XII.3 Analysis Results for ARRA Projects: Enabling Fuel Cell Market Transformation

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Subcontractors:
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Project End Date: December 2012, with future evaluations covered under DOE's Technology Validation sub-program

Objectives

- Perform an independent assessment of technology in real-world operation conditions, focusing on fuel cell systems and hydrogen infrastructure
- Leverage data processing and analysis capabilities developed under the Fuel Cell Vehicle Learning Demonstration
- Support market growth through reporting on technology status to key stakeholders and performing analyses relevant to the markets' value proposition
- Study fuel cell systems operating in material handling equipment (MHE), backup power, portable power, and stationary power applications; the project includes approximately 1,000 deployed fuel cell systems.

Relevance to the American Recovery and Reinvestment Act (ARRA) of 2009 Goals

This technology validation project supports the ARRA project goals of accelerating the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services through the independent technology assessments and reports. The analyses focus on performance areas such as durability, safety, and reliability that are critical to the successful implementation and continued operation. The analyses are reported publically in aggregated data sets to inform and educate hydrogen and fuel cell stakeholders as well as current and potential end users. Individual, detailed results are shared with each project partner for deep dive performance status (down to individual systems) and technology benchmarking. This project studies and tracks 1,111 fuel cell systems in operation.

Technical Barriers

This project addresses the technical barrier of commercialization of fuel cells in key early markets and the associated performance capabilities and benefits. Specific areas of hydrogen fuel cell systems in material handling and backup power applications include:

- Technology status
- Value proposition
- Durability and reliability
- Safety

Technical Targets and Milestones

Deployment of up to 1,000 fuel cell systems: Successfully achieved with 1,111 systems in operation by December 2011.

Accomplishments

- By December 2011, 1,111 fuel cell systems were in operation throughout the United States, more than double the number of systems that were in operation at the end of 2010. All of the MHE sites are fully operational, and in backup power, the number of installed sites increased from 5 to 292 in just 18 months.
- The technical results published in April 2012 include 13 backup power composite data products (CDPs) and 63 MHE CDPs. The results are categorized as deployment, fuel cell operation, infrastructure operation, fuel cell safety, infrastructure safety, fuel cell durability, fuel cell maintenance, infrastructure maintenance, fuel cell reliability, infrastructure reliability, and cost of ownership. There were 24 new CDPs created in the past year.
- Deployment CDPs were updated to depict the number of systems delivered and in operation by application, the system/site locations, and the number of systems deployed with ARRA funds by state.
- The number of successful backup power starts was validated at 99.7%, or 1,187 good starts from 1,191 attempted starts.

- A continuous run time of 29 hours was demonstrated for at least one backup power system.
- The average fill time for 504 MHE units was 2.2 minutes per fill, providing a significant operating savings for the facilities.
- A detailed cost of ownership analysis of MHE, comparing battery and hydrogen fuel cell lifts, showed an annual savings of $1,900 dollars per lift in high-use facilities.

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Introduction

The DOE has designated more than $40 million in ARRA funds for the deployment of up to 1,000 fuel cell systems. This investment is enabling fuel cell market transformation through development of fuel cell technology, manufacturing, and operation in strategic markets where fuel cells can compete with conventional technologies. The strategic markets include MHE, backup power, stationary power, and portable power, and the majority of the deployed systems are in the MHE and backup power markets. NREL is analyzing operational data from these key deployments to better understand and highlight the business case for fuel cell technologies and report on the technology status.

Approach

The project's data collection plan builds on other technology validation activities. Data (operation, maintenance, and safety) are collected on-site by the project partners for the fuel cell system(s) and infrastructure. NREL receives the data quarterly and stores, processes, and analyzes the data in NREL's Hydrogen Secure Data Center (HSDC). The HSDC is an off-network room with access for a small set of approved users. An internal analysis of all available data is completed quarterly and a set of technical CDPs is published every six months. The CDPs present aggregated data across multiple systems, sites, and teams in order to protect proprietary data and summarize the performance of hundreds of fuel cell systems and thousands of data records. A review cycle is completed before the publication of CDPs. The review cycle includes providing detailed data products (DDPs) of individual system and site performance results to the individual data provider. DDPs also identify the individual contribution to CDPs. The NREL Fleet Analysis Toolkit (NRELFAT) is an internally developed tool for data processing and analysis structured for flexibility, growth, and simple addition of new applications. Analyses are created for general performance studies as well as application- or technology-specific studies.

Results

An objective of the ARRA fuel cell project—to deploy up to 1,000 fuel cell systems in key early markets—was met within two years from the first deployments. Early market end users are operating 1,111 fuel cell units at 301 sites in 20 states (Figure 1). By the end of 2011, 504 MHE fuel cell units were operating at eight facilities, and 607 backup power fuel cell units were operating at 293 sites. The results have

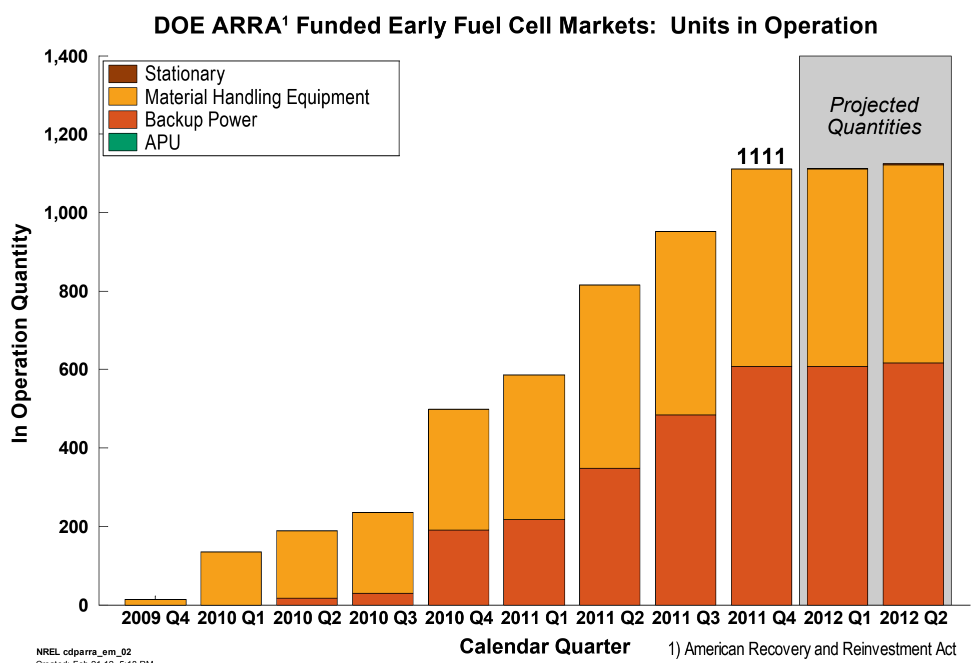

FIGURE 1. DOE ARRA-funded early fuel cell markets: units in operation

shown that MHE and backup power are two markets where fuel cells are capable of meeting the operating demands, and deployments can be leveraged to accelerate fuel cell commercialization.

In 1.5 years the number of backup power fuel cell sites has increased from 5 to 292. The project partners have identified many challenges with installation, such as determining the correct site and permitting, but these systems can be installed and in operation quickly. Backup power fuel cell systems can also be installed just about anywhere, as long as hydrogen can be delivered, and the deployments include urban and remote sites. Backup power fuel cell systems have demonstrated high reliability for successful starts, at 99.7%, and more than half of the starts are because of grid outages or site demands (see Figure 2). These reliable backup power fuel cell systems are operating in many different U.S. regions and are capable of long continuous run times with little or no emissions. At least one system has demonstrated a continuous operation of more than 29 hours due to an unscheduled outage.

The MHE fuel cell systems accumulated 959,887 hours by the end of 2011 and are estimated to have accumulated 1 million operation hours in early 2012. High operation hours on the 504 systems indicate these systems are successfully performing and making an impact at the high-productivity facilities. These end-user facilities have had experience with battery and propane lifts and expected the fuel cell systems to meet and exceed performance expectations in a few key areas for both the retrofit and greenfield sites. These key performance areas include fill amount, operation per fill, operation per day (and year), mean time between failure, and voltage degradation (or fuel cell operation durability). These areas were studied in detail for each system, fleet, and lift classification. A difference in operating conditions exists between lift classes and is observed in the reliability and durability results; Class 3 lifts demonstrated higher reliability and durability than Class 1 and Class 2 lifts (see Figure 3). These differences warrant additional investigation, but two potential reasons for the higher performance observed in Class 3 lifts are that they use a smaller system and have less demanding operation than the other lift classes studied. Operation time accumulates quickly in MHE facilities, providing a large set of data to study fuel cell durability and system reliability. The average projected time to 10% fuel cell voltage degradation is 5,500 hours, and only 15% of the fuel cell stacks have actually seen 10% voltage degradation. System reliability is also analyzed to provide a more complete picture of the fuel cell MHE performance. The average system availability is high at approximately 98%, but more than a third of the systems have a mean time between failure of less than 250 hours.

Fuel cell MHEs can have a lower annual operating cost than battery MHEs at high-use facilities. The cost of ownership analysis shows that, for a facility with 58 Class 1 and 2 fuel cell MHEs that average 2,100 operation hours per year, a fuel cell MHE costs approximately $2,000 less to operate annually than a battery MHE (Figure 4). The primary, positive factors for the lower cost are decreased maintenance, fast fill times, and decreased interior space for

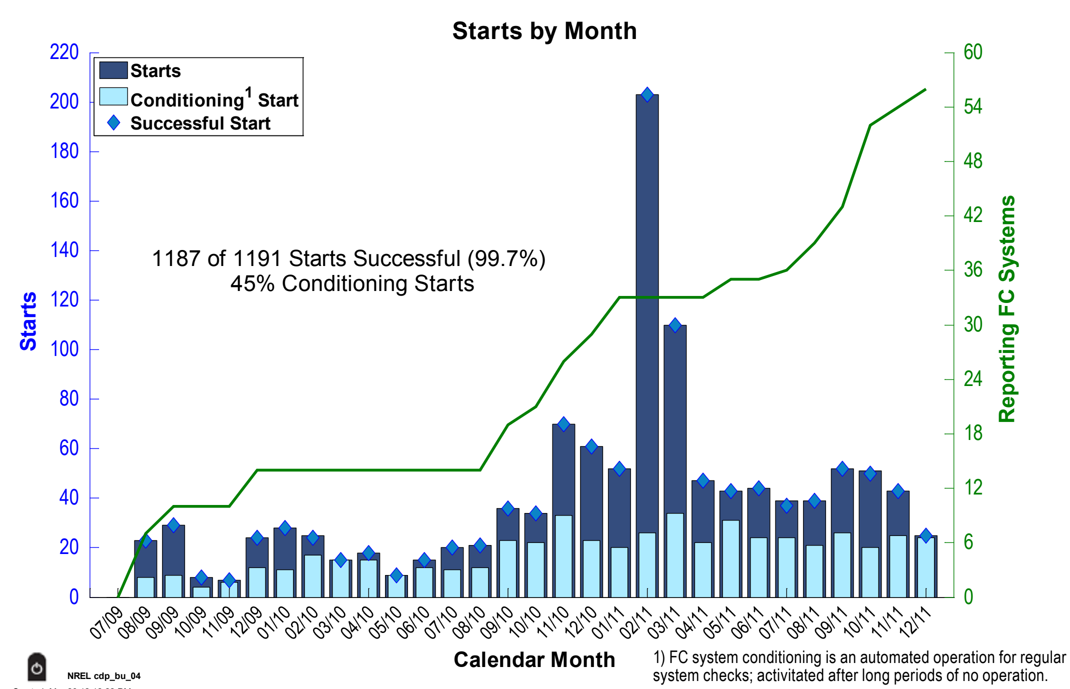

FIGURE 2. Backup power fuel cell system starts by month

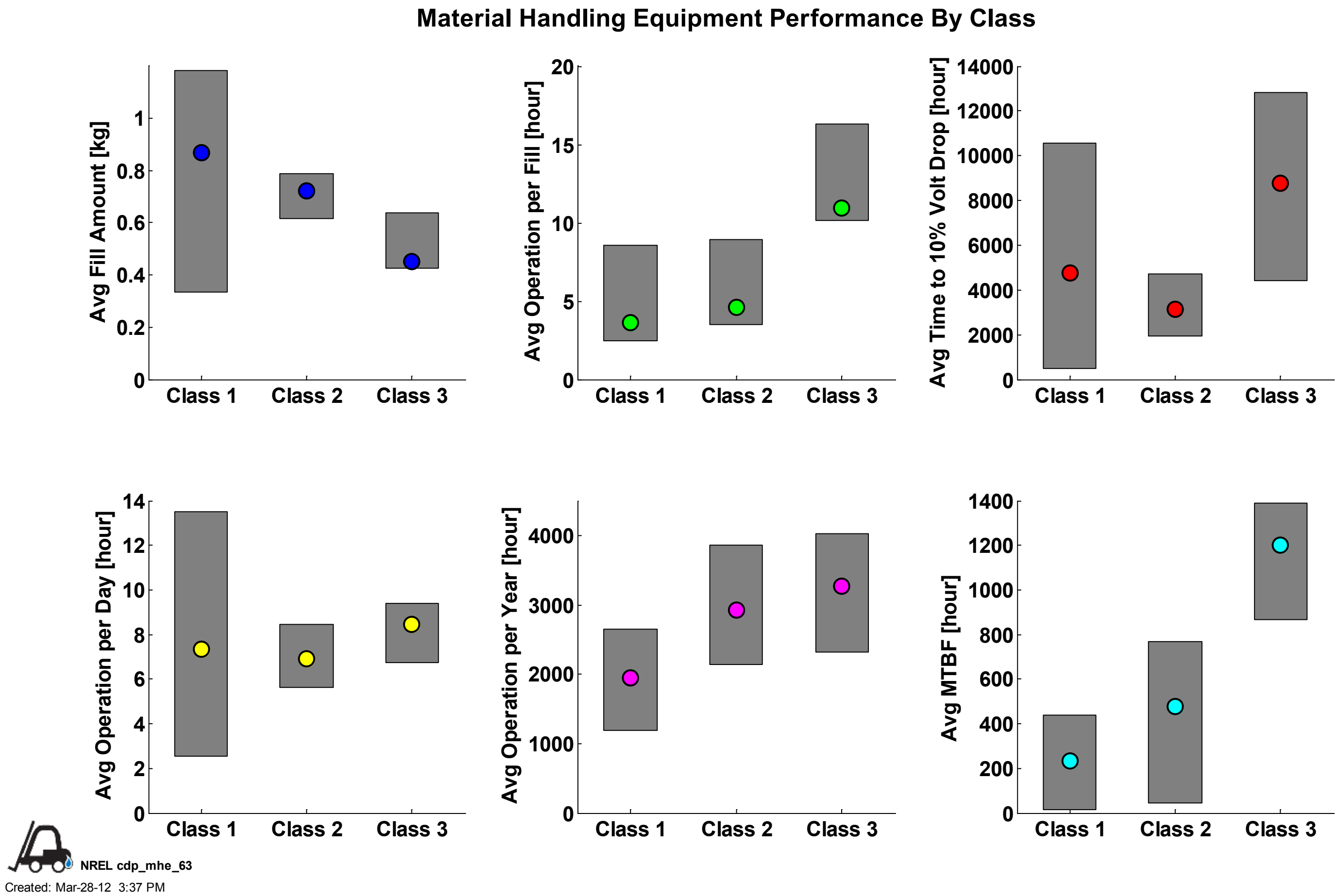

FIGURE 3. Material handling equipment performance by class

infrastructure. Even though fuel cell MHEs have a lower annual operating cost than battery MHEs, there are still cost categories where the fuel cell MHEs are more expensive than battery MHEs. Advancements that lower infrastructure capital costs, fuel cell capital costs, and hydrogen fuel costs will open up the possibility for low-fleet-size facilities to see the cost benefits of fuel cell MHEs.

Conclusions and Future Directions

The deployment of 1,111 fuel cell units has established a significant data set of successful and safe operation in the hands of end users, has increased fuel cell manufacturing and support capabilities, and has translated lessons learned from the field into improved fuel cell systems for future operation. The aggregated data showcase the significant use and performance status at end user sites over the last two years in MHE and backup power applications. The CDPs address a need for published results on the technology status that can be utilized by industry, developers, and end users. The analyses have evolved as the accumulated time and hydrogen dispensed have increased, providing an insight into market behaviors and expectations. Continued analyses will be covered under the Technology Validation sub-program and include:

- Quarterly analysis of operation data for MHE and backup power systems
- Publication of bi-annual technical CDPs
- Demonstration of a 72-hour continuous run time for a backup power fuel cell system
- Analysis of backup power value proposition.

FY 2012 Publications/Presentations

1. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Analysis Results for ARRA Projects: Enabling Fuel Cell Market Transformation" NREL Presentation 2011 DOE Hydrogen and Fuel Cells Program, and Vehicle Technologies Program Annual Merit Review and Peer Evaluation. 5/12/2011

2. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "ARRA Fuel Cell Deployments:Operation Data Overview" presented at the Hydrogen Safety Panel Meeting in Washington, D.C. 4/7/2011

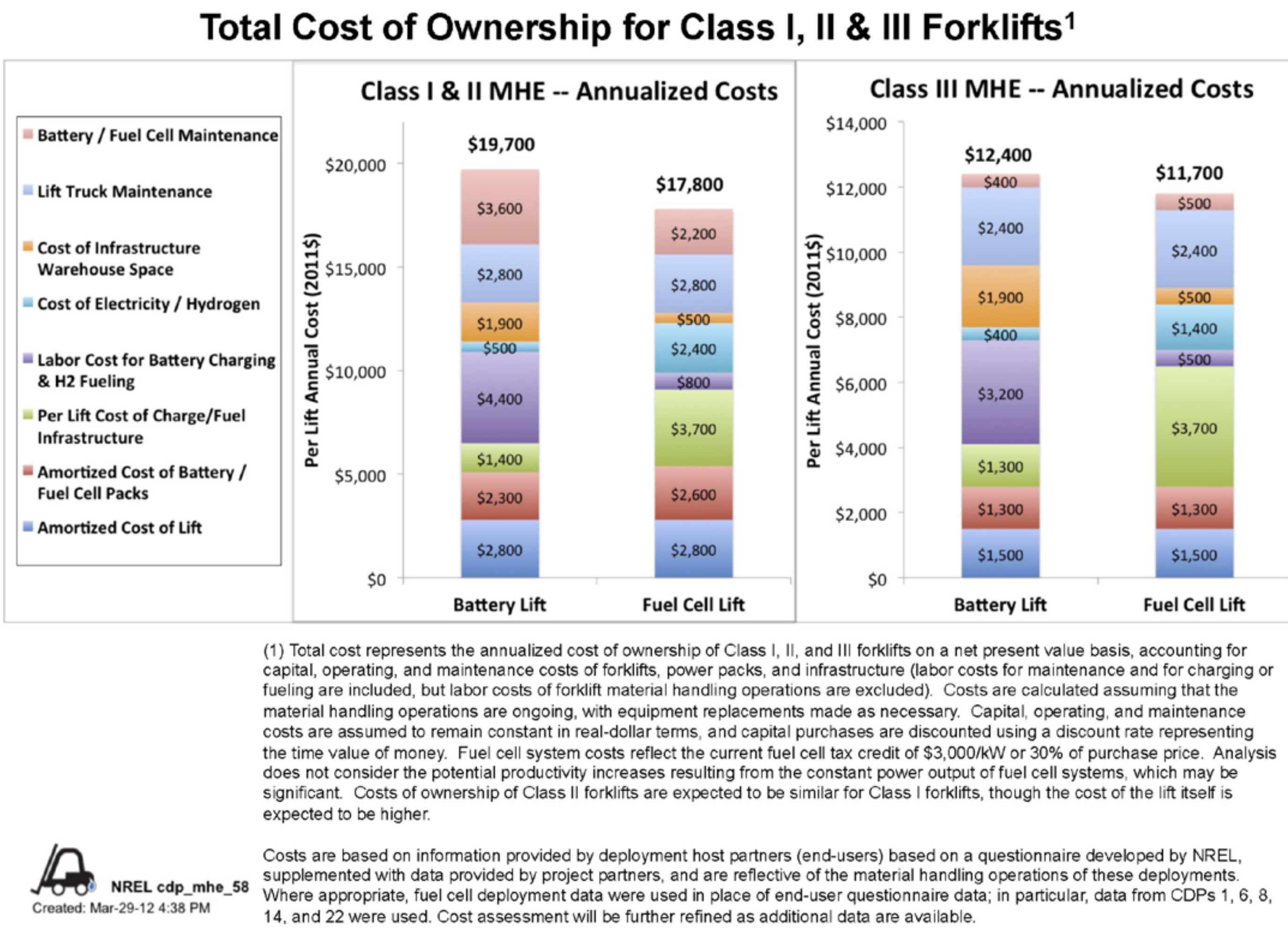

FIGURE 4. Total cost of ownership for Class 1, 2, and 3 forklifts

3. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "ARRA MHE Composite Data Products for Data Through 2011 Q4" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 4/4/2012

4. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Spring 2012 Composite Data Products - Backup Power" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 4/3/2012

4. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Early Fuel Cell Market Deployments: ARRA and Combined (IAA, DLA, ARRA), Quarter 1 2012, Composite Data Products – Deployment" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 3/8/2012

6. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Early Fuel Cell Market Deployments: ARRA and Combined (IAA, DLA, ARRA), November 2011, Composite Data Products – Deployment" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 11/30/2011

7. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Fall 2011 Composite Data Products: ARRA Material Handling Equipment" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 9/30/2011

8. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "Fall 2011 Composite Data Products: Backup Power" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 9/30/2011

9. Kurtz, J., Wipke, K., Sprik, S., Ramsden, T., Ainscough, C., Saur, G., "2011 Early Fuel Cell Market Deployments: ARRA and Combined (IAA, DLA, ARRA)" Composite data products produced by the NREL Hydrogen & Fuel Cells Research early fuel cell market demonstrations team. 9/30/2011