

## X.2 Maritime Fuel Cell Generator Project

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Project End Date: March 31, 2015

### Overall Objectives

- Lower the technology risk of future port fuel cell deployments by providing performance data of hydrogen polymer electrolyte membrane (PEM) fuel cell technology in this environment
- Lower the investment risk by providing a validated business case assessment for this and future potential projects
- Enable easier permitting and acceptance of hydrogen fuel cell technology in maritime applications by assisting U.S. Coast Guard (USCG) and the American Bureau of Shipping (ABS) develop hydrogen and fuel cell codes and standards
- Act as a stepping stone for more widespread shipboard fuel cell auxiliary power unit deployments
- Reduce port emissions with this and future deployments

### Fiscal Year (FY) 2015 Objectives

- Enable new maritime-specific regulations for hydrogen and fuel cells
- Enable new user experiences
- Lower technology and business risk
- Maintain hydrogen infrastructure capability on Oahu in support of this and future strategic projects

### Technical Barriers

This project addresses the following technical barriers from the Market Transformation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- (A) Inadequate standards and complex and expensive permitting procedures
- (E) A lack of flexible, simple, and proven financing mechanisms
- (F) Inadequate user experience for many hydrogen and fuel cell applications

### Technical Targets

No specific technical targets have been set.

### FY 2015 Accomplishments

- Finished prototype design
- Completed hydrogen supply plan
- Finished site preparations
- Satisfactorily completed Factory Acceptance Testing of the prototype
- Performed site-specific quantitative risk assessment
- Began broad outreach campaign
- Obtained final USCG design and operating approval
- Performed on-site hydrogen safety and awareness training for over 200 Young Brothers Ltd. (YB) personnel, first responders, the USCG, and other stakeholders
- Provided product development leverage for technology supplier
- Supported Hickam hydrogen fueling station
- Provided leverage for a new, high capacity hydrogen delivery trailer



### INTRODUCTION

Fuel costs and emissions in maritime ports are an opportunity for transportation energy efficiency and emissions reduction efforts. For example, a 2004 study showed the Port of Los Angeles had average daily emissions exceeding that of 500,000 vehicles [1]. Diesel fuel costs continue to rise as low-sulfur limits are imposed, making

power generation more expensive for fleets. Hydrogen fuel cells have the potential to meet the electrical demands of vessels in the port as well as supply power for other port uses such as yard trucks, forklifts, and other material handling specialty equipment. Validation of the commercial value proposition of both the application and the hydrogen supply infrastructure is the next step towards widespread use of hydrogen fuel cells in the maritime environment, and is determined by meeting necessary equipment and operating costs and customer expectations such as reliability, form and function.

Sandia National Laboratories' recent report, "Vessel Cold-Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility," identified several opportunities for demonstrating technical and commercial viability of a fuel cell in the maritime environment [2]. One identified opportunity is in Honolulu Harbor at the YB wharf. YB provides barge transport of goods between Oahu and the Hawaiian neighbor islands and is an ideal demonstration location because of their high fuel costs and corporate interest in low emission, low environmental impact solutions (Figure 1). YB uses refrigerated containers ("reefers"), which keep perishable goods cold while on the dock and on the barge by using dedicated diesel generators mounted inside mobile 20-foot containers. Sandia's report concluded that it is technically feasible to build a containerized hydrogen fuel cell generator to replace the diesel generator in YB operations (Figure 2).

## APPROACH

This project develops and demonstrates a nominally 100 kW, integrated fuel cell prototype for marine

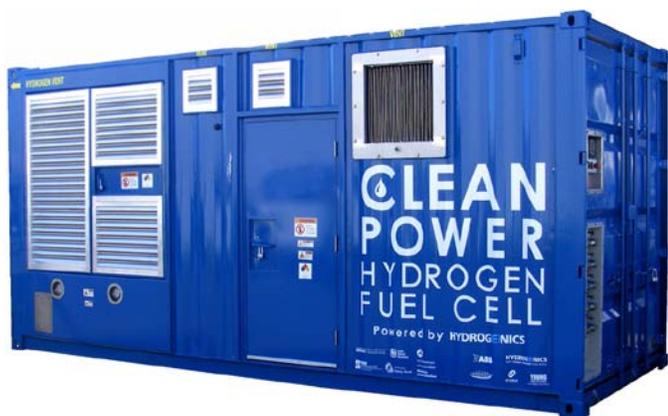
applications. This project brings together industry partners in this prototype development as a first step towards eventual commercialization of the technology. To be successful, the project incorporates interested industry and regulatory stakeholders: an end user, technology supplier and product integrator, and land- and maritime-based safety and code authorities. Project costs have been shared by the primary stakeholders in the form of funds, in-kind contribution, and material/equipment either loaned or donated to the project. Funding provided by the Department of Transportation's Maritime Administration (MARAD) is used to provide assistance with the integrated system and packaging designs, data collection and assistance during the demonstration period, and technical assistance and project management throughout the project. In addition, some MARAD funds are used to purchase specialized equipment needed to construct the prototype. DOE funds are used to provide overall project management, technical design assistance, and deployment facilitation, and are used via subcontract to the prototype manufacturer for the design, build, and testing of the final product.

The project has four phases:

1. Establishment and specification (September 2013–December 2013)
2. Detailed design and engineering (January 2014–March 2015)
3. Prototype fabrication/site construction (October 2014–June 2015)
4. Deployment (on-site demonstration) and analysis (August 2015–March 2016)



**FIGURE 1.** The Maritime Fuel Cell Generator will be used on the dock and over the ocean on barges such as this one, providing power for refrigerated containers during transit.



**FIGURE 2.** The Maritime Fuel Cell Generator contains 75 kg of compressed hydrogen storage and produces over 100 kW net electricity, packaged in a 20-foot shipping container.

## RESULTS

Key prototype build-related accomplishments (by subcontractor Hydrogenics) in FY 2015:

- Completed hydrogen storage tank factor certification testing and delivery
- Completed inverter factory testing
- Completed draft failure mode effects analysis (FMEA), and resolved potential operational handling issues.
- Designed and built hydrogen storage rack and ruggedized fuel cell rack
- Completed fuel cell module assembly
- Finalized procurement for container
- Finalized FMEA
- Submitted complete design package the USCG and ABS for review
- Built and commissioned all four 30 kW fuel cell modules.
- Released detailed container design drawings to subcontractor and completed 75% of container modifications
- Completed electrical system testing: fuel cell rack + inverter + ultracapacitor
- Completed hydrogen storage rack
- Completed container build
- Completed equipment mounting within container
- Completed all interconnecting piping and wiring
- Finished complete build
- Completed shakedown testing

- Completed Factory Acceptance Testing
- Shipped to Honolulu for deployment

The project team finalized the Data Collection and Analysis Plan, which describes how the project’s work will be captured and made useful to fulfil the objectives of the sponsors and stakeholders. There are three categories of data to be collected during the deployment: technical, business, and regulatory. The technical data includes both prototype performance and usage as well as hydrogen supply and refueling information. Working with the National Renewable Energy Laboratory, the project team was able to ensure that data collected will be directly comparable with other DOE efforts.

The YB-preferred method of fueling the prototype at the Hickam station was finalized. In this arrangement the prototype is placed on a container handling trailer (“chassis”) and a truck will drive it to the Hickam station where it will be filled by the Hickam station operator. This method is also anticipated to be able to fill the prototype to 100% in less than one hour. Currently, YB prefers this method because of its apparent logistical simplicity and will begin the demonstration refueling the trailer by this method. In FY 2015 Sandia, the Hawaii Center for Advanced Transportation Technologies (HCATT), and YB formulated the logistics (primarily timing) for this arrangement. YB also finalized an arrangement with a local trucker to perform this service.

Sandia engaged its in-house safety and risk experts, and DOE’s Fuel Cell Technologies Office Safety, Codes and Standards subprogram to perform an analysis of the prototype’s operation in the specific context of YB operations. The goal of this analysis was to quantitatively determine the impact of any usage restrictions on safety risk and was necessary because of the lack of applicable codes and standards on this type of equipment in these environments (on the dock and on the barge). The assessment consisted of three parts: (1) identification of scenarios where the prototype’s operation may present a hazard in the context of YB operations, (2) fluid dynamics simulations of hydrogen releases into the environment to assess the distribution and extent of flammable hydrogen concentrations, and (3) quantitative risk assessment to quantify the risk to personnel. The accomplishment of these three tasks enabled the project team to confidently recommend minimal operational restrictions on the prototype. (More detail is contained within the project’s “Safety Features Integrated into Design and Use of System” fact sheet and the project’s Safety Plan).

The project team engaged Pacific Northwest National Laboratory (PNNL) to administer Hydrogen Safety Training to local first responders and YB personnel. In the second quarter, the training materials were solidified through a combination effort by PNNL, their subcontractor Jennifer Hamilton of the California Fuel Cell Partnership, YB,

Hydrogenics, and Sandia. The result was a customized training package that included not only the general first responder information from PNNL's National Training Program but also specific information on the prototype's safety features and operation as well as information for YB personnel on special handling and usage instructions. The training was given April 9–11, at the YB facility in Honolulu, Oahu, and April 15–17, at the Kahului Fire Station, Maui and reached over 200 personnel. A summary of the training was published by PNNL [3].

The training was videotaped and during the third quarter (Q3) the videographer worked on final editing of two versions of the training: a full-length version that captures all aspects of the training, and a shorter version which focuses on hydrogen familiarity and the prototype's use and operation. The shorter version will be used in the fourth quarter by YB to train their operational personnel who were not able to attend the April training in person. Both versions of the video can also be used in subsequent deployments of this prototype at other locations.

In Q3 the Sandia outreach team produced two project fact sheets, one that overviews the project and one that explains the safety features of the prototype. The outreach team also stood up a project website ([maritime.sandia.gov](http://maritime.sandia.gov)), organized a blog post announcing the shipping from Hydrogenics, and has been responsible for organizing a project “ribbon cutting” ceremony for the project on August 28, at YB's Honolulu facility. To ensure all project partners continue to be part of these efforts, the outreach team established an ongoing bi weekly call with appropriate partner personnel.

## CONCLUSIONS AND FUTURE DIRECTIONS

The Maritime Fuel Cell Project is a wholly-collaborative effort with early and continuous stakeholder feedback that is breaking down non technical barriers to hydrogen and fuel cell use. Future work in FY 2016 includes:

- Finish deployment and data collection
- Produce technical and business case analyses
- Continue outreach based on project results

## FY 2015 PUBLICATIONS/PRESENTATIONS

1. M. Elmore and J. Hamilton, “Final Report: Maritime Fuel Cell Project Hydrogen Safety and Emergency Response Training, Honolulu, Oahu and Kahului, Maui – Hawaii,” Pacific Northwest National Laboratory, PNNL-24327, April 2015.
2. “Maritime Hydrogen Fuel Cell – Hydrogen Fuel Cell Demonstration Project at Port of Honolulu,” Sandia National Laboratories Fact Sheet, SAND2015-2566 M, April 2015.
3. “Maritime Hydrogen Fuel Cell – Safety Features Integrated into Design and Use of System,” Sandia National Laboratories Fact Sheet, SAND2015-2559 M, April 2015.
4. “Hydrogen Fuel Cells Help Ports Meet Environmental Goals,” Partnerships Annual Report FY 2014, Sandia National Laboratories, April 2015.

## REFERENCES

1. D. Bailey, T. Plenys, G.M. Solomon, T.R. Campbell, G.R. Feuer, J. Masters, and B. Tonkonogy, “Harboring Pollution - Strategies to Clean Up U.S. Ports,” National Resources Defense Council, NY, August, 2004.
2. J.W. Pratt and A.P. Harris, “Vessel Cold Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility,” Sandia National Laboratories, Report SAND2013-0501, available at <http://energy.gov/eere/fuelcells/downloads/vessel-cold-ironing-using-barge-mounted-pem-fuel-cell-project-scoping-and>.
3. M. Elmore and J. Hamilton, “Final Report: Maritime Fuel Cell Project Hydrogen Safety and Emergency Response Training, Honolulu, Oahu and Kahului, Maui – Hawaii,” Pacific Northwest National Laboratory, PNNL-24327, April 2015.