2012 — Market Transformation
Summary of Annual Merit Review of the Market Transformation Sub-Program

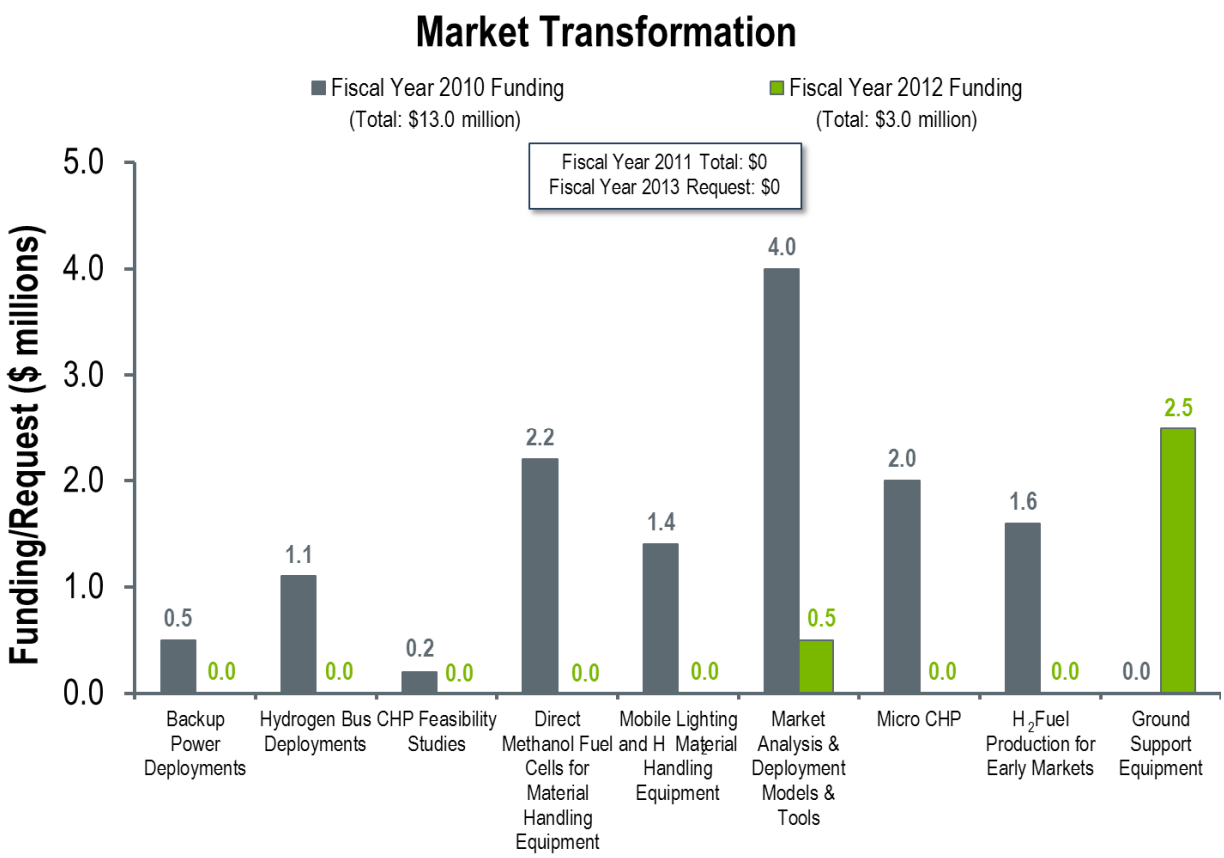
Summary of Reviewer Comments on the Market Transformation Sub-Program:

The purpose of the Market Transformation sub-program is to spur market growth for domestically produced hydrogen and fuel cell systems. By supporting increased sales in key early markets, this sub-program helps 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 the Market Transformation sub-program is to build on past successes in lift truck and emergency back-up power applications (part of the U.S. Department of Energy's [DOE's] American Recovery and Reinvestment Act of 2009 [Recovery Act] efforts) by exploring the market viability of other potential and emerging applications. Four projects were reviewed this year, and 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 the technologies can play a valuable role.

Generally, reviewer comments on the sub-program were positive, and its activities were considered to be important to enabling the commercialization of hydrogen and fuel cells. Reviewers considered the sub-program to be well-managed and noted the extensive collaboration involved in the projects and the substantial leveraging of federal funds by cost-sharing. However, a number of reviewers felt that the Program lacks an overall cohesive market transformation strategy and that the current projects do not seem to be part of an integrated plan.

Market Transformation Funding:

With the market successes that have been achieved by fuel cells in lift trucks and back-up 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 specialty vehicles. As shopwn in the chart on the next page, no funding was requested in FY 2011. FY 2012 funding was leveraged by partnering with other federal agencies and stakeholders to deploy fuel cell systems in their operations. Although not reflected in the FY 2012 budget, DOE invested $43 million under the Recovery Act to enable the deployment of up to 1,000 fuel cells for early market applications such as forklifts and back-up power. The Market Transformation budget request for FY 2013 is zero.



Majority of Reviewer Comments and Recommendations:

The Market Transformation sub-program's projects were rated average to high, and overall ratings ranged from 2.7 to 3.4, with an average score of 3.0. All projects were judged to be relevant to the DOE Hydrogen and Fuel Cells Program's (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.

Stationary Applications (Micro CHP): One project was reviewed, with a score of 2.7. Reviewers commented that this project was clearly relevant and could help build significant market share for hydrogen and fuel cells in the near term. They also observed that this project was well designed for collecting and analyzing data. However, reviewers expressed concern that too much effort is being spent on modeling and more attention is needed on understanding the results of the fuel cell in the real world.

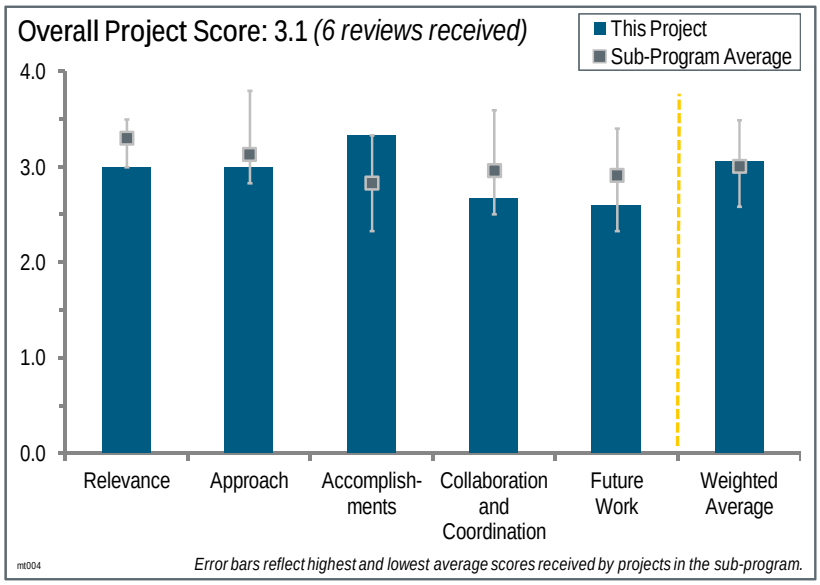
Transportation and other Mobile Applications (Direct Methanol Fuel Cells for Material Handling Equipment and Hydrogen Production for Early Markets): Three projects in this area were reviewed, with an average score of 3.1. In general, the reviewers were complimentary of the work being performed and pleased with the progress being made. While reviewers were encouraged by the relatively low cost to DOE and the high partner cost shares, they noted that the added complexity of multiple partners has caused delays on one project and schedule uncertainty on the others. Several comments were directed toward better aligning project objectives with Program goals.

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

Todd Ramsden; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) deploy and test fuel-cell-powered material handling equipment (MHE) using methanol in direct methanol fuel cells (DMFCs), and (2) compile operational data of DMFCs and validate their performance under real-world operating conditions. The longer-term objective is to help transform the market for fuel cells in material handling applications and provide information to help replicate successful deployments.



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

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

- It is extremely valuable to explore technologies that offer effective alternatives to hydrogen fuel cells. It is extremely useful to be able to test and operate in a real-world environment to develop the business case and make technological improvements. This type of project is also valuable for getting the word out as well as finding the "sweet" spots for further market adoption.
- The Battelle Early Fuel Cell Markets study had identified MHE as the most advantageous early market application of fuel cells because of its well-defined duty cycles, power plant size, and economics. This project can validate the results of that study as a major stepping stone to the commercialization of fuel cells for this and other applications.
- This work supports gaining experience on fuel cell operation in general; however, DMFCs only partly support the transition to a hydrogen economy.
- This project is clearly relevant to the mission; material handling in all its aspects seems to be gaining ground as a market for hydrogen fuel cells. Putting them on pallet jacks may be a "stretch," but it had to be tried.
- Logistic-type fuels for commercial fuel cell applications are always an obstacle. This project, which uses methanol as a fuel, helps solve that issue. However, studies have shown, for autos, that methanol-fueled vehicles do not reduce CO_2; so, to be consistent with DOE's CO_2 reduction goals, some effort should be made to show a CO_2 reduction for methanol in this type of vehicle. Perhaps this can be done by comparing the CO_2 emissions to the CO_2 emissions from the grid used to recharge battery vehicles.
- This project does provide a relevant application using the DMFC as a proxy for operational performance of hydrogen polymer electrolyte membrane fuel cell systems in forklift applications.

Question 2: Approach to performing the work

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

- The project approach is well defined and understood based on several years of supporting hydrogen fuel cell forklift deployments. The one factor that could improve the project is to have several performers. By only having Oorja Protonics performing, the project is not getting the type of technical, cost, and performance-type data that are available in the hydrogen fuel cell forklift projects. This reviewer recognizes this may be a result of funding and/or market maturity, but it is a limiting factor in the project.

- Fuel cell operating data are being obtained by the fuel cell vendor, Oorja Protonics, and the National Renewable Energy Laboratory (NREL) is compiling and analyzing the data in a manner similar to what was done for the fuel cell vehicle technology validation study. Those results were well received by the research community.
- This work displays a generally straightforward approach, but some more issues could be addressed, such as the energy chain (where the methanol comes from, or the efficiency of the DMFCs), or direct comparison to hydrogen-MHE (business case, greenhouse gases). It is unclear if the operating strategy (battery charging) really adapted to the user profile, and if different operational strategies are being tested.
- This was a well-structured "sub-project"—a piece of the larger NREL pie that provides the community with useful data on a wide range of the hydrogen fuel cell markets. It seems that the project, when complete, could give a clear picture of the potential of deriving real revenue from this segment of the material handling market.
- This project has a good approach, particularly with regard to refueling.
- The testing data achieved are significant and, at 65% completion, the project is well underway to achieving completion.

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

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

- The project's performance and data collection and analysis seem to all be on track. An analysis should be conducted to address the emissions factor, and DMFC technology should be discussed in relation to the hydrogen fuel cell and battery technologies, which are alternatives. In addition, a very careful evaluation should be conducted to analyze the total cost. Prior work suggests that there are some assumptions that fall victim to real-world experience.
- All 75 units have been deployed, as of June 2011. Significant operating data and experience information are being obtained. A large number of methanol fills have been conducted, with no incidents being reported. Several issues have been identified (methanol concentration sensor, electronics, mixer temperature, fuel leak) and corrected. Illustrative data from "good" and "failed" stacks were reported. It is unfortunate that fuel cell degradation data, although obtained, were not reported.
- This project has made good progress concerning the deployment of MHE and data collection, but the impression is that more information and more conclusions on DMFC could be drawn from the project. Data evaluation and results presentation could be more systematic and clear.
- This work met the goal of installing DMFCs on 75 Class III forklifts. It displayed good tracking of operation and "events" (maintenance and other). So far, very useful data is being produced.
- This project produced lots of real-life data, but it needs more information on stack life and costs. This reviewer particularly liked the chart that shows the issues, approaches to solving the issues, and the results.
- The progress seems valuable and significant progress has been made. The demonstration clearly establishes a forum for determining performance and operation and maintenance issues. It is noteworthy that the project team (Oorja Protonics) made system improvements during the program—this showed commitment to the goal of producing a viable product and not just taking data.

Question 4: Collaboration and coordination with other institutions

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

- This project has a good lineup of industry and government involvement. Having three different users is expanding collaboration and helping with the education and understanding in a wider population.
- Although collaborations with Oorja Protonics and the demonstration host sites were listed, this one being a DMFC project, there were no interactions listed with other fuel cell developers, even for similar applications.
- The collaboration seems limited to the strictly necessary work. Enhanced collaboration could increase the benefit of the project.
- This work has a solid relationship with Oorja Protonics and the three deployment sites.
- This project needs more input, in words, from customers who were using the equipment.
- It was good to see significant industry and private-sector collaboration among Oorja Protonics and the food distributor end users.

Question 5: Proposed future work

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

- The demonstration will be continued to its normal termination. Future activities will include maintenance and reliability analysis. Future work will also include an analysis of the cost of ownership.
- The main intention of the project should be explained more clearly.
- The team seems very well focused on wrapping this project up in a manner that will result in very useful data.
- This work is reasonable, but it needs more information on cost assumptions and life-cycle cost.
- There does not appear to be a plan for reuse after demonstration, though the refueling systems and some portion of the 75 units should be able to continue service.

Project strengths:

- The project appears to be well executed.
- This project has a pragmatic approach, real-world application, and conducts testing under challenging conditions.
- This project has good planning, a good team, and good execution. This reviewer is looking forward to seeing the final wrap-up.
- This project demonstrates several allocations with real operating information and real refueling experiences.
- This work demonstrates a significant number of units in a real-world environment.

Project weaknesses:

- The project needs more information on life and costs.
- Some of the results are not being released due to proprietary considerations. These include fuel cell degradation data, which is unfortunate. It is not clear if similar restrictions will also apply to the results of the analyses listed for future work.
- This work has an incomplete approach; many additional questions could have been addressed with the same budget. DMFC as an auxiliary path to the hydrogen economy should be compared directly with hydrogen MHE, including through an environmental impact study.
- One reviewer would like to have seen a bit more focus on classic technology readiness level analysis. Given the relatively large number of maintenance events, this reviewer would like to know how close DMFCs are to being really ready for prime time.
- Another reviewer felt there were no weaknesses.

Recommendations for additions/deletions to project scope:

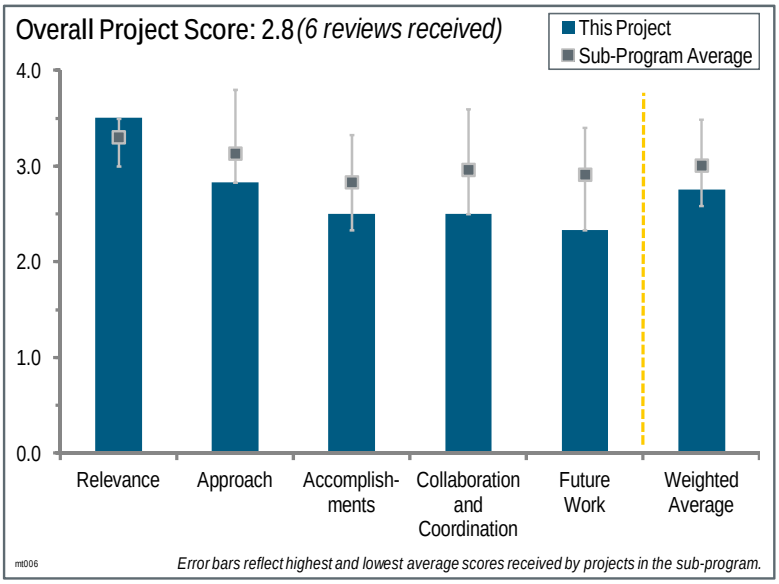
- The project should add a direct comparison of cost und well-to-wheels efficiency of DMFC and hydrogen fuel cells. This reviewer also suggests that the project test different operational strategies (such as battery charging or permanent fuel cell operation) and their effects on durability and fuel economy, and study the impact of methanol use on the environment.
- While manufacturers and owners of Class III forklifts are important, and their input seems to have been taken into account, in the end, the users are the key to product acceptance. If possible, it would be useful to collect data from this level on whether the benefits of refueling versus changing batteries outweigh adding a great big box on top of the battery pack.
- The project should maintain more information on costs, life, and customer experiences. The project also needs more information on the details of the fuel cell. This reviewer also suggests that the team carefully record the impurity levels in methanol and monitor air quality around units and emissions from the units, particularly trace organics.
- Another reviewer had no specific recommendations.

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

Dale King; Pacific Northwest National Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) demonstrate combined heat and power (CHP) fuel cell systems, (2) objectively assess their performance, and (3) analyze their market viability in commercial buildings. Fuel cell system durability, efficiency, production, and economics will be evaluated against stated manufacturer specifications. Commercialization "bottlenecks" will be identified to determine where industry needs to apply the greatest effort to achieve high market penetration.



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

This project was rated **3.5** for its relevance to DOE objectives.

- This Pacific Northwest National Laboratory (PNNL) project fully meets DOE research, development, and demonstration objectives and fully supports the eventual commercial development of stationary fuel cells. While the project is necessary, this judgment is based more on knowledge of the industry rather than the presentation itself. As presented, an observer might not get the same impression.
- This project aligns with the goals of the DOE Hydrogen and Fuel Cells Program (the Program). Demonstration of the real-world performance of "commercially ready systems" is key to validating the cost, reliability, and durability of the technology. Furthermore, operating data offers a resource to assess the cost/benefit of any DOE research and development funds spent to develop the demonstrated fuel cell system.
- This project is highly relevant to the objectives of the Program, especially when taking into consideration that CHP systems are likely to become commercialized early and on a larger scale than other fuel cell technologies.
- The project deploys "commercially available" fuel cell CHP systems in a wide variety of applications and geographical locations. Real-world cost, performance, and durability/reliability data are being obtained.
- This project is clearly relevant to the broad goals of the Program.
- Small-scale CHP is a critical application for fuel cells.

Question 2: Approach to performing the work

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

- The fit of fuel cell CHP for a given application is assessed by comparing heat and power requirements to what is provided by the fuel cell system. Assessment of fuel cell types includes polymer electrolyte membrane (PEM) and solid oxide fuel cell (SOFC). The project compares manufacturer claims with field data. Data collection and reporting are comprehensive and understandable.
- The presentation had no real discussion of critical barriers; it was more a presentation of data than a presentation of the program. In short, the grading of this program and its presentation could have been better if the project, and/or the report of the project, had focused more on programmatic issues than a report of observations.
- The approach is an excellent one—enlisting manufacturers and users in a comprehensive study of what it takes to get hydrogen fuel cells out into the real world. Long-term detailed monitoring of site performance may be "overkill," but in the end it will provide traceability of both good and bad performance.

- This project team spent too much time modeling and explaining the modeling; more time should be spent on understanding the fuel cell real-world results. Applications should be chosen where the building uses all the fuel cell electrical output and does not count on selling into the grid. Selling into the grid varies by state and at any time the local public service commission could change the rules.
- This project is well designed to collect operating data. Its creation of the small and large building model offers a reference to compare real operational data with the expected needs of buildings.
- The approach is well thought through and effective. Including a timeline in the "Approach" slide would be useful for monitoring progress in the future.

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

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

- So far, the deployments include PEM fuel cells from only one supplier. It would be interesting and instructive to include deployment of other fuel cell manufacturers and other types of fuel cells such as SOFC.
- The amount of data clearly indicates that PNNL focused on the objectives, but an absence of discussion on the barriers leaves too many questions. It is not clear to this reviewer what challenges existed in accumulating the data, if any.
- The amount of work that has been done on the project is truly impressive, but the "Overview" slide is very confusing. This reviewer questions how the project can be 33% complete, with 100% of the money spent. Clearly there is more work to be done, since the group says so in the "Future Work" section, but to imply that two thirds of the project is incomplete at this point seems very wrong. If it is really correct, then "Accomplishments and Progress" should be ranked as "poor!" The modeling work was good. A direct comparison with data from "large offices" (e.g., college, school, medical center) and "small offices" (e.g., grocery, laundry shelter) should be attempted. The cost analysis was particularly illuminating, though depressing—it is unclear how long subsidies of 50% will be required.
- The project has progressed from 5% (2011) to 33% (2012). Protocols for recording and analyzing data are in place. The remaining success in obtaining significant data for analysis will largely depend on the performance and availability of the fuel cell system.
- System acquisitions appear not to have been completed yet. Fifteen units in operation represents 40% of the total number of systems originally planned (38). It is not clear whether more systems will be coming online. System monitoring appears to be going well. The downward trend in the performance of virtually all units is worrisome; an average power loss of 20% over approximately 3,500 hours of operation is very high.
- The presentation was so poor that this reviewer could not tell what was accomplished.

Question 4: Collaboration and coordination with other institutions

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

- The discussion was too short on this critical review area. Except for an obligatory slide listing some partners, there was zero discussion about what anybody else did. In short, this project is apparently a PNNL-only affair.
- The group seems to have been able to enlist a large number of participants on the "user" side, and it is doing better on the supplier side. This reviewer would still like to see more fuel cell suppliers onboard.
- Four partner sites are adequate for diversity of operational data for the 15 fuel cell systems. Future presentations should comment on external site factors (non-fuel-cell-system factors) that impacted the fuel cell systems' operation or data (e.g., utility outages, site maintenance), as these are real-world factors.
- Collaboration with manufacturers and customers is good. Partners with expertise in fuel cell stack and system performance diagnostics may be needed soon, given severe performance losses to date.
- The presentation needs more words and opinions from the supplier and from the host sites.
- Collaborations and coordination are, appropriately, with fuel cell suppliers and deployment sites.

Question 5: Proposed future work

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

- The project's score continues to suffer because the presentation focused on data delivery rather than a complete review of programmatic issues. This reviewer does not recollect any discussion of future improvements.
- The presentation offered a limited definition of proposed future work at this time. If future sites and systems are added, the selection should be based on expanding the type and operating environments.
- Proposed future work concentrates almost entirely on data acquisition and analysis monitoring. More focus on understanding the causes of performance degradation is needed, including advanced diagnostics of individual cells in fuel cell stacks.
- The presentation needed more information on life and costs.
- The effort to broaden participation of other fuel cell suppliers and sites continues. The discussion is somewhat vague.

Project strengths:

- The installation of 15 units in the fourth quarter of fiscal year 2011 was an accomplishment. Performance monitoring has already yielded interesting data and pointed to possible durability issues with the systems. Data collection, analysis, and reporting are strong.
- This project's significant population (15) of fuel cell systems and five-year project duration offers a good base of data.
- This project shows a tremendous amount of data delivery, and the presenter was clearly in an area of strength.
- This project has a good handle on performance data and expected results.
- This project has a good variety of applications and a good choice of technology.

Project weaknesses:

- Having only one original equipment manufacturer limits the variability of systems and the relative performance of the PEM unit.
- The lack of diagnostics of the causes of performance loss is a weakness—especially in the context of a prohibitively fast performance loss of already installed systems.
- It is important to include other fuel cell types and systems from additional suppliers.
- The presentation of the project was almost a book-report-type presentation—a lot of discussion of what, but no discussion of what was, what will be, what could be, what should be, why, who, or what is next.
- The project's management approach seems a bit diffuse.
- The project's results were very poorly presented.

Recommendations for additions/deletions to project scope:

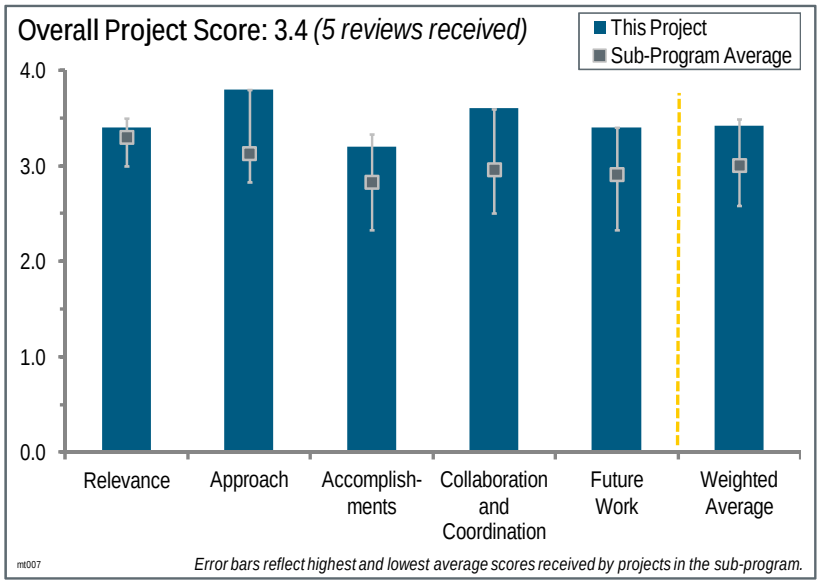
- A clearer picture of the funding for this project, and how it is being used, would be very helpful in evaluating the bottom line. The project still needs to enlist more than one fuel cell maker. The modeling work was good. A direct comparison with data from "large offices" (e.g., college, school, medical center) and "small offices" should be attempted.
- Provide less information on the model and more information on operating results and life-cycle costs, including capital, today or projected, and maintenance.
- The reasons for performance degradation should be identified, which will likely require monitoring of individual cells in stacks. Maximum acceptable performance loss should be established. If performance loss of the 15 installed systems continues to be a problem, units from alternative sources should be acquired and deployed as soon as possible.
- The presenters should take a better look at what they present during a review and the criteria to be judged against. The PNNL work is too important for necessary elements to be overlooked (or ignored).
- This reviewer did not have any recommendations to add or delete to the project scope.

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

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

Brief Summary of Project:

The objectives of this project are to: (1) validate the business case and technical feasibility of using landfill gas (LFG) as a "distributed generation" option for hydrogen production, and (2) transfer "lessons learned" that may be applicable for other candidate waste streams. Commercially available equipment will be surveyed to determine the economic viability of the LFG-to-hydrogen approach for potential end users, and the technical viability of current systems to produce sufficiently pure hydrogen for use in motive or other applications will be demonstrated.



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

This project was rated **3.4** for its relevance to DOE objectives.

- This project is spot-on in that it is focused on market transformation rather than a science project. Over the course of the presentation, it became clear that the project's initiative was to truly advance the marketplace for fuel cell technology.
- This project has the objective of generating renewable hydrogen from LFG, and using this hydrogen to fuel the fuel cell material handling equipment (MHE)—i.e., forklift trucks, with commercially obtained equipment and components. Further, the project is being hosted by a large company, BMW, which would be interested in scaling up the project for its commercial use once the concept is proven at the project scale and a viable business case can be established. It was stated that the LFG source should be good for more than 20 years. This is a very worthwhile market transformation project; it has all the right ingredients.
- This project has a good future perspective and a big field of application, including a pilot implementation that can be spread to many other locations afterwards.
- Establishing LFG as a source of hydrogen is not really in the "mainline" of the DOE Hydrogen and Fuel Cells Program, but it certainly does support the production of hydrogen from renewable resources.
- This project uses LFG to generate on-site hydrogen for forklifts.

Question 2: Approach to performing the work

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

- This was one of the best planned, best presented projects this reviewer saw at the 2012 DOE Hydrogen and Fuel Cells Program Annual Merit Review. From selecting the "perfect site" (a plant that uses hydrogen MHE and is located virtually on top of a landfill) to working hand-in-hand with a very influential partner, South Carolina Research Authority (SCRA), the project team has done a superb job. The team showed great foresight and flexibility to adapt to changes out of the control of the immediate project team. The project had good focus on putting together a "real-world" example of exactly what the project is supposed to accomplish—demonstrating the utility of LFG-to- hydrogen production to serve the needs of an industrial user.
- The project began with a feasibility study and a business case analysis, which were completed in four months. From the beginning, the potential customer for the technology, BMW, was involved in settling the parameters for

the study, and it had a lead role in approving the project to proceed to Phase II. The project is currently in Phase II, conversion of LFG to hydrogen, where the purity of the product hydrogen will be monitored for two months to determine the variability in the process over this extended period. The final phase will be to conduct side-by-side trials of MHE fueled by the LFG-derived hydrogen and the current, commercially sourced hydrogen. This should validate the technical approach with a high degree of confidence in the results of the project.

- The project takes advantage of existing LFG infrastructure at BMW for the demonstration. BMW has direct experience with hydrogen fuel cell forklifts. However, the discussion of hydrogen purity requirements is lacking. This project builds a system from known technology components so no new science or breakthroughs are required.
- This project displays a very stringent approach that is focused on a feasibility study and business case analysis. With this approach, decision makers can easily evaluate if this is an option for their application. Limitation to commercially available technology limits the technological risk for implementation.
- This work is clearly and directly focused on meeting the goals of market transformation, not to keep working, but to transform business opportunities.

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

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

- The major accomplishment to date is the completion of the feasibility study, which showed that at a large enough scale, perhaps 500 kg H_2/day, the LFG-derived hydrogen would be cost competitive with industrial gas hydrogen, based on a 10-year analysis. Longer analysis periods and larger scales of production would further reduce the cost of LFG hydrogen. In other progress, it was reported that the LFG gas clean-up skid has been built and tested by team member GTI, and that it will be shipped to the BMW host site shortly.
- This project had good results from the feasibility study, which will provide a solid basis for future decision making on further steps.
- This project seems to be on track, and it is likely to meet the July milestone. Considering the relatively low cost and high (50%) "leverage," this reviewer recommends funding Phase III of this project if this milestone is met.
- The progress of this work is difficult to gauge based on the information provided. It is not entirely clear if the project is on schedule.
- This project displays clear and definitive progress toward implementing a useful product.

Question 4: Collaboration and coordination with other institutions

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

- This project is clearly partnering with BMW; BMW is not just listed as a project participant but is a focal point of the project. Other principal investigators should take a look at how SCRA partnered with BMW.
- It would be good to have the MHE supplier on the team. Otherwise, all expertise is present. BMW involvement as the site host is advantageous.
- This work displays very good communication with project partners, which was essential for project success because partners had to be convinced of the business case in order to proceed with the next phase.
- This reviewer was impressed with the way the project brought BMW on board, and pulled together the rest of the team.
- The project team includes industry and not-for-profit organizations.

Question 5: Proposed future work

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

- SCRA fully meets the definition of "Outstanding"; the future work will continue to execute the project as planned, which is the appropriate path to follow.
- The project is taking further steps based on the existing hydrogen-MHE infrastructure, and the new hydrogen source will be incorporated into the system. A comparison between different hydrogen sources will be of great value.

- Future work plans are logical and consistent with the project timeline.

Project strengths:

- This work had quite a number of strengths, but two stood out: (1) SCRA's partnering with BMW indicated that the two entities were very much together in this project and (2) the focus on achieving a fundamental transformation, rather than on advancing a single narrow objective that would hamper real progress.
- This project has a multifaceted, well-coordinated project team and strong involvement from BMW, the host organization. The presentation displayed a good understanding and discussion of the critical issues, as given in the reviewer-only slides.
- This work is combining a new hydrogen source with an existing hydrogen infrastructure, which will be a reference for future projects.
- The project's strengths include excellent planning, a tight focus on execution, an impressive team, and a convincing business model.

Project weaknesses:

- The project's potential problem is in getting a valid "side-by-side" comparison of locally produced hydrogen with trucked-in gas. This reviewer questioned if the plan is now to pipe the reformed gas to the outdoor refueling site.
- One reviewer felt that no significant weaknesses were evident.
- Another reviewer felt there were no weaknesses.

Recommendations for additions/deletions to project scope:

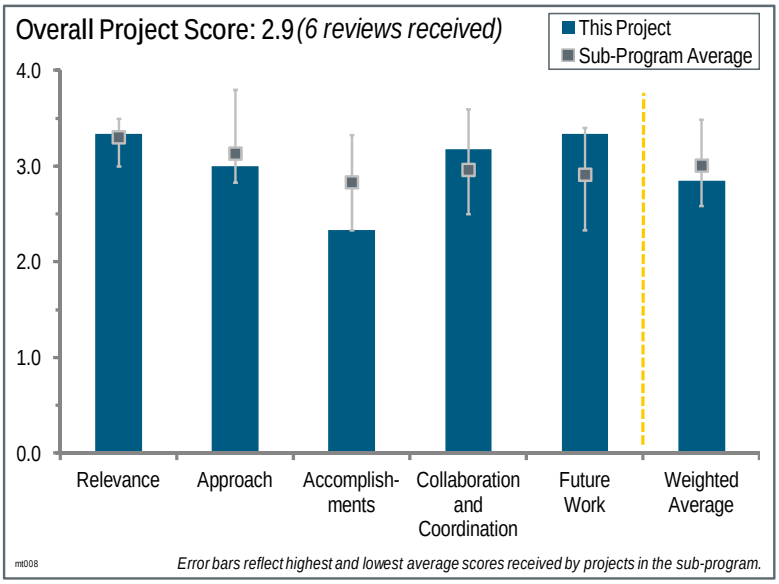
- One reviewer recommended extending the project to study the effects of landfill hydrogen not only on MHE fuel cells, but also on the existing refueling infrastructure.
- Another reviewer recommended funding Phase III if the July milestone is met.
- A third reviewer did not have any recommendations and commended the team on a good and complete job.

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

Mitch Ewan; Hawaii Natural Energy Institute

Brief Summary of Project:

The objective of this project is to evolve energy systems through a four-step process of: (1) developing and validating rigorous analytic models for electricity and transportation, (2) developing and modeling scenarios for deployment of new energy systems including additional renewable energy systems, (3) identifying and analyzing mitigating technologies to address systems integration (grid stability) and institutional issues, and (4) conducting testing and evaluations to validate potential solutions to facilitate utility acceptance.



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

This project was rated **3.3** for its relevance to DOE objectives.

- The concept provides a way to combine and levelize renewable energy (geothermal and wind) through electrolysis hydrogen production. The current project is to use the hydrogen generated by hydroelectric hydrolysis to power vehicles. The hydrogen could also be used for grid leveling through fuel cells. The electrolyzer could also be used for grid management by reducing electrolyzer load when the renewable source (such as wind) is in a lull.
- The activities in this project are to: (1) demonstrate the use of a dynamically responsive electrolyzer and to characterize its performance, ostensibly when it is hooked up to a variable source, such us a wind turbine; (2) provide hydrogen to shuttle buses; and (3) conduct performance/cost analyses to assess the benefits of the integrated system, including grid services and off-grid revenue streams. None of these activities appears to be in direct support of DOE's Fuel Cell Technologies Program.
- This is the perfect opportunity to demonstrate the integrated energy system of the future. If this project is a success, it will serve as an example for larger-scale applications.
- The integration with other renewable/non-polluting sources of energy is of importance to the acceptance of hydrogen power technology. This project addresses key issues by creating and monitoring real-world deployments.
- This project covers a variety of DOE Hydrogen and Fuel Cells Program technologies and objectives, electrolyzers, buses, grid interaction, and fuel cells. The project's goals are ambitious.
- This work is extremely relevant to advancing a hydrogen economy, an effort necessary to tie a variety of initiatives into accomplishing a useful end result.

Question 2: Approach to performing the work

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

- The discussion on slides 6 to 8 refers to grid management to mitigate the negative impacts of intermittent renewable energy sources.
- As far as the technical approach goes, co-locating electrolyzers and fuel cells with renewable (wind, geothermal, solar) sources on-site is one way to maximize efficiency. This project is well focused on fostering acceptance of

hydrogen power technology. As far as the management approach, planning for the project could have been much better—some of the delays might have been foreseen.
- The approach is system orientated. Every step takes into account the overall objective. The approach could possibly be more focused to optimize the use of limited project resources.
- The approach utilizes renewable geothermal energy to produce hydrogen for fueling hydrogen-powered fuel cell electric vehicles (FCEVs). The plan is logical and methodical and does not require technical breakthroughs.
- This is a comprehensive, focused project that identified a number of critical challenges and investigated means to achieve a successful result.
- The approach is good; however, given the number of partners and parties involved, it is not surprising that there have been delays in getting actions initiated.

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

This project was rated **2.3** for its accomplishments and progress.

- Of the eight accomplishments listed on slide 21, four are administrative activities—contract awards, started (but not completed) environmental assessment, memorandum of agreement with Puna Geothermal Ventures 95% complete; two are vague—developing site design and replaced Ford buses with an El Dorado bus; and two are lining up additional funds. It is difficult to accept any of these as significant accomplishments. The presentation at the 2011 DOE Hydrogen and Fuel Cells Program Annual Merit Review (AMR) and the current presentation at the 2012 AMR were not all that different.
- This project has made good progress toward the objectives; the modifications on the way (e.g., switching from hydrogen internal combustion engines to FCEVs) are consistent, but it has had delays due to authorities outside the project.
- Some pieces are still needed to bring this work together. Completing tasks 4 through 7 in 2012 seems aggressive; however, the project is worthy of continuing its effort to fulfill demonstration.
- Progress on this project has been slow, primarily because of non-technical issues such as liability assignment and partner negotiation. A no-cost extension is under consideration.
- This work has achieved tremendous results specific to the project and in the team's overall efforts.
- This project is seriously behind schedule.

Question 4: Collaboration and coordination with other institutions

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

- Most of the relevant entities are (or will be) engaged, including a geothermal energy producer and a hydrogen fuel cell bus owner/operator. The performance and durability of the electrolyzer for this dynamic service seems to be unverified. This is a key part of the system concept. The project is well coordinated and depends on other related projects.
- While Hawaii Natural Energy Institute (HNEI) alone was the presenter of the project, it is apparent that HNEI also represents a well integrated and complete team effort by an organization with true partners; HNEI and their partners were together every step of the way.
- Collaborations listed on slide 22 include five that are either the principal investigator's (PI's) own organization or the project sponsors or managers. These only faintly qualify as collaborators in the technical sense. An additional one is listed as an "Interested Observer," which is vague and not very informative.
- Good collaboration is essential in a project such as this, but delays are due mainly to coordination and collaboration issues. Nevertheless, this reviewer gives the project a good rating because in this project the coordination with authorities seems to be difficult.
- This project has shown excellent "leveraging" of DOE funding and outstanding integration with local government and commercial partners.
- This project has displayed a high degree of collaboration among federal, state, and private entities. Given the complexity of getting all of the pieces together, the success to date is admirable.

Question 5: Proposed future work

This project was rated **3.3** for its proposed future work.

- The proposed future work is still the bulk of the project. However, with the addition of significant new financial resources, and the painful lessons learned in the first two years of the project, the team seems to have a better handle on how to do the job. The team should pay closer attention to project milestones, and in particular, the establishment of "backup" plans that can help overcome potential problems.
- The proposed future work to collect data from the various systems is promising. All will be predicated on the completion of the various tasks to get systems online.
- This is a complete and comprehensive project that presents a step-by-step approach to achieving meaningful goals to advance a hydrogen economy.
- The proposed work shown on slide 23 appears to be consistent with what will be needed to carry out the project.
- The proposed future work is very consistent with the overall project goals.
- The plan is logical and appropriate.

Project strengths:

- This project shows on a small scale what can be the energy grid of the future. Showing the alternative options of using hydrogen is another strength.
- This project displays an excellent understanding of how to work in the unique local environment and shows good project "vision."
- This is a complete and overall worthy project to accomplish serious goals. The PI is highly enthusiastic.
- The strength of this work is the diversity of its activities.

Project weaknesses:

- Extended time for permitting, etc., should have been foreseen. The presentation had a lack of clarity on the budget. On the "Summary" slide, the "total project funding" was listed as $1,796,515, yet in the same quadrant, fiscal year 2011 funding in the amount of $2.6 million was listed from various sources. Apparently, the $1,796,515 is just the DOE share, because it is approximately (but not exactly) the same as the DOE budget listed in the 2011 presentation. This seems like a minor point, but it calls into question the ability of the team to focus on the bottom line—despite its very impressive ability to leverage DOE funding.
- The electrolyzer performance has not been established for sustained cyclic operation, and the electrolyzer supplier does not seem to be a formal partner. The source of water for the electrolyzer is not identified. Operation near a volcano could have a negative impact.
- It is not clear how the project addresses "Barrier J, renewable electricity generation integration," which is, presumably, meant for variable energy sources, such as wind or solar. It is not clear just which non-technical issues preventing full commercialization of hydrogen are being addressed by this project.
- This is a very ambitious project with a small budget. Only one option of hydrogen use will be demonstrated. The mobile refueler solution (small trailer) is only applicable to very special cases such as this; it is pragmatic, but without relevance for larger-scale applications.
- This project's weakness is its complex administrative setup before real-world demonstrations can begin.
- One reviewer felt there were no weaknesses.

Recommendations for additions/deletions to project scope:

- One reviewer recommends adding projection for future extensions; for example, feeding electricity back to the grid and implementing a real vehicle refueling infrastructure with permanent refueling stations. This reviewer also recommends adding a study for transferring the results to bigger grids.
- Another reviewer recommends paying closer attention to project milestones, and establishing "backup" plans that can help overcome potential problems.

- A third reviewer recommends establishing electrolyzer suitability for the intended service.
- A fourth reviewer found it difficult to offer any specific recommendations, because the technical or market transformation objectives of the project are not very clear.
- Two reviewers did not recommend any changes.

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