Technology Validation: Fuel Cell Bus Evaluations

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May 18, 2007

Presented at the 2007 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review, Washington, DC

Project ID#
TV10

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Evaluations typically cover two years of data
- Start date determined by bus delivery
- International collaboration ongoing

Budget

- FY 2007: $288K
- FY 2006: $288K
- FY 2005: $338 K

Barriers

A. Lack of fuel cell vehicle performance and durability data

C. Lack of H_2 fueling infrastructure performance and availability data

D. Maintenance and training facilities

Partners

- Fleets: Operational data, fleet experience
- Manufacturers: Vehicle specs, data and review
- Fuel Providers: Fueling data and review
- International: Exchange of results

Objectives

- Overall: Validate fuel cell and hydrogen technologies in transit applications
  - Show progress of the technology toward commercialization
  - Provide “lessons learned” on implementing next generation fuel cell systems in transit operations
  - Harmonize data collection efforts with other fuel cell bus demonstrations worldwide (in coordination with FTA and other U.S. and international partners)
- 2006
  - Complete analysis and reporting on VTA
  - Complete interim analysis and reporting for AC Transit and SunLine

Evaluation Approach

Two levels of data collected

- Non-sensitive data
  - Follows existing protocol
  - Data collected mainly from fleet
  - Results are made public after project team review
- Proprietary data
  - Collected from manufacturer
  - Protected in Secure Data Center at NREL
  - Only aggregate data products made public

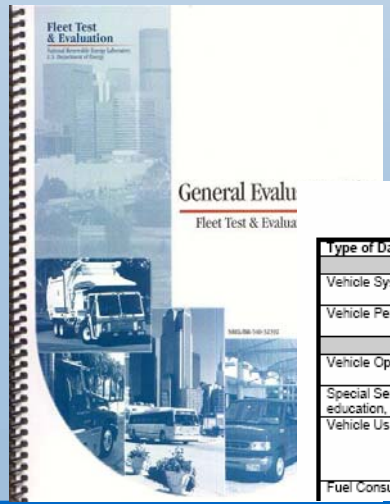
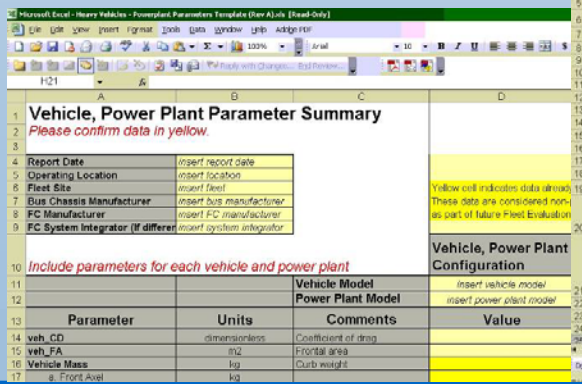
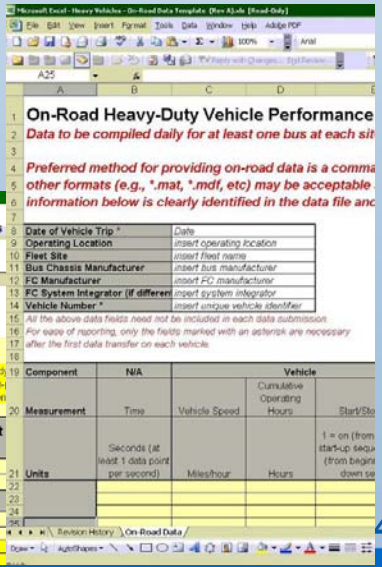


Table 1. Data Collection Items

Type of Data	Frequency Recorded	Data Items
Vehicle Specification and Performance Expectations		
Vehicle System Descriptions	Start of data collection and changes as needed	Data items shown in Appendix C
Vehicle Performance Expectations	Start of data collection and changes as needed	Criteria and testing results for performance expectations
Vehicle Operation		
Vehicle Operating Cycle	Start of data collection and changes as needed	General description of daily use of vehicles
Special Service (Press events, public education, etc.)	Each time vehicle is used for atypical service	Description of event, time out of service.
Vehicle Usage in Service	At each time usage is measured	Odometer reading; hours of vehicle and fuel cell operation
		Daily vehicle assignment
		GPS data (if needed)
Fuel Consumption	Each time a vehicle is fueled	Amount of fuel





Evaluation of Hydrogen and Fuel Cell Buses in Four Fleets

Santa Clara VTA, San Jose, CA

Ballard FC System: non-hybrid

AC Transit, Oakland, CA

UTC Power, ISE Corp: hybrid FCB

SunLine, Thousand Palms, CA

UTC Power, ISE Corp: hybrid FCB

ISE Corp: hybrid H_2 ICE

Hickam AFB, Honolulu, HI

Hydrogenics, Enova: hybrid system

Comparison of Hydrogen and Fuel Cell Buses to Conventional Technology

Targets for assessing the progress toward commercialization

- Performance characteristics
- Bus use
- Fuel economy
- Availability
- Reliability - miles between road call (MBRC)
- Cost - capital, fueling, and maintenance

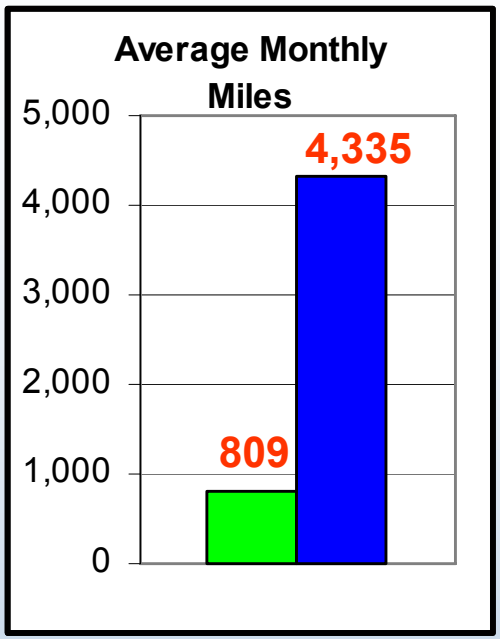
Fleet Data Summary: Santa Clara VTA

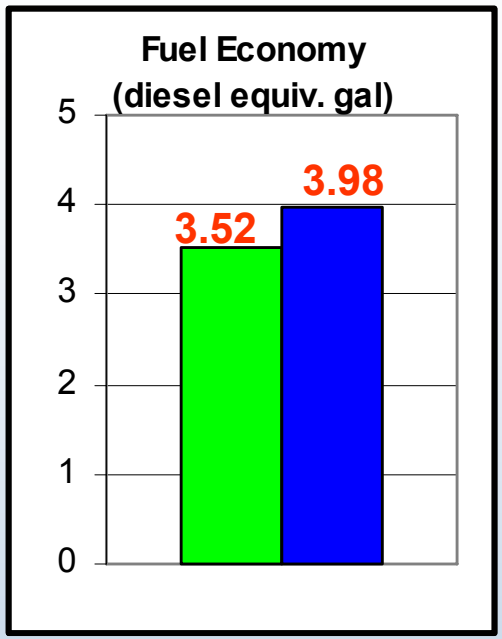
Fuel Cell Bus (non-hybrid system)

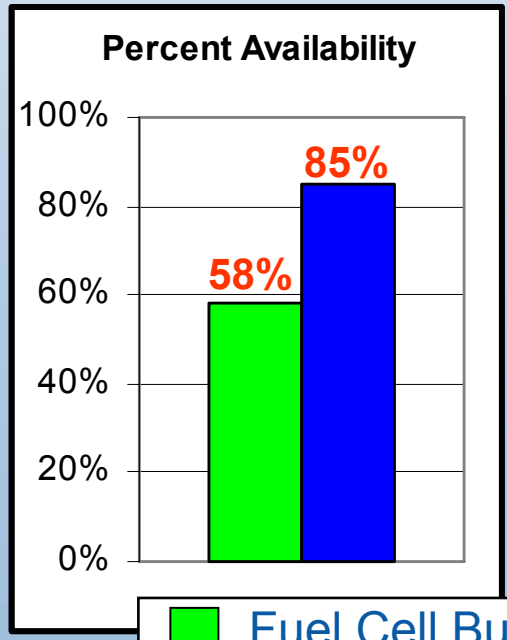
- 17 months operation of 3 FCBs
- Total miles: 40,208
- Total FC system hours: 3,219

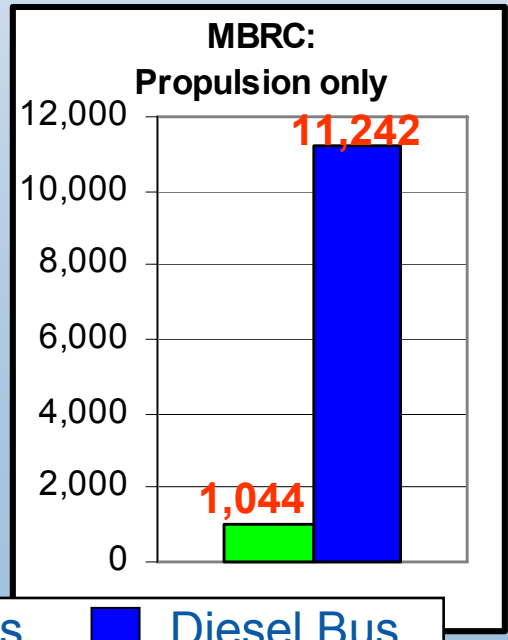
Diesel Bus (baseline)

- 17 months operation of 5 diesel buses
- Total miles: 360,447





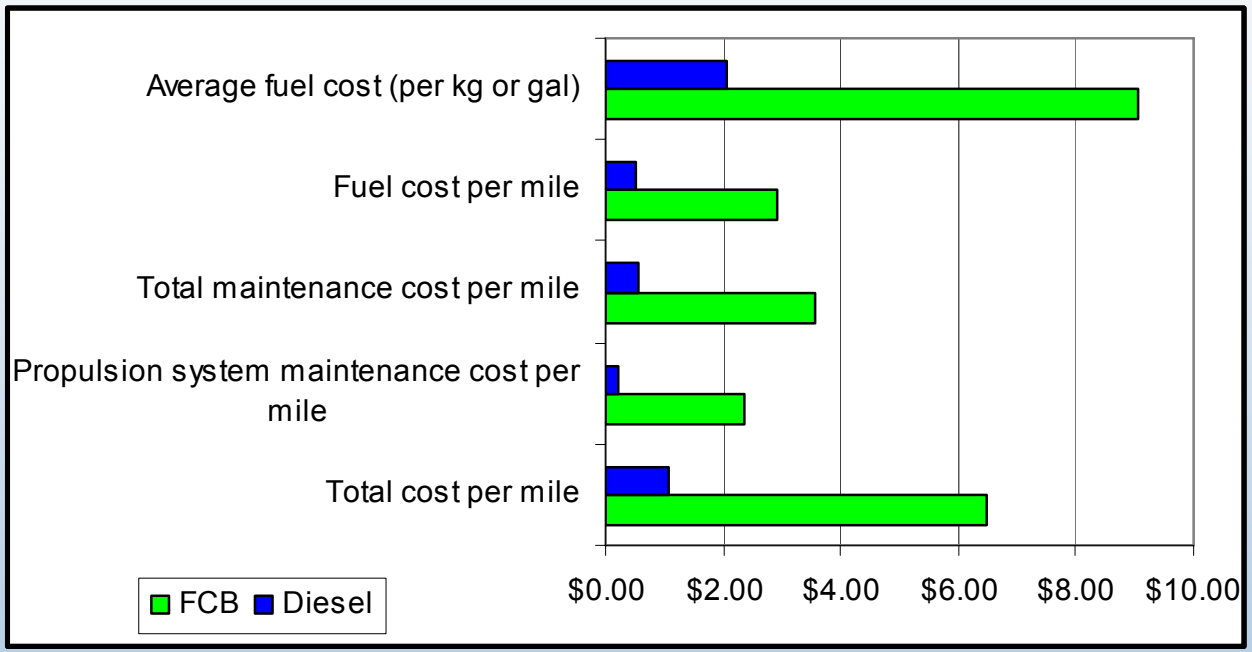




Fuel Cell Bus Diesel Bus

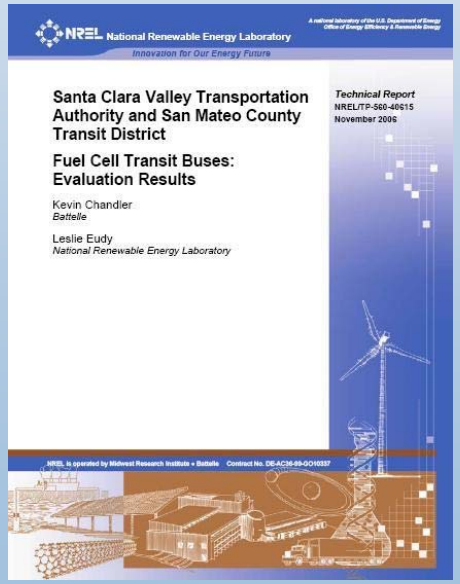
Fleet Data Summary: Santa Clara VTA

Summary of Costs



Evaluation Status

- Complete
- Report published



Report available online at
www.nrel.gov/hydrogen/pdfs/40615.pdf

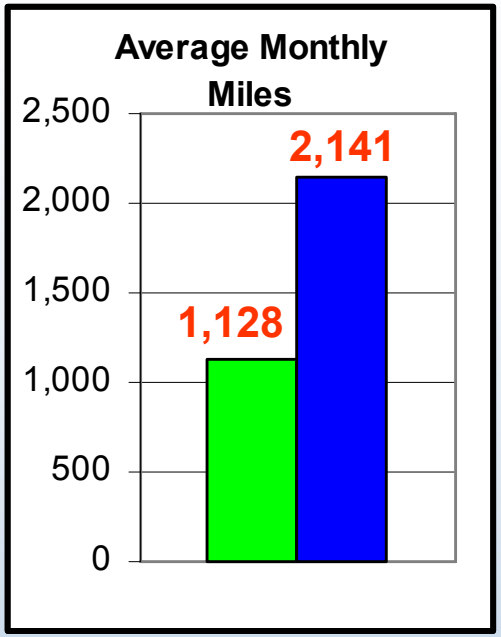
Fleet Data Summary: AC Transit

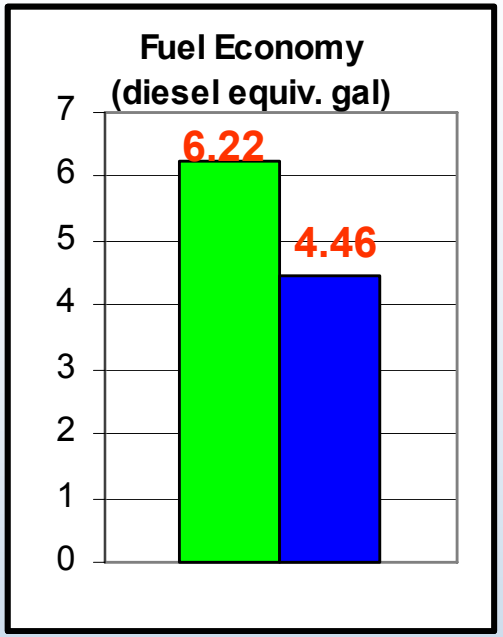
Fuel Cell Bus (hybrid system)

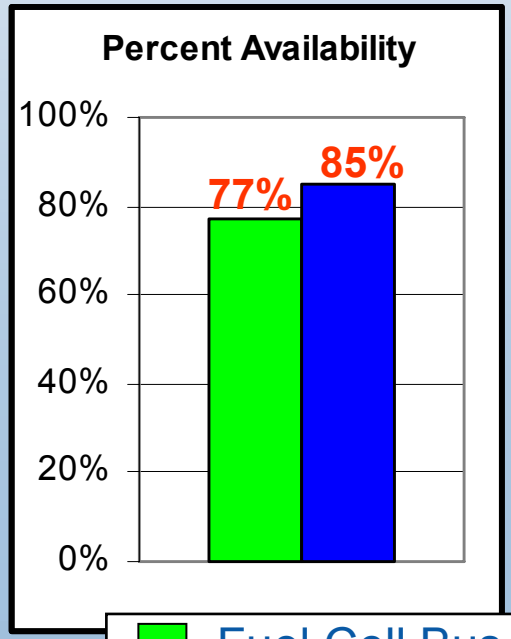
- 8 months operation of 3 FCBs
- Total miles: 27,065
- Total FC system hours: 2,338

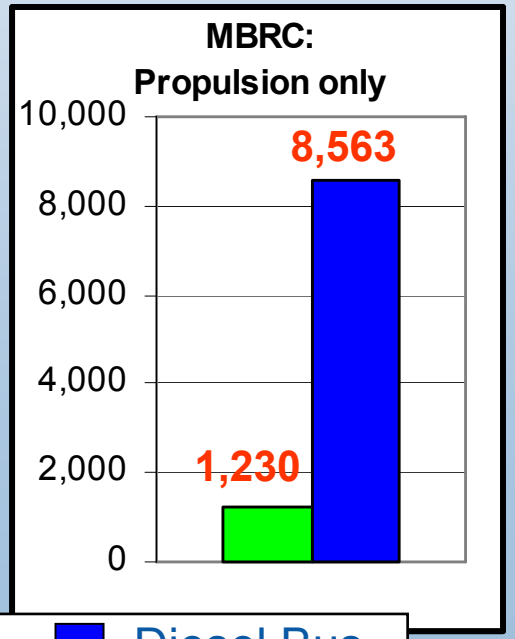
Diesel Bus (baseline)

- 8 months operation of 6 diesel buses
- Total miles: 102,755





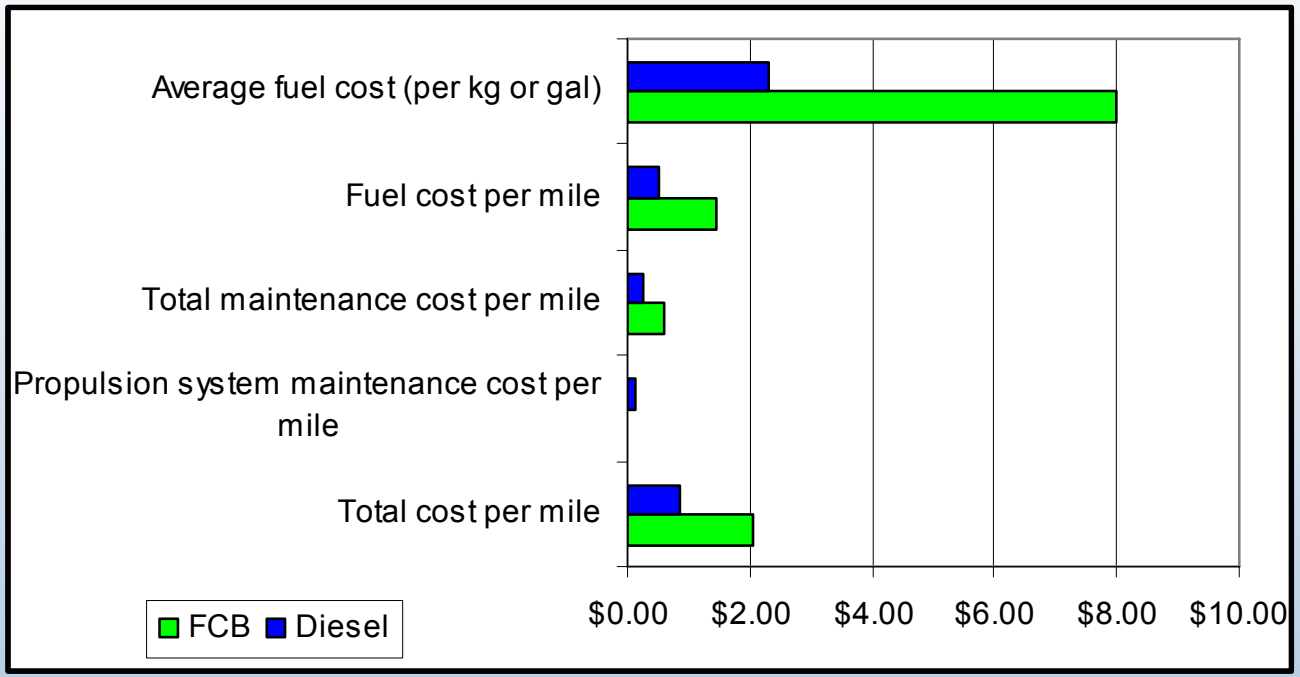




Fuel Cell Bus Diesel Bus

Fleet Data Summary: AC Transit

Summary of Costs



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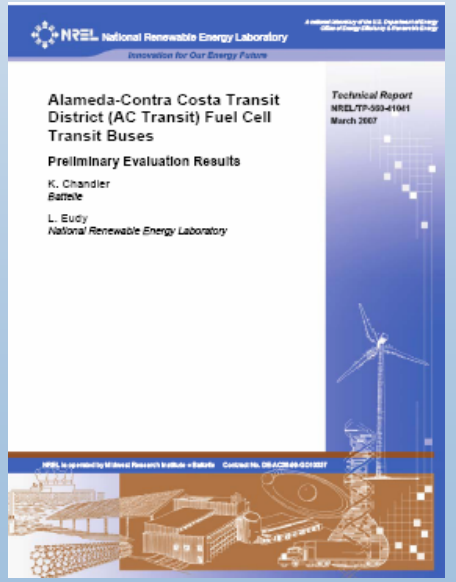
- Interim report published
- Second data report planned for fall 2007

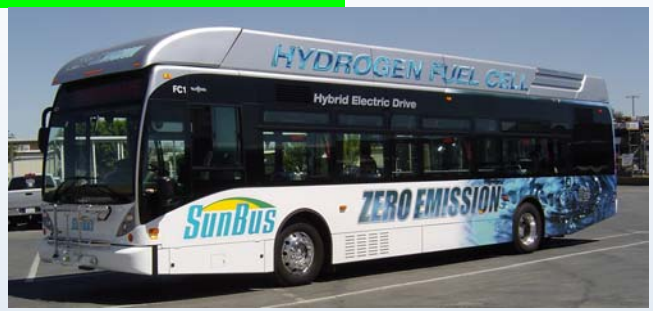


Report available online at
www.nrel.gov/hydrogen/pdfs/41041.pdf

Fleet Data Summary: SunLine

Fuel Cell Bus (hybrid system)

- 11 months operation of 1 FCB
- Total miles: 19,208
- Total FC system hours: 1,345

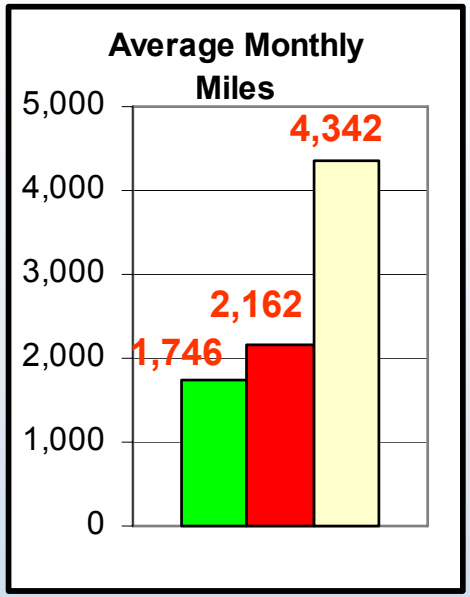


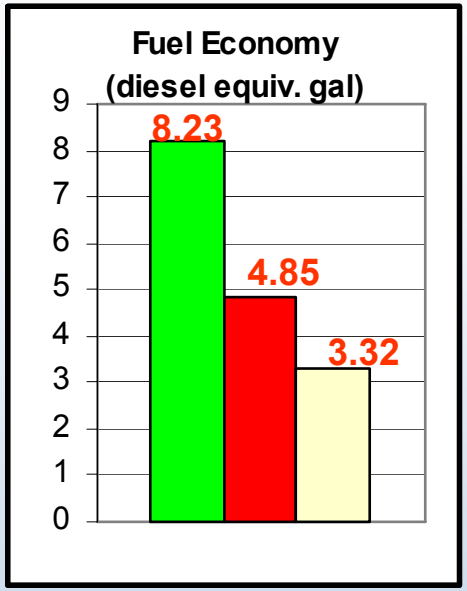
HHICE Bus

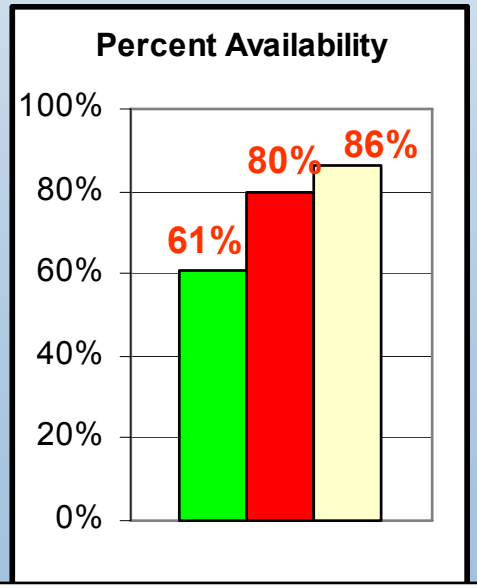
- 11 months operation of 1 HHICE bus
- Total miles: 23,661

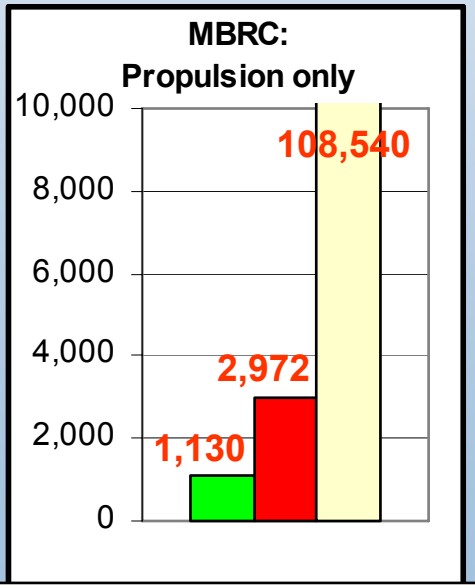
CNG Bus

- 5 months operation of 5 CNG buses
- Total miles: 108,540







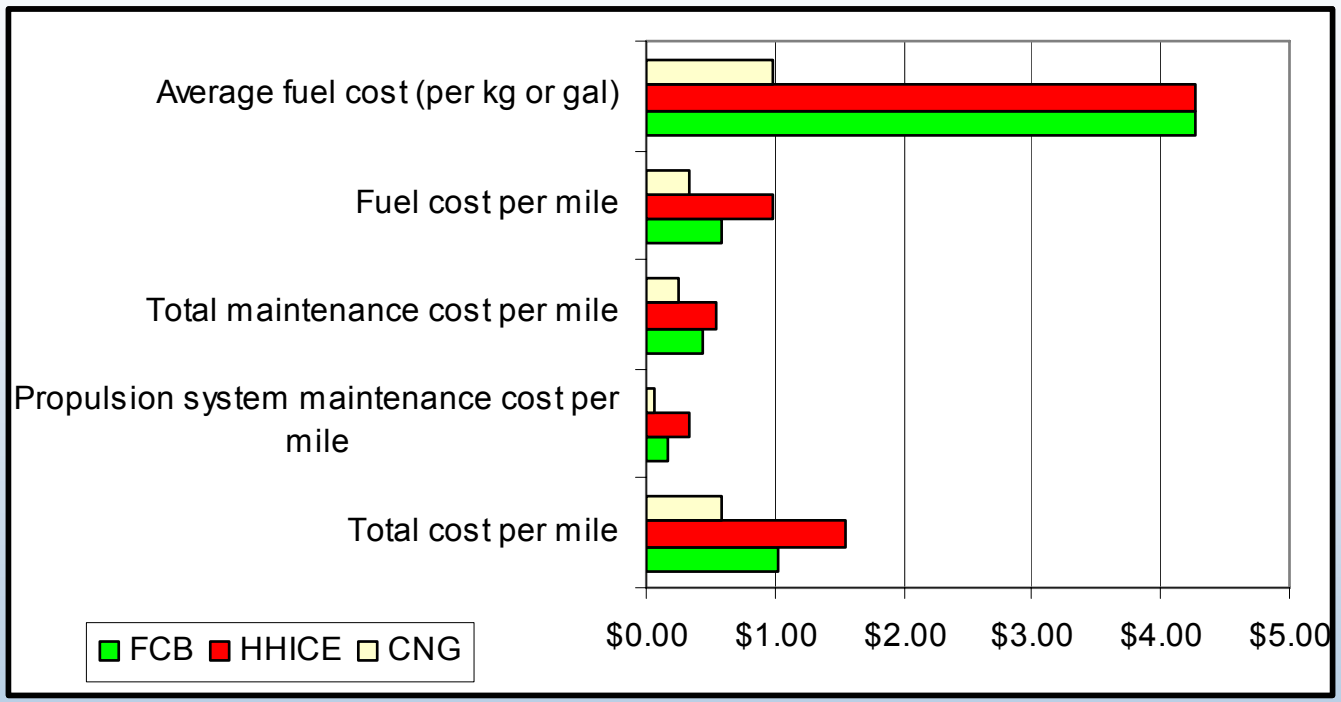


Fuel Cell Bus | HHICE bus | CNG Bus

*HHICE – hybrid H_2 internal combustion engine

Fleet Data Summary: SunLine

Summary of Costs



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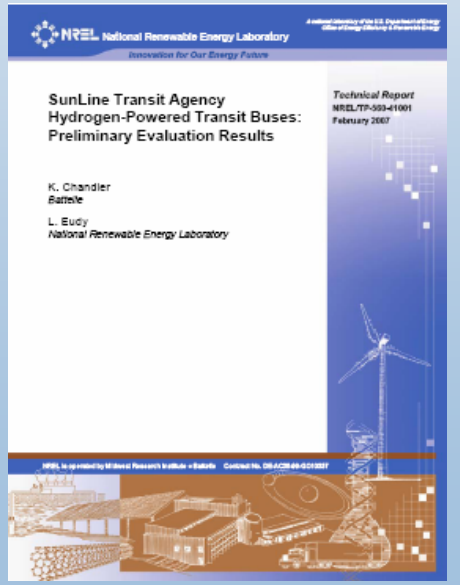
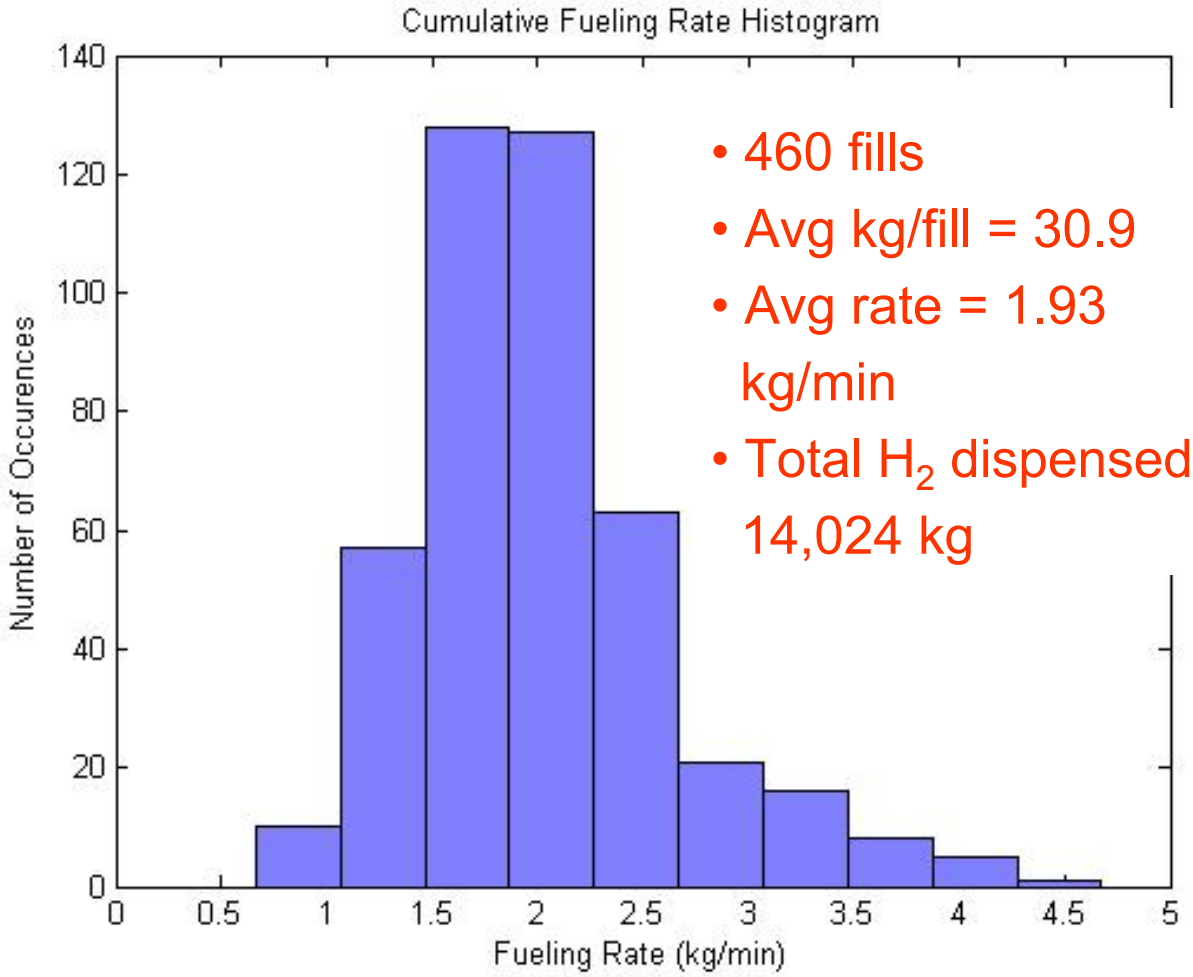


Report available online at
www.nrel.gov/hydrogen/pdfs/41001.pdf

Infrastructure Data Summary: VTA

VTA H_2 Fueling Station



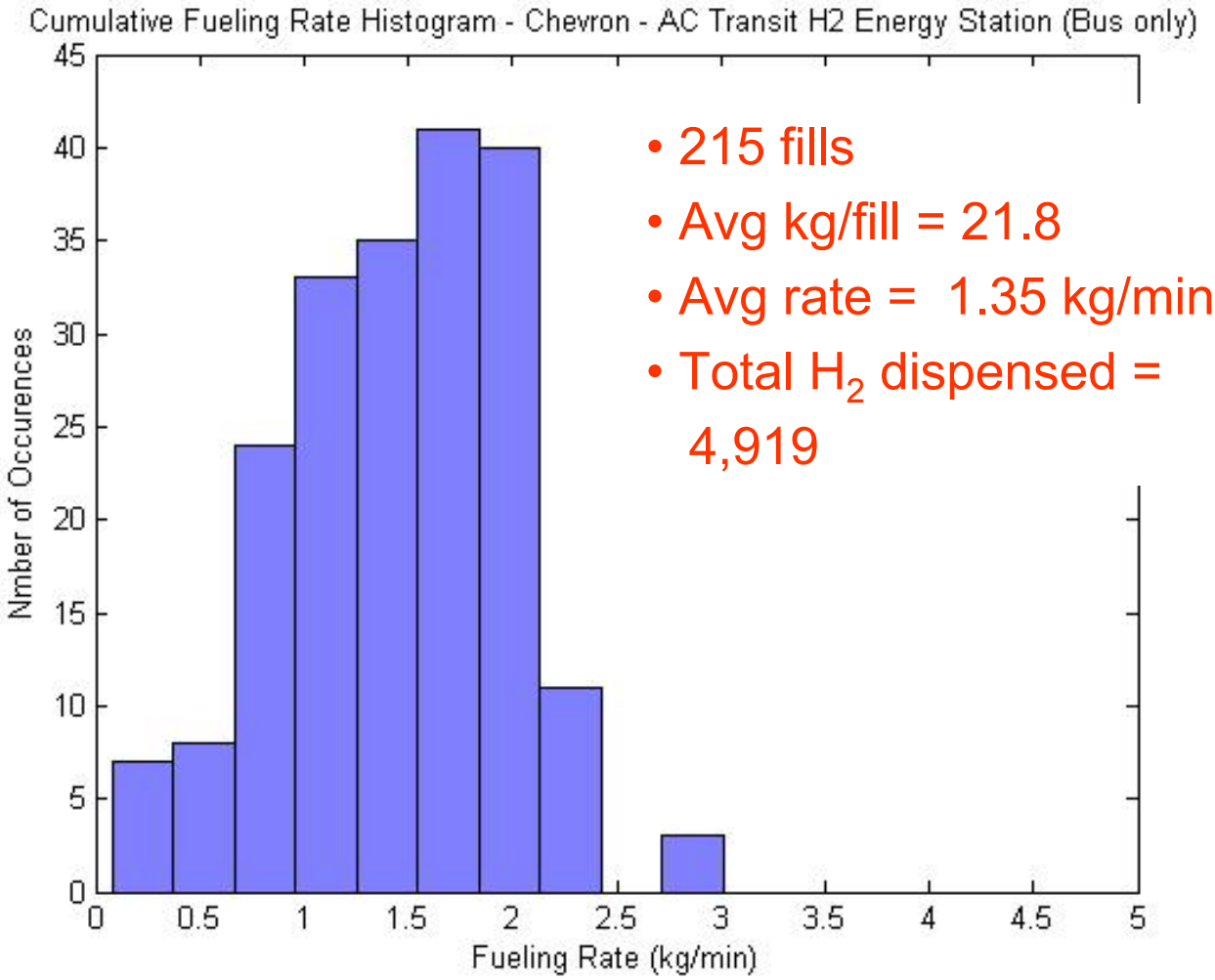
- 460 fills
- Avg kg/fill = 30.9
- Avg rate = 1.93 kg/min
- Total H_2 dispensed = 14,024 kg

VTA fueling station:

- Air Products
- Liquid H_2 storage
- Dispenses compressed H_2

Infrastructure Data Summary: AC Transit

Chevron - AC Transit H_2 Energy Station



- 215 fills
- Avg kg/fill = 21.8
- Avg rate = 1.35 kg/min
- Total H_2 dispensed = 4,919

ACT fueling station:

- Chevron Technology Ventures
- Natural gas reformer
- 150 kg H_2 per day
- 366 kg storage

Hickam Air Force Base: Status

Demonstration of two fuel cell vehicles

Vehicles

- 1 ElDorado 30-ft bus
  - Enova battery-dominant hybrid FC system, Hydrogenics 20kW FC
- 1 step van
  - Enova hybrid FC system, Hydrogenics 60kW FC

Status

- H_2 fueling available in late 2006
- Bus operating as visitor shuttle on base and in surrounding area
- Step van in service as maintenance support vehicle
- Interim report scheduled for publication in fall 2007

International Collaboration

4th workshop held in Yokohama, Japan in October 2006

- Overall goal: enhance information sharing and data exchange between international FCB demos
- Group discussion:
  - Developed a list of performance data available to share from all projects
  - Listed concerns and issues that must be solved prior to sharing
  - Established action items and a timeline for accomplishment
- Planning 5th International Fuel Cell Bus Workshop in summer 2008

IPHE Recognized Event

Future Work

- Remainder of FY 2007
  - Data analysis and draft preliminary data report on Hickam evaluation
  - Complete second data analysis and reports on AC Transit and SunLine
  - Collect more technical data on FCBs and infrastructure to complement DOE Controlled Fleet Demo
- FY 2008
  - Complete analysis and final data report on Hickam
  - Complete final data analysis and reports on SunLine and AC Transit
  - Initiate data collection for additional fleets

Summary

- Collected operational, performance, and cost data on 8 hydrogen fueled buses in real-world service at three transit agencies:
  - VTA: 17 months
  - SunLine: 11 months
  - AC Transit: 8 months
- Validated fuel cell bus performance characteristics equal to or better than diesel
  - Drivers report better acceleration and quiet operation
- Demonstrated that bus duty-cycle allows fast accumulation of miles/FC hours
  - Accumulated over 110,000 total miles and over 6,900 FC hours
- Collected performance and cost data on conventional technology to establish a baseline for tracking progress
  - Use of prototype FCBs is much less than standard buses
  - High cost for maintaining current generation prototype technology

Summary (continued)

- Fuel cell bus use less than baseline
  - Range from 50% below to 81% below standard bus use
- Fuel economy
  - Fuel economy results show need for hybridization
  - Improvement over conventional technology approaching 2X
  - Highly dependent on duty-cycle