

VIII.F.3 Technology Validation: Fuel Cell Bus Evaluations

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Projected End Date: Project continuation and direction determined annually by DOE

Objectives

- Determine the status of fuel cell bus (FCB) technologies in transit buses by evaluating them in real-world service.
- Coordinate with the Federal Transit Administration (FTA) and international FCB demonstration programs to harmonize data collection methods and enable comparison of a wider set of vehicles.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A. Vehicles
- B. Storage
- C. Hydrogen Fueling Infrastructure
- D. Maintenance and Training Facilities
- E. Codes and Standards

Contribution to Achievement of DOE Technology Validation Technical Targets

- *Milestone 2: Demonstrate fuel cell vehicles (FCVs) that achieve 50% higher fuel economy than gasoline vehicles.* We are demonstrating nine heavy-duty FCVs of various configurations and comparing them to baseline diesel or compressed natural gas (CNG) vehicles. Fuel economy testing to date shows that a hybridized 30-ft FCB has up to 2.4 times greater fuel economy than a 40-ft CNG bus in the same service.
- *Milestone 5: Validate fuel cell demonstration vehicle range of ~200 miles and durability of ~1,000 hours.* To date, testing of the demonstration buses has resulted in a range of up to 170 miles at 95% fill. In-service testing has been performed up to 655 hours on a 30-ft bus. The full-size buses went into service in early 2005, and the results will be reported after 6 full months in service.

Approach

- Collect and analyze performance data on FCBs and associated infrastructure at Santa Clara Valley Transportation Authority (VTA; San Jose, California); Hickam Air Force Base (Honolulu, Hawaii); AC Transit District (Oakland, California); and SunLine Transit Agency (Thousand Palms, California).
- Coordinate with other FCB project representatives to begin sharing data.

Accomplishments

- Collected performance and operational data on the first three full-size FCBs in revenue service in the United States.
- Gained agreement from international FCB demonstration partners to share specific data on bus and infrastructure performance.

Future Directions

- Collect, analyze, and report on performance data of nine FCBs in service at:
 - Santa Clara Valley Transportation Authority: three FCBs
 - Hickam Air Force Base: one battery-dominant FCB, one fuel-cell-dominant shuttle van
 - AC Transit District: three hybrid FCBs
 - SunLine Transit Agency: one hybrid FCB, one hybrid hydrogen-fueled internal-combustion-engine bus
- Investigate reliability, durability, and life cycle of FCBs as a part of ongoing evaluations. These efforts complement the DOE light-duty FCV demonstrations.
- Coordinate with FTA to plan the third International Fuel Cell Bus Workshop in conjunction with the next Electric Drive Transportation Association (EDTA) conference in Vancouver, British Columbia, in December 2005.

Introduction

Fuel cell systems for buses have significantly improved during the last several years. Heavy-duty vehicles offer the advantage of extra space for larger propulsion systems—sometimes at the cost of passenger or cargo space. Although progress has been made, more work is needed to improve reliability and durability.

Demonstration programs are necessary to validate the performance of the current generation of fuel cell systems. Lessons learned in evaluating buses in revenue service will help assess the status of FCB technology and determine issues that require further development. Evaluating an early prototype bus proved that an FCB can deliver service similar to that of a conventional bus in transit applications, as well as operate in a hot desert climate. Barriers to the use of fuel cells in transportation applications need to be surmounted, however, before these technologies can be commercialized. Future

evaluations should help address these issues, which include extending the life of a fuel cell, improving reliability and durability of the systems, and lowering vehicle and infrastructure costs.

Coordinating with demonstration programs worldwide is important for gathering and comparing data from a larger statistical set of vehicles and for leveraging resources without duplicating efforts.

Approach

The National Renewable Energy Laboratory (NREL) and Battelle researchers have developed an evaluation protocol to provide:

- Comprehensive, unbiased evaluation results of advanced technology vehicle development and operations
- Evaluations of hydrogen infrastructure development and operations
- Descriptions of facility modifications required for safe operation of FCVs

These evaluations include economic, technical, emissions, and safety factors, and are conducted in collaboration with the transit fleet, the vehicle and fuel cell manufacturers, and applicable government partners.

This evaluation project has three major goals:

- To yield credible data results and evaluations that go beyond the “proof of concept” of FCBs and infrastructure, to inform the transit bus and fuel cell industries.
- To create results that focus on performance and use, including progress over time and experience from integrating vehicle systems, operations, and facilities for FCBs and supporting infrastructure.
- To collect detailed results on fuel cell systems for buses and the requisite hydrogen infrastructure, to complement the light-duty demonstrations and further DOE goals.

Results

Bus Evaluations

NREL is working with four fleets to evaluate FCBs in real-world service:

- Santa Clara VTA
- Hickam Air Force Base
- AC Transit District
- SunLine Transit Agency

The four FCBs that will be demonstrated by AC Transit and SunLine are currently in production and are expected to be delivered in early 2006. These buses utilize a hybrid fuel cell system developed by ISE Research with a UTC fuel cell. VTA and Hickam have received their buses and are using them in daily operations.

Santa Clara VTA: This fleet received all three of its fuel cell buses by the end of 2004. Manufactured by Gillig Corporation, these buses use a fuel cell system developed by Ballard Power Systems. The FCB is shown in Figure 1. Table 1 lists the specifications of the buses, which were operated in test mode for several months on routes without passengers. This allowed the fleet to become familiar with the capabilities of the bus and to work out any issues before carrying passengers. The buses



Figure 1. The Buses at VTA Utilize a Fuel Cell System Developed by Ballard Power Systems

Table 1. VTA Fuel Cell Bus Specifications

Bus Chassis	Gillig, low-floor
Model Year	2004
Length/Width/Height	40 ft/102 in./144 in.
GVWR/Curb Weight	40,600 lb/34,100 lb
Drive System	Fuel cell powerplant, inverter, one electric propulsion motor, six-speed transmission
Powerplant	Ballard Power Systems PEM fuel cell, 190 kW
Propulsion Motor	Reuland electric three-phase induction motor 275 kW @ 2100 rpm
Fuel	Gaseous hydrogen
Hydrogen Storage	11 on-board, Dynetek Dynecell carbon fiber-wrapped tanks

were officially placed in service after a kick-off event held on February 24, 2005.

The FCBs will be used for extra service instead of replacing existing diesel buses. Two of the buses will be used for service and one will serve as a spare. This will allow for potential service interruptions if a bus needs maintenance or is scheduled for an event, which may include training sessions for fleet staff or first responders and educational activities to increase public awareness. Transit applications have the potential to reach a much larger audience than most light-duty applications.

VTA provided the first set of data to NREL for processing. Once the data are analyzed, results will be used to assess the status of the technology for



Figure 2. The Fuel Cell Bus at Hickam AFB

transit applications. This information will be fed back to DOE to refocus R&D activities as appropriate.

Hickam Air Force Base: The FCB in service at Hickam was developed by Enova Systems and Hydrogenics under direction of the Hawaii Center for Advanced Transportation Technologies (see Figure 2). The early success of this partnership resulted in a hybrid fuel cell system that was designed, developed, and integrated into an existing bus chassis in about four months. The system is a battery-dominant hybrid with a 20-kW (kilowatt) fuel cell used as a range extender. Figure 3 illustrates the layout of the fuel cell system. This is the first FCB to be deployed by the U.S. Department of Defense, and successful results could lead to projects at other locations.

The FCB is used in shuttle operation around the base and community. The route is a 7-mile loop that the bus completes 20 times each day. One loop takes approximately 26 minutes with 4 minutes of idle time. The average speed of the bus is 14 miles per hour (mph). The fleet manager anticipates that a midday hydrogen fueling will be required to complete the 140-mile distance each day. The bus has been operating on battery power because of difficulties getting the infrastructure in place. Plans are under way to build a permanent hydrogen fueling station at the site.

A second FCV, a fuel-cell-dominant system using a 60-kW fuel cell by Hydrogenics, is planned for demonstration at Hickam. The project team is willing to share data on this vehicle with NREL as part of the current work.

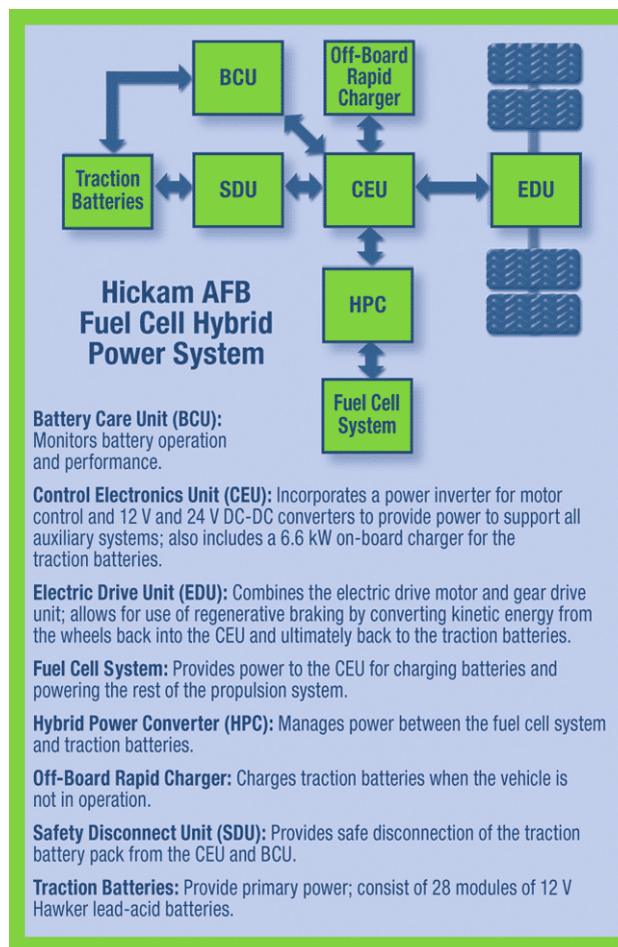


Figure 3. Hickam Air Force Base Fuel Cell Hybrid Power System

International FCB Coordination

NREL continues to work with international groups to collaborate among FCB demonstrations worldwide. A core group of agencies—including NREL, FTA, EDTA, the European Commission, and the Flemish Institute for Technological Studies—coordinated the second International Fuel Cell Bus Workshop in Porto, Portugal, in November 2004. The goals of the workshop were to:

- Enhance information sharing on FCB demonstrations worldwide
- Develop a standard set of data elements on the performance of FCBs and hydrogen infrastructure to collect and share

- Investigate the potential for further collaboration and coordination of future FCB demonstrations

This workshop afforded participants the opportunity to further discuss coordination with the Clean Urban Transport for Europe (CUTE) Program and other FCB demonstrations. In addition, the workshop supported DOE's International Partnership for the Hydrogen Economy by strengthening the coordination of international R&D activities to avoid duplicated efforts.

In addition to presenting DOE's evaluation strategy for FCBs in California, NREL chaired a session and led a facilitated discussion on data collection. The participants agreed to:

- Share a set of informational data in a common template for easy comparison. Informational data includes project summaries, descriptions of the fleet and infrastructure, status of the demonstration, and vehicle specifications. No proprietary data are included.
- Share summary data and lessons learned during the FCB demonstrations. The list of specific data was discussed, but not finalized.
- Form a Fuel Cell Bus Working Group that will meet once each calendar year. A working committee made up of representatives from the key stakeholders will propose specific projects for the larger group.

Following the workshop, an organizing team was formed to spearhead the work. The team will develop a plan for accomplishing the goals of the working group.

Conclusions

Fuel cell propulsion systems, such as those used in the demonstration buses, are prototypes in the early stages of technological development. The evaluations of these prototype buses will result in opportunities to record experiences with FCBs and hydrogen infrastructure technologies, show the progress of these technologies, and facilitate understanding of the work that remains to be done to make the technologies viable and to meet DOE technical targets.

Coordinating data sharing between international demonstrations will allow us to leverage limited resources to help assess the status of the technology and determine what effort is yet needed to commercialize fuel cells in transportation applications.

FY 2005 Publications/Presentations

1. Eudy, L., and Chandler, K. (2004). *Fuel Cell Bus Demonstration Projects: Fuel Cell Hybrid Bus Lands at Hickam AFB*. DOE/GO-102004-1968, NREL, Golden, CO.
2. Eudy, L. (2004). NREL Fuel Cell Bus Evaluation Projects. Presented at Electric Drive Transportation Association Conference, Orlando, FL, September.
3. Eudy, L. (2004). DOE/NREL Fuel Cell Bus Evaluation Plan. Presented at Second International Fuel Cell Bus Workshop, Porto, Portugal, November.
4. Eudy, L. (2005). Technology Validation: Fuel Cell Bus Evaluations. Poster Presentation at the 2005 Annual Merit Review, Arlington, VA, May.