develop case studies for replicating successful deployments in other similar communities; and (4) build relationships with communities embracing hydrogen and fuel cell technologies.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.8** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project addresses one of the key hurdles to the widespread deployment of hydrogen and fuel cell technologies—identifying early market candidates that are best suited to obtain the greatest benefits from these technologies. The project is developing methods and techniques for identifying and evaluating "communities" and assisting the selected candidate communities in integrating hydrogen and fuel cell technologies with their other conservation, energy efficiency, and sustainable energy components and plans.
- This is a valuable effort because it takes an integrated approach, looking at the role of hydrogen and fuel cells in the context of a whole community and together with other energy and environmental actions. Insights gained from these projects will also serve as good guidelines for future efforts by other communities, thus helping the technology develop and enter the market rather than waiting for a one-size-fits-all approach to developing the technology on a national basis.
- The project plan seems well designed. As there are no specific projects identified yet, it is impossible to gauge whether implementation will conform to DOE objectives. Hopefully, next year's Annual Merit Review will provide more information on that.
- This project mostly aligns with the DOE Hydrogen and Fuel Cells Program. It is focused more on emerging markets than research and development and should be able to provide needed data to DOE and manufacturers on how the systems perform in real environments and which configurations perform best.

Question 2: Approach to performing the work

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

- The project approach discussed in slides 6–8 appears to be well suited to meeting the objectives of the project. The project has evaluated a spectrum of community types and developed a matrix approach to ranking the suitability of the communities to achieve maximum impact of the deployed projects. In addition to technical feasibility, the project attempts to assess economic feasibility and integration with other renewable energy activities that already exist within the selected communities. Important aspects of the defined approach are

determining acceptable financial criteria and setting project goals so that the deployment performance can be measured against predetermined objectives.
- Using a formal methodology to evaluate and rank candidate community types and investigating a wide variety of potential project types is a strong approach.
- It is not clear how the project team addressed the first barrier to expand market opportunities. The market opportunities that the investigators identified were already well known. The project team did not include any details on how it was going to increase public awareness, which was one of the three barriers it was supposed to address. The information that the investigators will be gathering seems limited. It is unclear if the data will be sufficient to do the intended analysis, particularly given the budget.
- It seems that the response time for full proposals was compressed beyond what was necessary. Allowing 60 days from the request for proposal (RFP) date to the time when proposals are due would allow teams more of an opportunity to put meaningful proposals together.

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

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

- This project is still in its early stages—no specific installation has yet occurred. The project has developed a decision matrix tool, however, and solicited responses from interested communities and hydrogen and fuel cell technologies vendors. The project has already identified the following opportunities:
  - An anaerobic-digester-based off-grid installation for a combined heat and power (CHP) system that also uses the product carbon dioxide (and water vapor) to support food production in a community greenhouse
  - A fuel cell system operating in a grid-parallel configuration to support key components (computer servers) in the event of a grid supply disruption
  - A CHP fuel cell system for a community of buildings
  - A municipal combined heat, hydrogen, and power system that uses hydrogen for energy storage as well as for fueling municipal vehicles
- Not much has been accomplished other than the project plan, due to the early stage of implementation. Consequently, the project's progress is sparse at this point.
- The investigators identified markets that were already well-known (no new markets were identified). The budget seems low for the type of deployments that the project team is proposing. The investigators are making progress towards the deployment.
- Some more details on community requirements (e.g., heat, power, and fuel) and technical solutions (e.g., efficiency, availability, and investment) would be appreciated.

Question 4: Collaboration and coordination with other institutions

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

- Specific collaborators were not identified at the Annual Merit Review, pending completion of contracting activities. However, the wide variety of projects and installations mentioned clearly indicates that the project will include a highly desirable mix of collaborating organizations and entities.
- The project team made efforts to solicit input from potential collaborators and is in the process of identifying the collaborators. The project's success will be dependent on receiving quality proposals in response to the RFP. Many of the proposed or example concepts would require more funds than what this project can provide, which may limit the deployment opportunities.
- It is too early to say whether there is sufficient collaboration, given the status of the project; however, it seems as though the intent is there.
- Comments on communities' reactions to the suggestion of hydrogen fuel cell systems would be appreciated.
- The project team could have also solicited input from industry stakeholders in developing the ranking criteria.

Question 5: Proposed future work

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

- It is too early to comment on future work, as the project is in its early stages.
- The proposed future work is consistent with the project plans. It was not clear from the discussion, however, what the criteria for success were (e.g., technical, financial, or other), and how success would be measured. Also, the intended duration of the deployment test/demonstration was not discussed.
- The investigators should add more information on developing cost analysis and business cases. The project team needs to include how it will do outreach and education, and where this outreach will be. Outreach should not be limited to the fuel cell community, but the majority of the efforts should be to the communities where investigators will be deploying the fuel cells.

Project strengths:

- The very strong response to the Sources Sought notice, including many responses from communities and technology vendors, is a very strong start to the project. The project approach is well reasoned.
- The project has an integrated approach, educational value, and great greenhouse gas relevance.
- Combining fuel cells in "green" communities should facilitate user acceptance, given that other new technologies are supposedly also being rolled out in the same communities.
- This project's strengths include its analyses of potential deployment opportunities, use of decision-making methods, and consideration of a wide range of project types.

Project weaknesses:

- Investigators need to develop an outreach plan. Additionally, they are only monitoring the project for two years. It will most likely take longer than that to realize the full benefits of the fuel cell technology.
- It would be helpful to develop some defined test plans, rather than just document how the systems operate over the test period.
- The compressed RFP response time is an area of weakness.

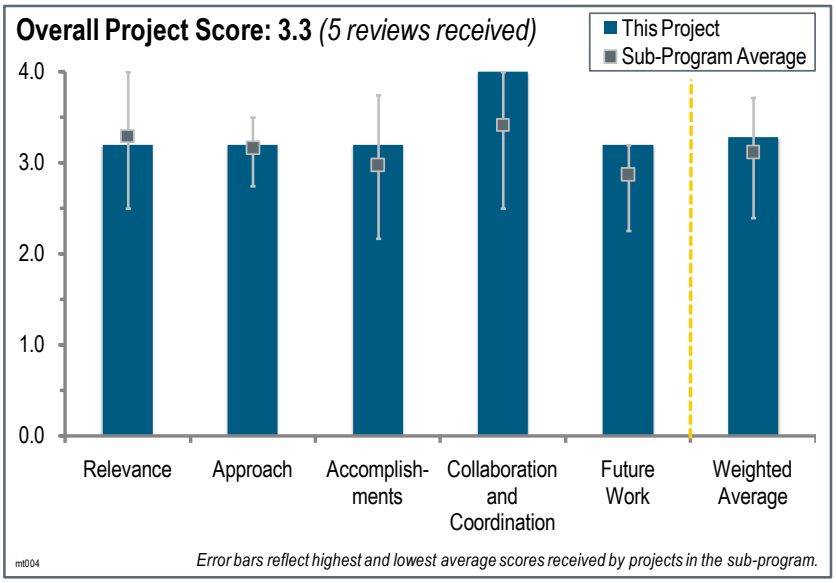
Recommendations for additions/deletions to project scope:

- The project team needs to develop a solid outreach plan and increase the time spent monitoring the equipment. The team should also include development of various business cases for each type of deployment, but it is not clear if it will be gathering sufficient data to make the business case.
- Education and outreach, including case studies and other efforts, should be a strong component of the results of this project. The results, both the positive and negative aspects, should be communicated to a wider variety of audiences—not just to champions of the technology, but also to (and especially to) skeptics.
- Address the weakness.
- Add business case examples for selected communities.

Project # MT-004: Direct Methanol Fuel Cell Material Handling Equipment Demonstration

Todd Ramsden; National Renewable Energy Laboratory

Brief Summary of Project:



The primary objective of this effort is to deploy and test fuel-cell-powered material handling equipment (MHE) using renewable liquid fuels (in particular, methanol). A second objective is to compile operational data of direct methanol fuel cells (DMFCs) and validate their performance under real-world operating conditions, which will: (1) provide an independent technology assessment focusing on fuel cell system and infrastructure performance, operation, and safety and (2) illuminate the market viability of these fuel cell technologies and inform the business case for DMFCs. The longer term objective is to help transform the market for fuel cells in material handling applications and provide information that enables replication of successful deployments.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.2** for its relevance to U.S. Department of Energy (DOE) objectives.

- There is increasing evidence that MHE could be a significant market for fuel cells in the near term. This application could help fuel cells gain market traction and result in manufacturing cost reduction. Hydrogen infrastructure and related costs are serious issues that negatively affect the value proposition of fuel cells for MHE. Methanol fuel cells could alleviate fuel-related challenges and costs while maintaining the operational benefits of fuel cells. This project should provide significant information on the viability of and value proposition for DMFCs. The result could be a more cost-effective fuel cell system for powering MHE. This is a legitimate market transformation project and is in line with DOE's 2010 draft *Hydrogen and Fuel Cells Program Plan*.
- A real-world demonstration of range extension using fuel cell or battery-powered MHE provides operating and durability data and experience. The experience helps guide future research and development.
- This project attempts to validate the results of an earlier Battelle study that indicated that fuel-cell-powered material handling applications offer significant advantages over current technology. If the performance and operating results bear out the projections of the Battelle study, this project would provide reinforcement for early entry of this technology into the material handling marketplace. In particular, the project has the objective to demonstrate the successful use of a liquid fuel (methanol) in this application of fuel cell power systems.
- The approach is sound and is needed to convince a skeptical user base that the economics are favorable.
- The Program should focus on hydrogen fuel cells, as methanol is not greenhouse gas (GHG) relevant and a parallel methanol infrastructure does not seem to be reasonable.

Question 2: Approach to performing the work

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

- The original equipment manufacturer will ensure that the fuel cell power systems integrate well mechanically, electrically, and operationally with the existing pallet trucks. They will use on-site measurements and analyses to

ensure a high degree of compatibility with the current equipment and its use profiles. A relatively large number of units, 75, will be deployed at three different end-user sites for over a year, and each unit will accumulate more than 5,000 hours of operating time. The project should, therefore, provide statistically significant results that offer a high degree of confidence to potential future users of this fuel cell technology. Performance and operating data will be acquired remotely and in real time and will be processed to develop and publish reports on the technology.

- The task structure is straightforward and logical. The demonstration of DMFC technology in actual operations at four commercial distribution centers will complement the MHE operational projects already underway. Including this project in the National Renewable Energy Laboratory's thorough data-gathering and analysis activity is key to realizing the benefits of the demonstrations. Significant data will be generated and analyzed. The use of renewable-sourced methanol is a plus. The subcontract was awarded competitively, which is good. It would be useful to know if a project using DMFCs to provide power directly for equipment operation (rather than indirectly by recharging batteries) was considered. If such a project was not considered, there should be an explanation. If such a project was considered, the investigators should explain why a battery recharging system was selected. Another reviewer pointed out that methanol quality is an issue deserving attention.
- Deployment of fuel cells in operating MHE for a direct comparison with incumbent battery charging infrastructure provides excellent technical insights. The initial cost of the new technology (approximately eight times higher) is an issue. DMFC systems require only minimum new infrastructure.
- Investigators need to baseline current technology against business metrics such as durability, turns, refueling (charging) times, etc., to prove the business case. This was not clearly defined.
- Comparison should not be limited to the battery system, but also include hydrogen systems.

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

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

- The project appears to have progressed very well. In less than one year since the funding was provided, pre-solicitation, solicitation, and contract award have been completed. Prototype DMFC systems have been tested for their ability to meet customer requirements. Of the 75 systems to be deployed, 66 had been built and 50 were operational at the end-user sites by the time of the Annual Merit Review. Early tests showed 14 hours of operation on a single refueling (3.5 gallons), more than twice the average operating time of battery-only systems (slide 14). In addition, the battery state-of-charge was maintained at a significantly higher and steadier level—while avoiding deep discharges—than for systems without the DMFC system (slide 15).
- The new hybrid units have been shown to double the range of MHE compared to batteries alone. "Refueling/charging" time is also greatly reduced (minutes versus hours). Of the 75 units proposed, 66 have been delivered and 50 are in operation. It would have been instructive to hear something about the ease of retrofitting.
- The majority of this project is just getting underway, almost a year after the start date, and the key subcontract, to Oorja Protonics, was not awarded until February 2011. Therefore, no operational data has been reported and this criterion cannot be objectively evaluated yet. Systems integration work and some testing have been accomplished and suggest that excellent results will be achieved on forklift range extension and enhanced battery life.
- The project is just starting and deployment is currently underway, but current business metrics and costs could be understood before deployment.

Question 4: Collaboration and coordination with other institutions

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

- A fuel cell manufacturer, a methanol fuel provider, forklift customers, and a national laboratory all have key roles in project implementation. A report on project results will be provided to fuel cell and MHE stakeholders, which is a plus. The inclusion of Oorja and its DMFC technology operating at multiple sites creates a more robust DOE/U.S. Department of Defense fuel cell MHE demonstration portfolio.
- The project team consists of a national laboratory, a fuel cell and system manufacturer, and three end-user organizations, with significant cost share being provided by the non-government entities. Thus, the team includes a spectrum of stakeholders who will be in a position to observe and determine the advantages, and shortcomings, on a first-hand basis.

- This project includes good coordination between end users and producers to understand the economics of DMFC deployment.
- A fuel cell supplier and several commercial warehouses are involved. It appears that pallet jacks from several MHE manufacturers have been modified.

Question 5: Proposed future work

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

- As part of this project, plans are in place to collect substantial data on site operations, fueling infrastructure, and forklift performance. This DMFC demonstration will directly address the barriers associated with hydrogen infrastructure requirements and provide information on the merits of a viable alternative to hydrogen fuel cells.
- Once all the units are deployed in the field by early in the fourth quarter of fiscal year 2011, the main ongoing project activities will be DMFC and infrastructure operation and maintenance, data collection and compilation, and reporting. Examples of reporting were included in the presentation.
- About 15 months of operation will provide data on operating and refilling characteristics.
- An understanding of the current economic and business case as a baseline is needed and was not clearly defined.
- The objective of the project is not clear.

Project strengths:

- This project is demonstrating an alternative to hydrogen polymer electrolyte membrane fuel cells for MHE applications. Other project strengths include the significant cost share, multiple project sites and MHE operations, and NREL's data acquisition and analysis experience.
- The project appears to have very strong partners who are already well along in the deployment and use of this advanced technology. The project is well designed and well structured.
- Retrofitting MHE from several manufacturers and deploying it to several different warehouse entities should provide broad data representative of the industry in general.
- Only one application is being studied, thus the economics can be very well understood and analyzed.
- This project's intent to simplify the infrastructure is a positive.

Project weaknesses:

- The methanol fuel quality should be monitored. There may be contaminants in the fuel that can cause short- or long-term degradation of the fuel cell system. Additionally, depending on the design of the DMFC system, there is the potential to emit significant amounts of methanol vapor in the system exhaust. Such emissions, if any, should be determined at least in a laboratory setting and preferably in the industrial setting. These emissions should be documented in the data compilation and reporting.
- There is a lack of understanding of the current economics. The investigators need to understand this as soon as possible to compare this project with new DMFC technology.
- Assessing DMFCs only as a means to charge MHE batteries is an area of weakness. It would be even better to have a project that also demonstrates DMFCs as a replacement for batteries. The reviewer questions if this is a reasonable possibility for the future.
- Methanol is not the fuel of the future. It has been investigated in the past and has shown not to be attractive. It is not renewable (biofuels are questionable to this respect) and is toxic.

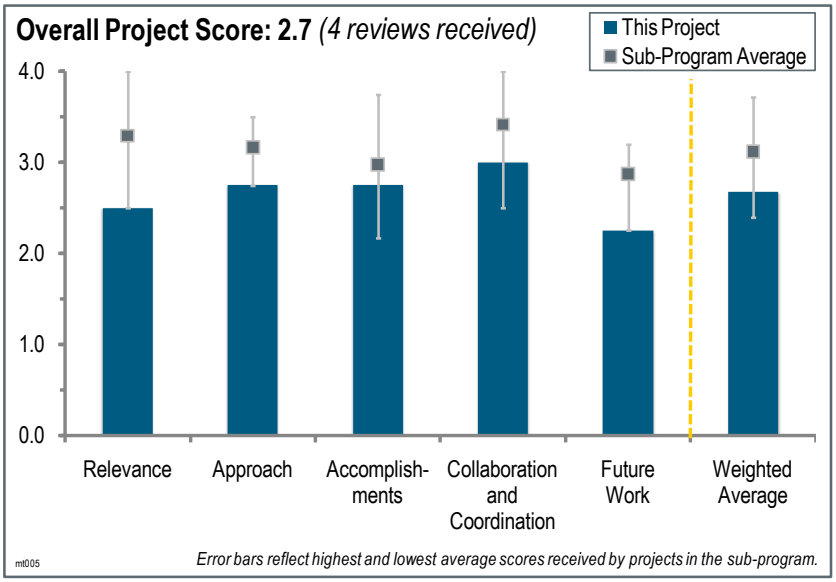
Recommendations for additions/deletions to project scope:

- This reviewer has no recommendations for additions to this project. If funds are available, investigators could consider a similar project with a DMFC as the forklift power source, rather than as a battery recharger.
- The project team should compare the methanol system with the hydrogen system in a full system evaluation (e.g., onsite infrastructure, operating cost, fuel consumption, and environmental impact).
- Investigators should address current economic metrics before deployment is complete to accelerate the project.
- Investigators should take steps to address the project's weaknesses.

Project # MT-005: Bus Fleet and Infrastructure Deployment

Bob Glass; Lawrence Livermore National Laboratory

Brief Summary of Project:



The U.S. Department of Energy (DOE) requested that the national laboratories host hydrogen internal combustion engine (ICE) buses to promote early market adoption of hydrogen technology, displace diesel-fueled vehicles at the laboratories, and promote public education on the benefits of hydrogen and fuel cell technology. The approach for this project is to: (1) receive two hydrogen ICE buses from Ford; (2) integrate them into the existing Lawrence Livermore National Laboratory (LLNL)/Sandia National Laboratories (SNL) shuttle bus fleet; (3) establish a reliable source of hydrogen refueling for the shuttle buses; and (4) use the shuttle buses as a method of educating the local public on the benefits of hydrogen and fuel cell technology. The LLNL/SNL shuttle buses are now in routine use.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **2.5** for its relevance to DOE objectives.

- This project helps national laboratories both "walk the talk" and have the opportunity to showcase the technology to a wide variety of stakeholders, which helps to overcome misconceptions and aids in education and outreach.
- This project is far from demonstrating economic benefit and market readiness, but it is a good first step in demonstrating acceptable performance.
- This project could be more easily justified if the vehicles were on some sort of commercialization pathway (or even close to one). There do not appear to be any serious efforts ongoing to commercialize hydrogen ICE engines for either passenger or shuttle vehicles, so it is unclear why the investigators should perpetuate their use.

Question 2: Approach to performing the work

This project was rated **2.8** for its approach.

- It is valuable that the shuttle bus also makes trips outside of the laboratory campus, thus enhancing visibility. It is also good that the bus participates in different outreach events.
- The project participants fail to show how this project advances hydrogen technologies beyond what was available 10 years ago. Some education and outreach benefits may have accrued, but they seem minimal given that the vehicles were mostly operated on a research campus that is closed to the public.
- It would have been preferred to use the shuttle buses for public transportation.

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

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

- Hydrogen fueling is in place, and the buses are running and being used.

- This project failed to display any significant accomplishments. The vehicles were idle for about a year according to the presentation and, when they did operate, failed to show the efficiency or emissions benefits of hydrogen, given that the hydrogen had to be trucked in via a compressed gas trailer.

Question 4: Collaboration and coordination with other institutions

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

- This project featured a very strong team of collaborators (e.g., Ford and Air Products), and very good coordination and outreach to the community.
- Involving both industry and local officials as partners was an area of strength.
- Neither Ford nor Air Products are shown as having contributed anything to this project and should be listed as vendors rather than collaborators. Consequently, the only collaborator seems to have been the local junior college. It appears that little effort was taken to leverage this project to generate interest in hydrogen technology.

Question 5: Proposed future work

This project was rated **2.3** for its proposed future work.

- The project could have a stronger emphasis on outreach programs and public awareness.
- Thankfully, the project participants do not seem to be planning any additional work.

Project strengths:

- The buses seemed to mostly operate reliably.
- This project helped enhance the visibility of hydrogen and fuel cell technologies.

Project weaknesses:

- This project had limited access to the public.
- The project included a cancelled vehicle product line as well as compressed hydrogen delivery, which is not a new concept. The project also seemed mostly inaccessible to the general public. Vehicles were idle for a significant part of the project period.

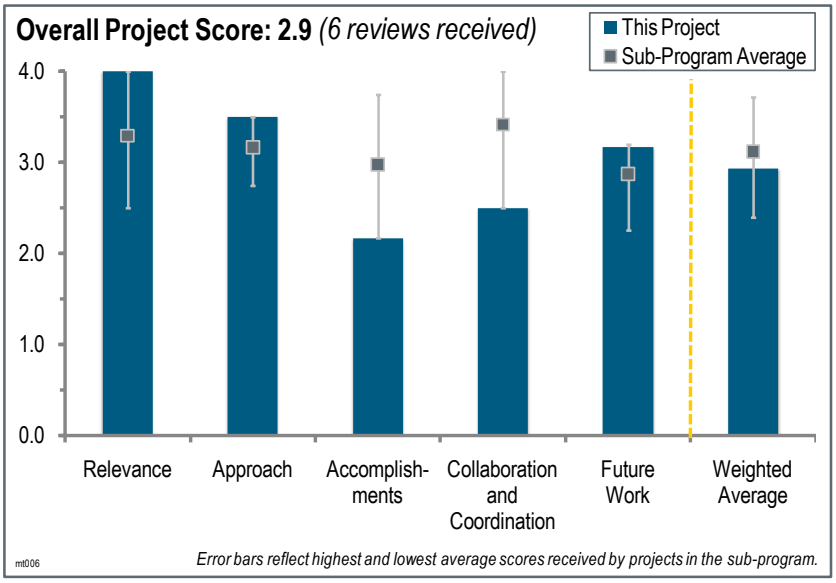
Recommendations for additions/deletions to project scope:

- Further opportunities should be sought to engage more stakeholders and identify events at which to showcase the technology.
- Hopefully DOE will not extend funding on this project.

Project # MT-006: Fuel Cell Combined Heat and Power Industrial Demonstration

Mike Rinker; Pacific Northwest National Laboratory

Brief Summary of Project:



The primary objective of this effort is to demonstrate combined heat and power (CHP) fuel cell systems and assess their performance to help determine and document market viability. Systems will be demonstrated in commercial industrial applications and the long-term technical and economic performance, energy efficiency, and environmental benefits will be validated and documented. Deployment information will provide benefits by: (1) aiding the domestic supply base; (2) increasing user confidence; (3) increasing marketplace standing in terms of value provided; and (4) providing favorable lifecycle cost, energy, and emissions savings.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **4.0** for its relevance to U.S. Department of Energy (DOE) objectives.

- There is evidence that CHP production could be a significant market for fuel cells in the near term. This application could help fuel cells gain market traction and result in manufacturing cost reductions. This project should provide significant information on the viability of and value proposition for stationary fuel cells. It is important for determining fuel cell benefits and identifying issues that must still be addressed in order for fuel cells to be commercially competitive. This is a legitimate market transformation project, and is in line with DOE's 2010 draft *Hydrogen and Fuel Cells Program Plan*. The technology demonstration will complement "commercial" fuel cell stationary power projects already underway and result in a more robust data set. Focusing on 5–100 kilowatt systems fills a gap in ongoing demonstration and "early commercialization" activities.
- Studies such as this are necessary for the customer base to gain confidence in both the economics and durability of these systems.
- Projects such as this one can be instrumental in establishing the technical, operational, and commercial viability of fuel-cell-based CHP systems.
- This is a great project—the variety of demonstrations conducted will help identify the most promising applications.
- This is exactly the sort of project that DOE should be funding to get real-world performance information from fuel cell systems.
- CHP fuel cell systems are a key component and application of hydrogen and fuel cell systems, with benefits and value propositions. Thus, investigating and demonstrating this technology is of value to the Program.

Question 2: Approach to performing the work

This project was rated **3.5** for its approach.

- Multiple installations will enable the assessment of fuel cell technology merits for a variety of applications and conditions. Baseline modeling by Pacific Northwest National Laboratory (PNNL) should be a useful complement to the results of field operations, and the model inputs seem comprehensive. However, PNNL's presentation

should more clearly establish the link between the modeling activity and the subsequent project tasks. Modeling and analysis has evidently been employed to help guide decisions related to project content and installations. For example, sites included in the project should be able to use nearly all of the heat generated by the fuel cells. The list of parameters to be monitored and measured is comprehensive and complete. Evidently there will be a single vendor (fuel cell manufacturer). In the absence of additional information, this seems sub-optimal.

- The breadth of the CHP user base included in the demonstrations will yield a vast amount of information to prospective customers regarding the utility of these systems.
- Developing a baseline model, encouraging end-user partnering, and communicating with manufacturers prior to developing the request for proposal (RFP) were all positive steps. However, choosing one vendor might be limiting.
- The project participants seem to have laid out a good approach for system evaluation. The approach could be improved by looking at fuel cell systems over a broader geographic area.
- The project will develop models for the engineering, financial, and environmental performance of the fuel cell systems, acquire commercial systems for deployment at end-user sites, monitor the performance of the systems, and analyze and document the operational data to develop recommendations for going forward.
- This is a great project with lots of diverse applications.

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

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

- The project is only 5% complete, so this criterion cannot be objectively evaluated yet. There is no operational data. The subcontractor, who is key to the project's success, has not yet been identified (as of May 10). Resolving contractual and other issues has taken longer than planned. Seeking manufacturer input for RFP development and the technical requirements document was a positive step. A project time extension will be needed to acquire two years of operational data.
- Although a considerable amount of procurement (solicitation) activity has been completed during the period under review, and a single vendor for 38 fuel cell systems has been selected for 10 different industrial and commercial deployment sites, the contract with the fuel cell vendor is not yet in place and no specific information could be provided about the project for the reviewers to assess its progress.
- The project has just started with the user base being defined—thus progress is minimal, as expected.
- There have been delays in getting a contracting place, which is typical.
- During the oral presentation, it was learned that only one fuel cell vendor has been selected through the competitive RFP process for the 38 systems to be deployed. The lack of manufacturer participation is likely to severely impair the quality of information gathered for this project and undermine the relevance of the project, which was so well defined in the project overview.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.5** for its collaboration and coordination.

- The project team worked with manufacturers in developing the RFP.
- This is difficult to evaluate because the vendor and sites at which the CHP fuel cell systems will be operated have not been disclosed. The list of "industrial" locations does not seem "industrial," and only includes one manufacturing site. However, the variety of facilities is fine for this project. Sites selected for the project will evidently take advantage of California state-level incentives. Communication should be established with appropriate state government agencies. There has been no communication with the National Renewable Energy Laboratory (NREL) staff regarding data collection and analysis. This should be done to take advantage of NREL's expertise and experience. PNNL should plan to share data on project results with potential fuel cell customers.
- The project will involve active collaboration by the fuel cell vendor(s) and the end-user site operators. Although these entities and sites have been selected, very little specific information was provided. Selection of a single fuel cell vendor, rather than multiple vendors, raised many questions that the presenters were unable to address.
- This reviewer would recommend working more closely with user groups and trade associations for the various applications.

- It is possible that the poor RFP response is a result of insufficient collaboration with possible fuel cell vendors prior to the RFP being issued. Having only one manufacturer represented (once a contract is finalized) could represent a severe shortcoming for this project.
- Once the user base is defined, coordination can be assessed.

Question 5: Proposed future work

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

- Most of the project activity remains to be accomplished. Implementation of the planned approach should lead to valuable results. Future project activities and milestones are described only in general terms.
- This reviewer is absolutely amazed with the amount of work in this project, considering the amount of money it has been allotted.
- This looks like a very well rounded project that covers both technical and economic assessments of CHP fuel cell systems.
- After awarding the contract to the fuel cell vendor, the systems are expected to be installed and operational by August 2011.
- The project concept is great, but implementation will be impaired by the lack of multiple fuel cell vendor participation.
- Proposed plans do not give details on the project's next steps, including the approach to be used and the value of these steps.

Project strengths:

- Long-term demonstrations and data acquisition are vital to proving the benefits of CHP fuel cells for potential customers and establishing the value proposition. This project enables the assessment of fuel cell performance in a variety of real-world operating conditions at multiple sites. Significant cost share is anticipated.
- The breadth of the user base will yield a wide array of user data.
- This project features lots of applications and great data.
- The data being gathered is very important. Projects like this need to be funded.
- End-user partnerships with manufacturers were sought in selecting the fuel cell system supplier. The baseline model was initially developed for cost and technical performance. A variety of locations will be used for different types of applications.
- In the absence of specific information about project participants, it is difficult to assess the project's strengths.

Project weaknesses:

- Due to the large user base and the lack of control of systems and utilization, this project will yield uncontrolled data. This will require thought relating to data comparisons and the ultimate economic conclusions.
- Evidently, there is only one vendor of fuel cell systems for the project. There is no indication of plans to coordinate data collection and analysis with other organizations responsible for fuel cell market transformation or Recovery Act projects. There have been delays in awarding subcontracts to fuel cell vendors and commercial partners.
- The investigators only chose one vendor with one specific type of fuel cell. The principal investigators could not comment at the time on why this choice was made, due to the contract not being signed yet. The reason for only choosing one vendor might be valid, but diversity of vendors and fuel cell types probably would have provided more value. Deployments seem to be mainly in areas with strong financial incentives for fuel cells. It would have been valuable to also have an example of what conditions might be required to make a business case in an area without supporting incentives.
- The major weakness was the inability of the presenters to answer any of the specific questions asked by the reviewers or others in the audience. It was frustrating to be told repeatedly that they could not answer the question. Perhaps the presentation should have been pulled from this year's Annual Merit Review.
- This project needs a better plan for presenting the work results to the "Global User Group."

- The lack of geographic diversity will limit the quality of data collected. The lack of fuel cell vendor diversification is also a problem.

Recommendations for additions/deletions to project scope:

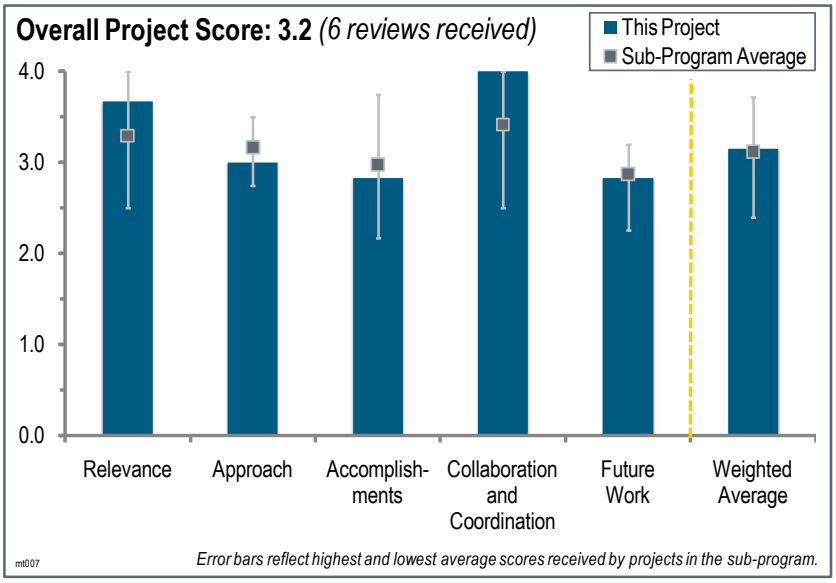
- Reviewers lack specific information about the project, so it is premature to make any recommendations.
- Once data has been collected from these deployments, it would be valuable to develop case study type documents to disseminate lessons learned, benefits, barriers, and synergies, among other information, to a wide range of relevant stakeholders.
- Investigators should share data collection and analysis plans with NREL and seek feedback. Plans to share results with potential fuel cell customers, the financial community, and insurance companies should be incorporated into the project.
- Early on, investigators should carefully define the term “availability,” The project team should plan to present its work both in meetings and publications to the ultimate users of the technology.
- The lack of multiple fuel cell vendor participation in this project is a major problem and could be grounds for putting the project on pause. The project participants should consider re-scoping and re-issuing their RFP in order to gain better participation. They run the risk of proceeding with a project that may yield little meaningful information except on the performance of one, specific product that may or may not be optimal for the applications selected for this project.
- The project team should understand user utilization and economic drivers early to aid assessments.

Project # MT-007: Landfill Gas-to-Hydrogen

Shannon Baxter-Clemmons; South Carolina Hydrogen and Fuel Cell Alliance

Brief Summary of Project:

The project objectives are to: (1) validate the business case for landfill gas-to-hydrogen technology, should the technology prove viable; (2) ensure the landfill gas-to-hydrogen conversion process is stable under the actual operating environment; and (3) validate that the hydrogen produced from landfill gas yields commensurate fuel cell performance and durability compared with hydrogen produced from traditional sources and delivered in bulk to the host site.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.7** for its relevance to U.S. Department of Energy (DOE) objectives.

- This is a great example of a market transformation project: investigating a good idea that people think makes sense but wouldn't otherwise pursue because of the high risk involved in being the first one to do it. If this project with BMW is successful, it will provide an example to many other companies that they may be able to green their forklift operations in the same way. This concept is a great way to maximize the use of renewable hydrogen from landfill gas.
- This project is being executed in a real-world commercial setting, where helping or hindering the normal plant operations will have direct positive or negative consequences. Such prototype deployments of hydrogen and fuel cell technologies are essential in building confidence in the technologies to help promote their widespread deployment for similar and other applications. Important aspects of this project are determining if there is a viable business case for this technology in this application and laying the groundwork for establishing the business cases for deployment in other situations.
- Landfill gas is an interesting renewable resource. An integrated test of landfill gas as a resource to identify potential issues is necessary. In addition, the technology is ready for this type of test.
- If this proves economic and sustainable, it could be really important.
- The project team is looking at using landfill gas to power fuel cells, which directly supports the DOE research, development, and demonstration plan. The use of landfill gas to provide power to material handling equipment (MHE) is useful and interesting.
- This is a nice demonstration project, but it does not feature any new technology advancements.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- As pointed out in the discussion, the project does not involve technical developments in component technologies, such as landfill gas cleanup, methane reforming, product purification, compression, or dispensing, among others. Project objectives are successfully integrating these components into a well-functioning system, achieving a technical demonstration of the integrated system, and providing the basis for analyzing the financials of this approach to providing hydrogen for MHE as compared to conventional delivered hydrogen from industrial gas suppliers. In this phased project, successful completion of Phase 2 (two months of performance data to validate

the landfill gas-to-hydrogen under the existing BMW landfill gas supply conditions, page 10) will lead to a side-by-side comparison of forklift trucks operating on hydrogen from landfill gas and hydrogen delivered by an industrial gas supplier. This comparison will be conducted over statistically significant time frames and test a statistically significant number of units (page 11). Successful completion of the project (page 12) will support all of the major objectives of the market transformation activities of the DOE Hydrogen and Fuel Cells Program.

- The approach decreases the risk to BMW of a full-scale deployment through performing analysis, limited small-scale testing, and a go/no-go decision before embarking on Phase 3, which is a side-by-side performance comparison with delivered hydrogen. A recommendation to BMW for full-scale deployment would only be made after success in all three phases. The project has created an incredibly strong team with multiple partners in industry and the state, bringing both funding and expertise to the project.
- The approach needs to be expanded. Investigators should include development of a business case for the different scenarios. Their plans are very ambitious, but it is not clear they will have sufficient funds to complete the scope.
- This reviewer is concerned that the scope might be a little too aggressive. Investigators appear to be unsure what will be measured to determine acceptable variations in the output hydrogen purity.
- This project does not fully realize the many, many issues associated with landfill gas, such as how gas composition and variability can affect cleanup costs and project feasibility.

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

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

- The project started in April 2011, so not many accomplishments are expected yet. The project has succeeded in establishing a solid work plan, which should lead to a successful project in a very short amount of time. The project achieved a major accomplishment through gathering a greater than 50% cost-share from state, local, and private sources.
- The only accomplishment this reviewer can see thus far is assembling a top team.
- This is a new start, so investigators have not accomplished much yet. They have been able to bring many more partners on board.
- This project has not yet started, so there are no real accomplishments. Pulling together the team appears to be an accomplishment unto itself.
- The project is still at an early stage. Planning and feasibility studies are underway.

Question 4: Collaboration and coordination with other institutions

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

- This project involves governmental, non-profit, commercial, engineering, and educational and public outreach organizations for maximum benefit from the work of the project. Working closely with BMW, a major automobile manufacturer, is certainly a plus, and is important for validating the business case.
- The investigators have a good team that should be able to achieve the objectives. The output target of a single paper for their work seems very modest considering the breadth of the scope they are undertaking.
- This project brings together a good mix of host site and collaborating institutions.
- This project features an excellent team.
- This project has an outstanding team.
- The South Carolina Research Authority has put together an excellent team and coordinated with the right partners to bring about project success.

Question 5: Proposed future work

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

- Investigators stated that they have no plans for future work, which is a shame because this project should have considerable follow-on work.
- No specific future work or activities were specified, beyond completing the planned activities.

- Despite the fact that the poster says "Proposed Future Research – None at present" the project does in fact have clearly focused plans and go/no-go decision points.
- Analysis of impurity levels versus time should be a top priority.
- The detailed work plan is solid and includes strong partners, multiple phases, and a reasonable go/no-go decision between Phase 2 and Phase 3.
- This reviewer is concerned that the scope might be too ambitious, but it is an interesting project. The reviewer would like the investigators to publish everything possible from the business case analysis.

Project strengths:

- The project team has done its homework during the planning portion of the project, lining up strong partners and generating a detailed execution plan. The project promises to become a landmark case study for others to follow on how to use waste gas to power fuel cells forklifts (or other hydrogen applications). Including the Gas Technology Institute on the team should really help with questions or issues about gas quality.
- This project features a strong team, as well as a large amount of industrial support, which indicates industrial interest.
- Strengths of this project include a strong project team, a well-established and interested end user, well defined component technologies, and development of a viable business case.
- This project features a great team.
- This project has a great concept and a great team.

Project weaknesses:

- No project weaknesses were identified.
- The plans do not seem well defined, particularly given the technical expertise on the team.
- Several abbreviations and acronyms were not defined in the presentation, although they were not used in the technical details of the project.
- The resources may be too limited for the desired scope.
- The project team does not realize the importance of getting early gas analysis and how those results can significantly affect cost.

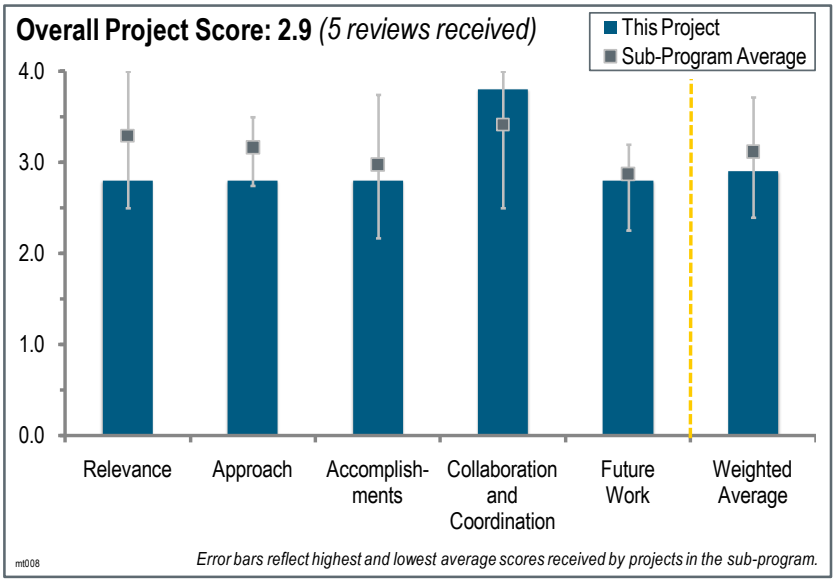
Recommendations for additions/deletions to project scope:

- The project should include many periodic waste-gas quality checks, as landfill gas typically varies throughout the day and throughout the year. Investigators need to ensure that the reformer can handle all of the extremes of gas quality while still providing extremely clean hydrogen. One way to objectively evaluate the fuel cell forklift degradation of the stacks running on landfill gas versus delivered hydrogen would be to provide the fuel cell forklift data to the National Renewable Energy Laboratory (NREL). NREL could then perform its degradation analysis and determine whether there is a statistically significant difference in stack degradation rates. The project should evaluate other potential uses of hydrogen at BMW, such as providing backup power for critical operations or equipment and potentially powering some of the corporate cars using BMW's hydrogen internal combustion engine technology, which is already proven.
- Investigators need to include the business plan as a deliverable and should include the cost analysis for using the landfill gas compared to the cost of natural gas reforming and hydrogen delivery.
- All the pieces are necessary, but they are dependent upon getting use of a reformer at a very low cost.
- Immediate gas analysis is important. A literature review of landfill gas projects should be done.

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

Richard Rocheleau; Hawai'i Natural Energy Institute

Brief Summary of Project:



The overall objective of the project is to identify economically viable technologies to transform island energy infrastructures. Specific project objectives are to: (1) develop and validate rigorous analytic models for electricity and transportation; (2) develop and model scenarios for deploying new energy systems, including additional renewables; (3) identify and analyze mitigating technologies such as demand-side management, storage, smart grid, advanced controls, forecasting, and FutureGen to address systems integration, grid stability, and institutional issues; and (4) conduct testing and evaluation to validate potential solutions to facilitate utility acceptance.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **2.8** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project is a valuable demonstration project because it investigates the potential of hydrogen and fuel cell systems to provide grid management, energy storage, and other services (such as fuel, fertilizer, etc.). This strengthens the value proposition of this technology, as it showcases the benefits of these diverse applications and technology capabilities. The curtailment of renewable energy is especially a problem (and a huge waste of resources) in many locations, so resolving that problem while providing other benefits is of value. Further understanding gained from this project will benefit future efforts of similar deployments elsewhere, thus helping market introduction and commercialization of the technology.
- This project appears to address grid management where the variability in the renewable power generation (wind) is balanced by a dynamically responsive electrolyzer. It does not offer any grid-scale energy storage, contrary to the implication of slide 8, on which the benefits of energy storage (1 megawatt [MW] for 60 seconds or 1 MW infinite) are clearly shown. It is essentially renewables-based hydrogen generation, where the electrolyzer provides the variable load in tandem with the variable power generation. Later in the presentation, it was stated (slide 18) that hydrogen would be produced using geothermal energy (a relatively steady source) rather than from wind power (an inherently variable source).
- The stated goal of this project is to keep the grid operating smoothly. Use of excess renewable energy (geothermal) to generate hydrogen through electrolysis helps keep the grid balanced and grid frequency fluctuations to a minimum. The hydrogen will then be used to power buses. There seems to be no technology innovation—geothermal energy, electrolysis, hydrogen buses, and using electrical loads to balance the grid are all established technologies.
- This project fits well within the DOE Hydrogen and Fuel Cells Program objectives, as it involves looking at renewable energy to produce hydrogen and using hydrogen to firm up the grid.
- The project is loosely related to Program objectives. Hydrogen internal combustion engine buses are consistent with the goals in the DOE Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Program *Multi-Year Research, Development, and Demonstration Plan*, but the stated focus on grid management is not. This is a big resource commitment ($1.8 million from DOE plus others) to produce hydrogen for two buses. Renewable hydrogen production projects are mentioned in DOE's 2010 draft *Hydrogen and Fuel Cells Program*

Plan, so there is some fit with geothermal to hydrogen. The ability to better utilize Hawaii's renewable resources is a worthy objective, but this reviewer needs more information to be convinced about this project and the Hydrogen and Fuel Cells Program's central role. The reviewer wonders, for example, how much work is still needed to characterize the performance and durability of commercially available electrolyzers. If reviewed from an overall DOE perspective (not limited to DOE's Hydrogen and Fuel Cells Program), the project could get a higher mark for relevance.

Question 2: Approach to performing the work

This project was rated **2.8** for its approach.

- The investigators have a sound approach, and the project is well thought out. The use of analytic models for electricity and transportation to identify the solutions is an area of strength. They have done a good job of arranging for community support and cost share to augment the government funds. Traditionally, fuel cells require batteries to handle the transients—not because the fuel cells cannot handle the transients, but because of the impact on the durability of the fuel cell. It is likely that the electrolyzer will have the same problem. It is recommended that a battery is included or at least considered to handle some of the faster transients to increase the life of the electrolyzer.
- Investigators are working with a variety of partners, investigating various capabilities of the technology, and aiding in the outreach related to the benefits provided by the technology. The project is backed by comprehensive analytical models and developed scenarios. Outreach efforts should be continuous throughout the project to educate stakeholders, industry, and the public about all aspects of the project.
- The approach outlined in slide 5 is more appropriate for electric reliability than for hydrogen production or delivery, or for other objectives of the Program. Models show that even modest amounts of energy storage capability can mitigate the negative effects of high wind power penetration (slide 8), but this project does not have energy storage as a component. Of the approach schematic layout given in slide 11, only the electrolyzer component will apparently be involved in this project. There was no discussion of how the hydrogen produced by electrolysis will be purified to the Society of Automotive Engineers SAE J2719 fuel quality specifications, particularly for water vapor content of less than five parts per million (Element 2 on slide 17 shows only the electrolyzer, hydrogen buffer tank, compressor, and tube trailer fill system). There was considerable mention of the variability of wind power, but slide 18 suggests that the hydrogen will be produced using geothermal power rather than wind power.
- Based on statements during the oral presentation and responses to reviewer questions, this project is not large enough to develop settled conclusions about the project's goal of achieving improved grid management. Therefore, it seems more of a high price "proof of concept" than a commercial market transformation project. The oral presentation clarified that this project is part of step four, as described in slide five. As a result, this reviewer concluded that the information in slides 6–8 resulted from prior steps that are not part of this project. The presentation could be clearer about the connection between this project and prior work.
- The approach is logical and relatively simple, and requires no technological breakthroughs. Useful data on commercial electrolyzers under dynamic load will be obtained. The cost is not sufficiently discussed.

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

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

- Investigators have made good progress on their proposed work plan. It is not surprising that the contracts are taking longer to get in place than what the project team originally anticipated. Investigators have been able to identify sponsors and shareholders to augment their funds in order to achieve their goals. The dynamic operation seems low compared to the intermittency of wind and solar renewable power sources.
- The project activity is still in the early stages, thus this criterion cannot be objectively evaluated. Resolving memorandum of agreement (MOA) and contracting issues has taken longer than planned. Even though slide 13 indicates that the hydrogen system supplier has been selected, that information was not available at the oral presentation (May 10). This provides further evidence that progress is slower than anticipated.
- It is still early in the project. Much of the activity to date has been planning, developing system requirements and designs, and selecting suppliers.

- The project is fairly new and contracting has been delayed, therefore progress is slow.

Question 4: Collaboration and coordination with other institutions

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

- The project team is strong and balanced. The investigators were able to get a lot of cost share either in actual dollars or in-kind donations. They need to get out and present their information so it can be used by the fuel cell and hydrogen community to educate the public on the costs and benefits of this technology.
- The project has a number of partners and collaborators. Information on cost sharing amounts and types was provided during the oral presentation and should have been included in the slides. The Office of Naval Research (ONR) is evidently providing supplemental funds, but the amount was not included in the slide presentation or the oral presentation. Good coordination with other projects in Hawaii seems to be occurring. For example, the project may supply hydrogen for General Motors vehicles to be operated at the Marine Corps base.
- Collaboration is also ongoing with National Park representatives. The Hawaii Natural Energy Institute should develop plans to share detailed project results with utilities and other stakeholders outside of Hawaii.
- The project team has multiple sponsors, a transit agency, and utilities, including one that could expand the scale of deployment of the technology if the project is successful.
- There is a wide range of players involved with and supporting this project.
- All aspects of the project except for electrolysis are well covered by the named participants. The electrolysis supplier has been chosen but not identified.

Question 5: Proposed future work

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

- Future project tasks four through seven are clearly stated and presented. Statements during the May 10 oral presentation indicated that additional resources will be needed for a Phase 2 follow-on project. The size of electrolyzers will need to be increased to understand and test the grid management capability of the system. This suggests that the current project's goal was perhaps overstated. A better understanding of the resource requirements for achieving the stated goal, i.e., resolving the grid problems associated with renewable energy, is needed.
- The proposed future work is consistent with the project plans. The work will include procurement and installation of hydrogen production and fueling infrastructure, procurement and operation of the hydrogen-fueled shuttle buses, and the collection and analysis of data. There was no discussion of an electrolyzer test plan to evaluate the dynamic performance of the electrolyzer, a key step in validating this proposed approach to grid management.
- This is a deployment project following a logical plan. The future work follows the plan.
- The proposed future work is as expected for the investigators to achieve their goals.

Project strengths:

- Strengths of this project include its collaborations; partnerships; and cost share from other sources, such as the state of Hawaii, Puna Geothermal Venture, and ONR. Another strength is the project's integrated systems perspective and plan that encompasses a geothermal renewable energy source, a reduction of curtailed renewable energy, and production of hydrogen with a variety of potential uses.
- This project has a strong project team that is working in a part of the United States with large amounts of renewable energy and where the cost of hydrocarbon fuels is very high.
- The project brings together a collaborative team of key stakeholders, including several commercial organizations.
- This project is backed by comprehensive analytical models and developed scenarios and demonstrates a solution to a problem facing the renewables industry while providing extra benefits and value propositions.

Project weaknesses:

- This project provides minimal contributions to Program objectives and represents a very large expenditure of funding resources for the hydrogen-related learning expected to result. There have been some delays in completion of some of the initial project tasks.
- The project does not appear to be highly relevant to the activities of the Program.
- Legal agreements and liability issues are causing some problems.
- Investigators are not doing a cost analysis or examining the business case.

Recommendations for additions/deletions to project scope:

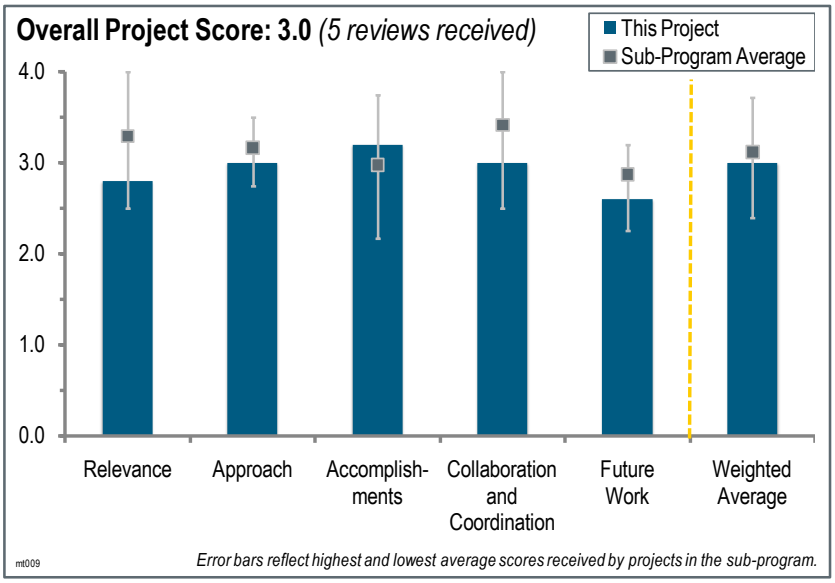
- As these systems are located in an area where sulfur emissions are high (due to the presence of volcanoes), it might be worthwhile to also investigate and track the effects of this contaminant on the operations and durability of the system. Once the project concludes and data is obtained, it would be valuable to develop case study type documents to disseminate lessons learned, benefits, barriers, and challenges, among other information, to a wide range of audiences and stakeholders.
- It would be interesting for investigators to perform hydrogen analysis and other standard analysis and then compare the analysis to the actual costs to gain an understanding of the accuracy of the projections. It would also be interesting to see the business case.
- This reviewer has no recommendations on additions or follow-on work until this project is much further along. If follow-on work is justified at a later point, investigators should seek funding support from other DOE organizations, such as the Geothermal Program and the Office of Electricity.

Project # MT-009: Economic Analysis of Bulk Hydrogen Storage for Renewable Utility Applications

Susan Schoenung; Longitude 122 West, Inc.

Brief Summary of Project:

The overall objective of the project is to facilitate the adoption of fuel cells across government and industry. Specific project objectives are to: (1) address the market for large-scale storage of hydrogen and hydrogen technologies; (2) enable greater penetration of clean renewable energy production; and (3) accelerate the commercialization and deployment of fuel cells.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **2.8** for its relevance to U.S. Department of Energy (DOE) objectives.

- The project raises interesting questions related to the cost-effectiveness of bulk hydrogen storage that have not previously been investigated, to this reviewer's knowledge.
- The project studies the economic feasibility and prospects of storing hydrogen as an energy storage medium. The work provides some quantitative measures of storing wind energy.
- The cost model addresses the effect of curtailed renewable energy production and hydrogen storage. Capturing curtailed resources can have a significant cost benefit.
- While this project is relevant to the goals of the DOE Hydrogen and Fuel Cells Program, it appears to be more of an analysis project than a market transformation project. It is not clear why this project is included in the Market Transformation sub-program. The project objective is to "facilitate the adoption of fuel cells across government and industry," but it is not clear how the project intends to do that simply based on analysis results. The project would need to take the next step to put together business teams to make proposals to stakeholders.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- The tasks are appropriate and address the cost benefits. The efficiency assumptions seem to be too optimistic. It would be more interesting to investigate the efficiency levels at which the proposed storage model would be attractive. The principal investigator indicated that the model can be used for a variety of studies and considerable more data is available. The project would benefit from more discussion on the methodology.
- Assuming that the technologies meet all DOE targets for electrolyzer and fuel cell costs would be fine for a "what if" analysis project. However, a market transformation project should use the current or near-term equipment costs to make the business case more relevant in the near term in order to facilitate adoption, which is one of the project's stated goals.
- This project's approach includes straightforward calculations. Most of the assumptions were presented or discussed, and the project is supported by the right entities.
- Given the limited budget, the approach seems strong. The project manager did a lot with a very small budget. This reviewer would like to have seen more investigation of bulk storage technology.

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

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

- The work has been very productive relative to the costs to DOE. Comparisons to other energy storage options show that the fuel cell option is quite attractive, given the optimistic efficiency values used.
- The model is essentially complete. There should have been more discussion of sensitivity analysis, at least regarding the definition of the high-impact parameters.
- The cost estimates for electricity "break-even" costs seem optimistic, but the study is interesting because of the questions it raises more so than its conclusions.
- The analysis results were clearly presented. The model behind the results appears to be relatively simplistic, and may not take into account the lack of full utilization of the equipment (only six hours per day rather than 24 hours per day) in the cost calculations. Because this is not the first time this analysis has been performed, the researcher should compare the results to prior results, such as the analysis performed by Darlene Steward and Todd Ramsden (National Renewable Energy Laboratory). This project concludes that avoiding curtailed wind is a viable business case, but only by making a huge assumption that the first six hours of electricity is free due to curtailed wind. Even if the wind power would otherwise need to be curtailed, the wind farm owner will still want to get paid for the wear and tear on his equipment.

Question 4: Collaboration and coordination with other institutions

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

- This project features good information exchange with several organizations.
- The project obviously attempted to collaborate with as many resources as possible, given the small budget.
- Additional collaborations would have been beneficial, especially vetting the assumptions with utilities that have looked at the business case for this type of work, such as Xcel Energy.
- The formal collaborations on slide two are inadequate. However, the informal participants listed on slide 14 fill in the gaps in expertise.

Question 5: Proposed future work

This project was rated **2.6** for its proposed future work.

- Investigators should forget the scaling and modeling proposals and focus on the value added by bulk hydrogen storage. If bulk hydrogen storage is not cost effective or technically feasible, then there is no point in pursuing this line of research. Consequently, future work should achieve the following:
  - Determine the amount that can be spent on bulk hydrogen storage
  - Determine the technical feasibility of bulk hydrogen storage
  - Determine the best technical approach for bulk hydrogen storage considering costs, codes, and geography
- Future plans are reasonable to complete the project, but plans beyond the end of the current project should be further reviewed by the hydrogen community to ensure relevance and avoid duplication of effort with limited resources.
- Expanding the scope of the scenarios (non-utility, location, etc.) should be deferred until the project team ensures the current model assumptions and methodology are acceptable.
- The project is nearing completion. Future work comprises of wrap-up activities.

Project strengths:

- The results look very promising. The model seems simple enough to allow parametric sensitivity.
- The model could be useful for the industry if an executable version was made widely available.
- This project examines an important opportunity for hydrogen technology to greatly increase the amount of renewables that can be supplied to today's grid without needing to expand the distribution network.
- Collaboration with utility companies was an area of strength for this project.
- This project raised good questions for further research.

Project weaknesses:

- Details of the model were not presented, but from the results it appears to be a simple model without some of the financial and technical complexities that make this business opportunity more difficult in reality. The reviewer asks if this project is repeating analysis that has already been performed.
- Basing cost and efficiency estimates on DOE targets places a strong constraint on the promise of this energy storage option.
- It would have been nice to spend a little more time discussing the methodology.

Recommendations for additions/deletions to project scope:

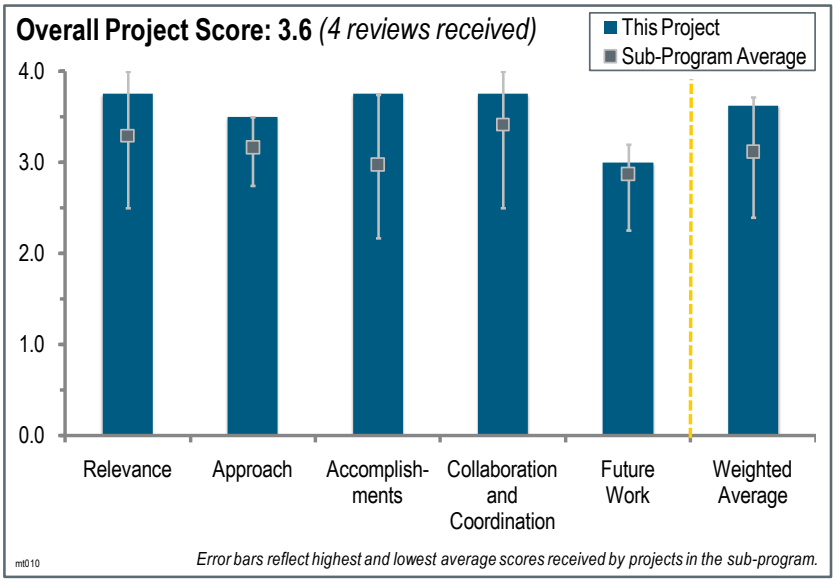
- Defining the parameter space (fuel cell cost, efficiency, etc.) where the proposed fuel-cell-based storage model is economically attractive could be very useful to defining the technical targets for this scenario. Investigators should present the data to competing model proponents (e.g., compressed air energy storage) to explore improved economics through hybridization.
- One suggestion would be to use existing and projected hydrogen technologies' costs as opposed to existing energy storage, as this provides a realistic and fair comparison.
- Going forward, the project should focus on bulk hydrogen storage, including potential technologies and their associated cost and benefits for reasonable applications.
- Investigators should be clearer in presenting how the costs are attributed to hardware that does not operate continuously (there is only a 25% utilization of the electrolyzers, for example). Other cases should be examined besides "free" curtailed wind power where all of the costs meet DOE targets.

Project # MT-010: Fuel Cell Mobile Lighting

Lennie Klebanoff; Sandia National Laboratories

Brief Summary of Project:

The U.S. Department of Energy (DOE) broadened the scope of the Hydrogen and Fuel Cells Program to include early market uses of fuel cells, including non-motive equipment for portable power, aviation ground support equipment (GSE), construction, backup power, and other non-vehicle applications. This project funds the design, construction, and field testing of five hydrogen fuel cell mobile lights that are suitable for aviation GSE and general construction. The overall objective is to produce a field-tested commercially available system, thereby expanding the use of fuel cell equipment in diverse applications.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.8** for its relevance to DOE objectives.

- This project is an excellent example of taking existing technologies (fuel cells for backup power and efficient lighting) and combining them to create a new market with multiple advantages over the incumbent technology. This project helps reduce noise, emissions, and greenhouse gases and clearly highlights the benefits of hydrogen fuel cell technology to a broad audience who might not have previously encountered the technology.
- The Program used to be more narrowly focused on just transportation applications. This focus has expanded over the past several years to include more diverse applications of the technology, therefore it is important to demonstrate feasibilities and value propositions. This project can have a strong education and outreach impact because one of the application areas is the entertainment industry.
- This project represents a good niche application. Projects like this should be funded. This project should have a high chance of success with good public relations and good data collection.

Question 2: Approach to performing the work

This project was rated **3.5** for its approach.

- This project features a well thought-out approach and a good breadth of partners.
- This project has a good project team that can take it all the way from concept to pre-production.
- It appears as though the approach quickly led to hardware that could be demonstrated, and once people saw the results, they wanted to try it out themselves.

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

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

- The project team has advanced the technology from the early prototype phase to the near-commercial phase. The project has engaged a variety of stakeholders and has been recognized in the public, further enhancing its outreach.
- Excellent progress has been demonstrated on this project. This reviewer cannot wait to see what ideas this project team comes up with next. The project has done a good job of publicizing the technology at appropriate trade shows and increasing its visibility by winning prestigious awards.
- The project seems to be on target.

Question 4: Collaboration and coordination with other institutions

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

- Excellent teamwork is apparent from all project partners. Including a company that could mass manufacture the future project is good because it prevents it from becoming a one-off project. The five demonstration sites (and partners) seem to have been strategically selected to gather useful data and expose future customers to the technology.
- This project was able to get together an impressive amount and diversity of stakeholders and partners.
- This project's collaboration seems better than most..

Question 5: Proposed future work

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

- The project team should also discuss plans beyond the current project and fiscal year, such as the plan that goes beyond these five units. The reviewer wonders if there is a way to demonstrate a larger deployment in the United States—for example, to have 50 units ready to deploy to the next natural disaster (e.g., hurricane, tornado, or earthquake).
- Not much was said about future work past the completion of this project. The investigators might want to elaborate on how the project findings will be used.

Project strengths:

- This project represents excellent execution of a novel idea. While the concept is simple, nobody had done it before, so this project paves the way. A strong, multidiscipline project team has been assembled to cover all aspects of the project. The project opens the door for creatively finding other opportunities to replace mobile generators with mobile (self-contained) fuel cell units.
- This project brings together a diverse set of partners and enhances the benefits of fuel cell technology by coupling with more efficient lighting systems. The project demonstrates the technology in a variety of applications and conditions, each able to provide feedback on different aspects of the technology. The project also promotes the hydrogen infrastructure and engages early market users.
- This project features a good approach, high-quality collaboration, and superior cost-effectiveness.

Project weaknesses:

- It does not appear as though any cost-benefit evaluation has been performed. Hydrogen fuel cells will always be cleaner and quieter than diesel generators, but they will not be broadly adopted unless the business case is evaluated and publicized. The presentation did not articulate how safety, codes, and standards were addressed for carrying around hydrogen in a small trailer. The reviewer questions whether this was addressed or simply ignored for the time being.
- This project's future work is unclear.

Recommendations for additions/deletions to project scope:

- Investigators should conduct an economic analysis, including an estimation of when the technology could become cost-competitive with the incumbent technology. The project team could also hold a "road show" and tow one of the trailers all over the country, refueling at hydrogen fueling stations by day and lighting up parking lots for concerts and football games by night. Investigators should initiate discussions with the Federal Emergency Management Agency about testing out some of the units during the next natural disaster. Having a run time that exceeds two days would certainly provide value for search and rescue activities by negating the need to refuel.
- Various case studies should be prepared upon project completion and disseminated to wide-ranging audiences, leveraging the reach of the project partners involved.

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