Harmonization and Sharing of Data from International Fuel Cell Bus Demonstrations

Leslie Eudy, NREL

Fuel Cell Seminar, 2006

Session: #1B : Transportation I
November 15, 2006
Honolulu, Hawaii
Disclaimer and Government License

This work has been authored by Midwest Research Institute (MRI) under Contract No. DE-AC36-99GO10337 with the U.S. Department of Energy (the “DOE”). The United States Government (the “Government”) retains and the publisher, by accepting the work for publication, acknowledges that the Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for Government purposes.

Neither MRI, the DOE, the Government, nor any other agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the Government or any agency thereof. The views and opinions of the authors and/or presenters expressed herein do not necessarily state or reflect those of MRI, the DOE, the Government, or any agency thereof.
Outline

• Overall Working Group Goals
• Challenges
• Workshop Summary
• Data Collection/Sharing
• Example Data from U.S.
  – Santa Clara VTA, San Jose, CA
In 2003, the U.S. Federal Transit Administration began an effort to form a Fuel Cell Bus (FCB) Work Group.

The goals of the group were to:

• Enhance information sharing on the status of FCB demonstrations worldwide
• Harmonize data collection and evaluation to maximize possible learnings
• Facilitate coordination and collaboration of research, development, and demonstration of future FCBs
Challenges

• Gaining participation from “appropriate” people:
  – Representatives involved with demonstration/data collection
  – Authority to commit to sharing data
  – Availability/willingness to attend workshops

• Solutions:
  – Hold workshops in conjunction with events likely to draw “appropriate” people
  – Invitations to specific individuals involved in demos
  – Establish diverse organizing committee (FTA joined by EU in planning and funding)
  – Rotate locations of workshops to cover multiple countries
Challenges

• Consensus on data collection:
  – Building common data element list
  – Addressing challenges from many country perspectives

• Solutions:
  – Develop multiple levels of data sharing:
    • High level data – non-sensitive data that can be made publicly available (Phase I and II)
    • More detailed data – potentially sensitive data shared with work group participants only
  – Begin constructing list by comparing common data items already being collected
  – Involve all work group participants in decision process
Challenges

• Gaining agreement to share data:
  – Involvement from all demonstrations/teams
  – Willingness to share information that will further advance the technology and not let marketing get ahead of the true status

• Solutions:
  – Begin with collecting the Phase I, high level data to build trust between participants
  – Work as a group to develop the strategy for collecting and sharing data
<table>
<thead>
<tr>
<th>Workshop</th>
<th>Location</th>
<th>Dates</th>
<th>Associated Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Workshop</td>
<td>Long Beach, California, USA</td>
<td>Nov. 19 – 20, 2003</td>
<td>EVS 20</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Workshop</td>
<td>Porto, Portugal</td>
<td>Nov. 18 – 20, 2004</td>
<td>CUTE project meeting</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Workshop</td>
<td>Vancouver, BC, Canada</td>
<td>Dec. 4 – 6, 2005</td>
<td>EDTA Conference</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Workshop</td>
<td>Yokohama, Japan</td>
<td>Oct 21 - 13, 2006</td>
<td>EVS 22</td>
</tr>
</tbody>
</table>
### Data Collection/Sharing

- **Established three levels of data:**

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Level</td>
<td>Medium Level</td>
</tr>
<tr>
<td>Non-sensitive</td>
<td>Somewhat sensitive</td>
</tr>
<tr>
<td>General information on project, operating fleet, buses, infrastructure</td>
<td><strong>Bus data:</strong> Fuel consumption, availability, reliability, maintenance <strong>Infrastructure data:</strong> fueling rates, efficiency, availability, maintenance</td>
</tr>
<tr>
<td>Will be shared</td>
<td>Will be shared</td>
</tr>
<tr>
<td>Status: Data collection in progress</td>
<td>Status: Finalizing list of data</td>
</tr>
</tbody>
</table>

**Detailed Data**

- Proprietary
- Detailed voltage and current data on the FC and systems
- Will not be shared
DOE/NREL FCB Evaluation Results

Santa Clara VTA

- 3 prototype FCBs: Gillig buses with Ballard FC system (non-hybrid)
- Diesel buses for baseline comparison

<table>
<thead>
<tr>
<th>Vehicle System</th>
<th>Cerone Depot</th>
<th>Fuel Cell Buses</th>
<th>Diesel Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Buses</td>
<td>Three</td>
<td>Gilig low-floor</td>
<td>Five</td>
</tr>
<tr>
<td>Bus Manufacturer and Model</td>
<td>Gillig low-floor</td>
<td>Gilig low-floor</td>
<td>Diesel low-floor</td>
</tr>
<tr>
<td>Model Year</td>
<td>2004</td>
<td>2002</td>
<td></td>
</tr>
<tr>
<td>Length/Width/Height</td>
<td>40 feet/102 in/144 in</td>
<td>40 feet/102 in/120 in</td>
<td></td>
</tr>
<tr>
<td>GVWR/Curb Weight</td>
<td>40,600 lb/34,100 lb</td>
<td>39,600 lb/27,300 lb</td>
<td></td>
</tr>
<tr>
<td>Wheelbase</td>
<td>284 in</td>
<td>284 in</td>
<td></td>
</tr>
<tr>
<td>Passenger Capacity</td>
<td>37 seated or 29 seated and two wheelchairs, five standing</td>
<td>38 seated or 31 seated and two wheelchairs, 43 standing</td>
<td></td>
</tr>
<tr>
<td>Engine Manufacturer and Model</td>
<td>Two Ballard fuel cell modules P5-2</td>
<td>Cummins ISL (8.9 liter)</td>
<td></td>
</tr>
<tr>
<td>Rated Power</td>
<td>150 kW each (300 kW total)</td>
<td>280 bhp @ 2,200 rpm</td>
<td></td>
</tr>
<tr>
<td>Rated Torque</td>
<td>790 lb-ft @ 1,350 rpm (1250 Nm)</td>
<td>900 lb-ft @ 1,300 rpm</td>
<td></td>
</tr>
<tr>
<td>Accessories</td>
<td>Mechanical</td>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>Emissions Equipment</td>
<td>None</td>
<td>Diesel oxidation catalyst</td>
<td></td>
</tr>
<tr>
<td>Fuel Capacity</td>
<td>Approx. 55 kg hydrogen at 5,000 psi</td>
<td>115 gallons</td>
<td></td>
</tr>
</tbody>
</table>

Fuel Cell Bus

Diesel Bus
FCB Usage

Cumulative and monthly mileage on VTA FCBs

- 40,000 total fleet miles
- 3,219 total FC hours
- All 3 buses over 1,000 hours
- Average monthly mileage/FCB: 809 mi
Fuel Economy

Average Fuel Economy for FCBs and Diesel Controls

Fuel economy for the FCBs averaged 3.12 mi/kg; 3.52 mi/diesel equivalent gallon vs. 3.98 mpg for the diesel control buses (-12%)
Availability

• Availability
  – Planned use of the FCB:
    • 2 of the 3 buses in service each weekday except for holidays
    • Extra service (between regularly scheduled buses)
  – Goal for FCBs: 67% availability
  – Actual availability during evaluation period: 58%
  – Diesel buses: 85%
  – Breakdown:

![Pie chart showing breakdown of availability: Preventive Maintenance 22%, Propulsion 65%, Non-Propulsion 4%, Roadcalls 9%]
Infrastructure

- Infrastructure
  - Liquid H₂ delivery and storage
  - Station availability: 99%

- Fueling Rates for the year in kg/min
  - 460 bus fills
  - Rate Max 4.67, Min 0.66
  - Avg Rate 1.93
  - Avg fill amt: 30.9 kg

Cumulative Fueling Rate Histogram for VTA Station
Acknowledgements

• U.S. Federal Transit Administration

• U.S. Department of Energy

• Northeast Advanced Vehicle Consortium
Questions

• Leslie Eudy, National Renewable Energy Laboratory
  – 303-275-4412
  – Leslie_Eudy@nrel.gov

• Christina Gikakis, U.S. Federal Transit Administration
  – 202-366-2637
  – Christina.Gikakis@dot.gov