VTA Prototype Fuel Cell Bus Evaluation: *Interim Results*

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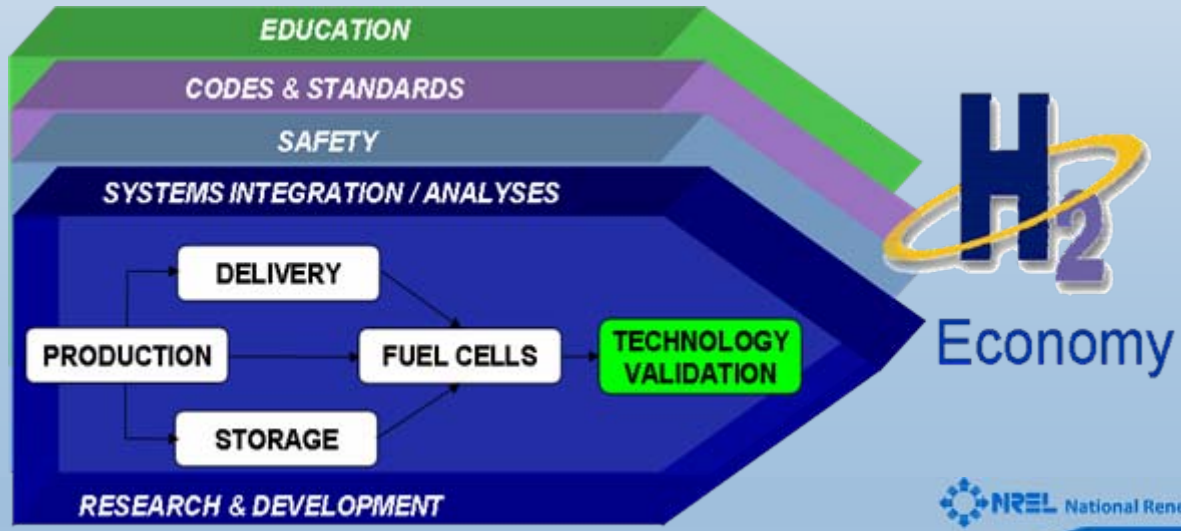
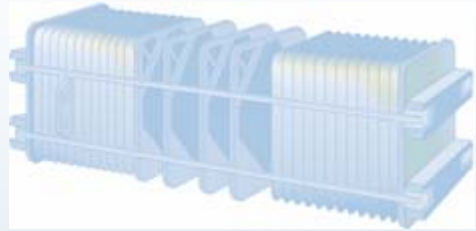
DOE Hydrogen FC Technology Validation Projects

Objectives:

- Validate hydrogen FC vehicles and infrastructure in parallel
- Identify current status of technology and its evolution
- Re-focus hydrogen research and development



Why Fuel Cell Technology?



- Strengthen national energy security
  - Reduce dependence on imported oil
- Reduce greenhouse gas emissions
  - GHGs are thought to be responsible for global climate change
- Improve air quality
  - Reduce smog and harmful particulates
- Increase energy efficiency
  - Fuel cells are inherently more energy efficient than internal-combustion engines
- Reduce noise levels
  - Fuel cell electric drive vehicles can be quieter than conventional vehicles

Current FCB Evaluations

Fleet	Vehicle/Technology	Number	Evaluation Status
VTA and SamTrans	Gillig/Ballard fuel cell transit bus	3	Evaluation in process, interim report published
U.S. Air Force/Hickam Air Force Base	Shuttle bus: Hydrogenics and Enova, battery-dominant fuel cell hybrid	1	Shuttle bus in operation, data collection will begin once permanent H2 fueling in place.
	Delivery van: Hydrogenics and Enova, fuel cell hybrid	1	Van in service June 2006
AC Transit and Golden Gate Bridge, Highway, and Transportation District	Van Hool/UTC fuel cell hybrid transit bus integrated by ISE Corp.	3	Buses in service; evaluation in process
SunLine Transit Agency	Van Hool/UTC fuel cell hybrid transit bus integrated by ISE Corp.	1	Bus in service, evaluation in process
	New Flyer ISE Corp. hydrogen internal combustion engine transit bus	1	Bus in service, evaluation in process

Why Evaluate Prototype Technology?

Demonstrations are a necessary part of the development process, but what do we really hope to accomplish?

- Show progress toward commercialization
  - Study the implementation process to document and share lessons learned
  - Provide a real data point in time to document:
    - Vehicle performance in real-world service
    - Comparison to conventional technology (baseline)
    - Costs
    - Effort required
- Provide a “reality check”
  - Keep the marketing from getting too far ahead of the progress

VTA/SamTrans: Interim Data Results

Data Period
March – October 2005

Partners/Service Area

- Fleets:
  - Santa Clara Valley Transportation Authority (VTA), San Jose, CA
  - San Mateo County Transit District (SamTrans) in San Carlos, CA
- Manufacturers
  - Ballard Power Systems
  - Gillig
- Infrastructure
  - Air Products & Chemicals

VTA/SamTrans ZEB Program

- CARB ZEB Requirements (for fleets with >200 buses)
  - By Feb 2006, Demonstrate 3 ZEBs and supporting infrastructure (Evaluate feasibility of fuel cell buses)
  - By Jul 2007, Results reports due to CARB
  - Beginning in 2008, 15% of bus purchases must be ZEBs
- Estimated total program cost $18,450,000
- ZEB Program Goals
  - Determine the status of fuel cell technology in transit applications.
  - Identify issues and challenges to overcome.
  - Provide community outreach and educate the public on fuel cell and hydrogen technology.

Fuel Cell Buses at VTA

- Three prototype fuel cell buses
- Diesel buses used for a baseline

The fuel cell bus has a non-hybrid fuel cell system by Ballard Power Systems

Bus Specifications

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

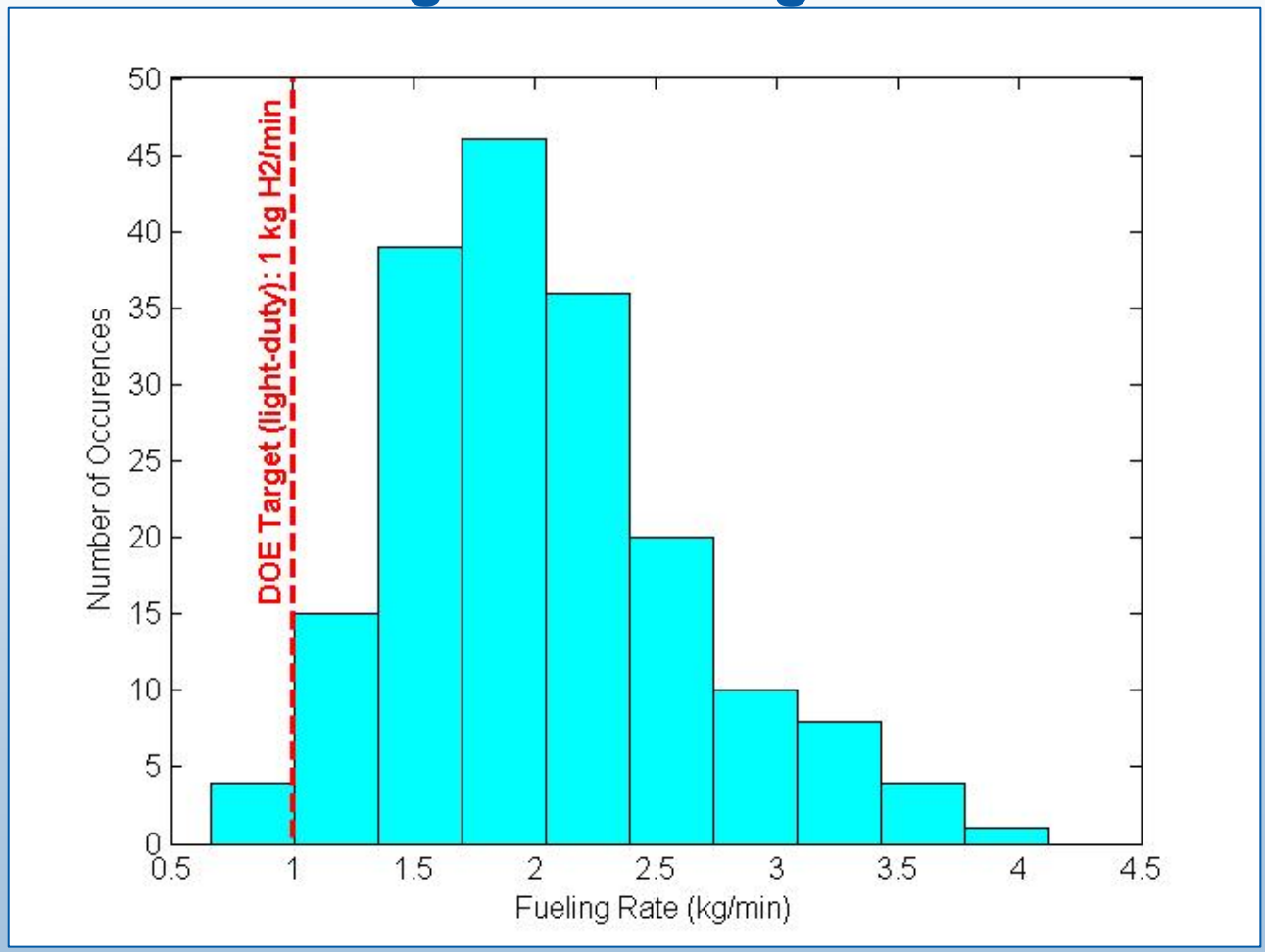
Infrastructure at VTA

Hydrogen Fueling Facility

- Facility designed, built and maintained by Air Products
- Liquid hydrogen delivery and storage
- Compressed to 6,000 psi and vaporized for storage in cascade
- Bus fueling capability goal of 8 minute fill with communications

Hydrogen Fueling Experience

Cumulative Fueling Rate Histogram: VTA Station

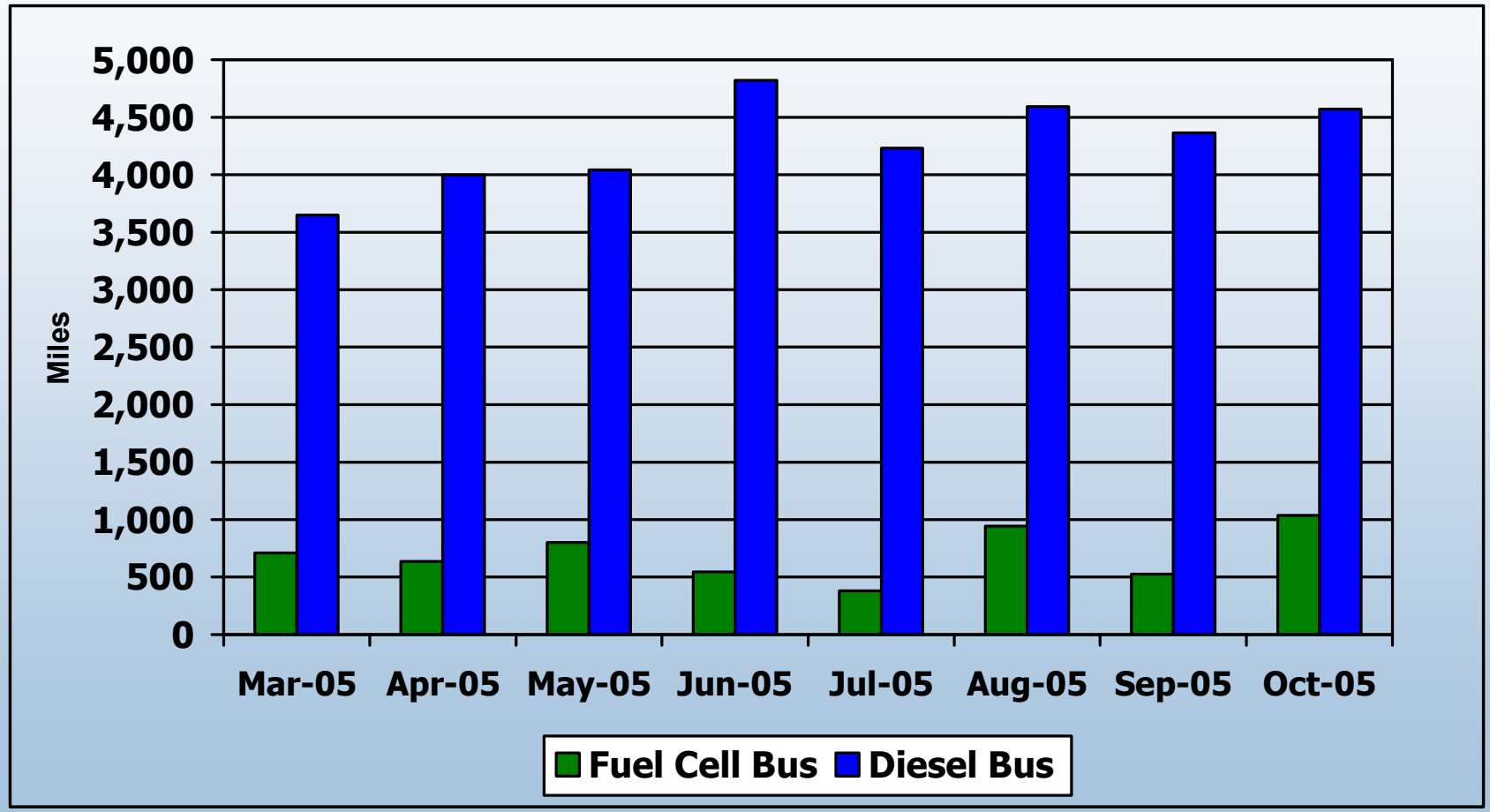


About 55 kg useful fuel – fast rate required for reasonable fill time

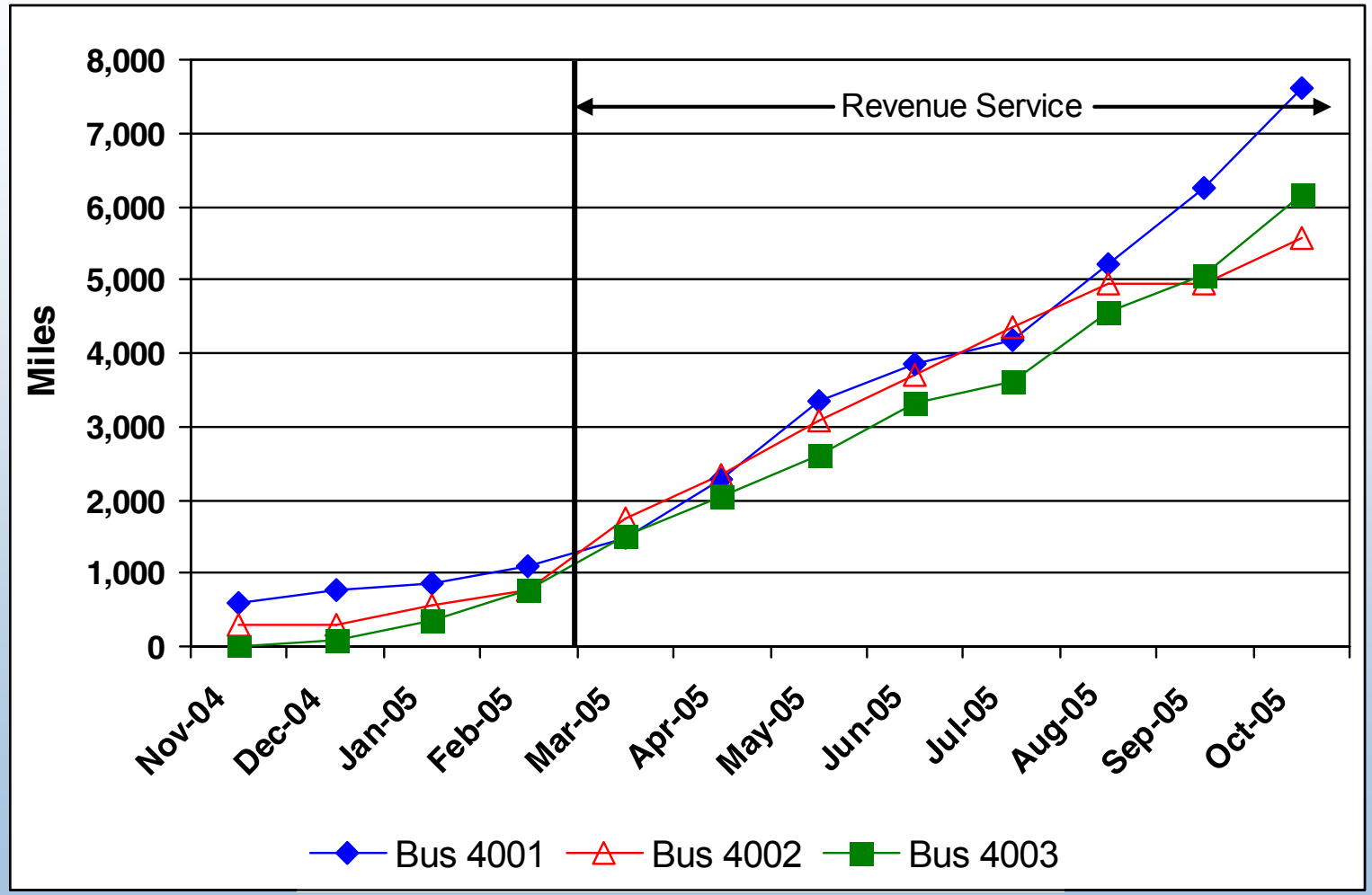
In-Use Bus Evaluation

- Comparison of FCBs to conventional diesel baseline
  - Three MY 2004 buses with non-hybrid FC system
  - Five MY 2002 diesel buses (Cummins ISL with DPF)
- FCBs limitations
  - Extra service (between scheduled diesel buses)
  - During the week only
  - Driver and mechanic availability
- Diesel buses randomly dispatched (7 days/week)
- Average speed 14.5 mph

Average Monthly Mileage per Bus

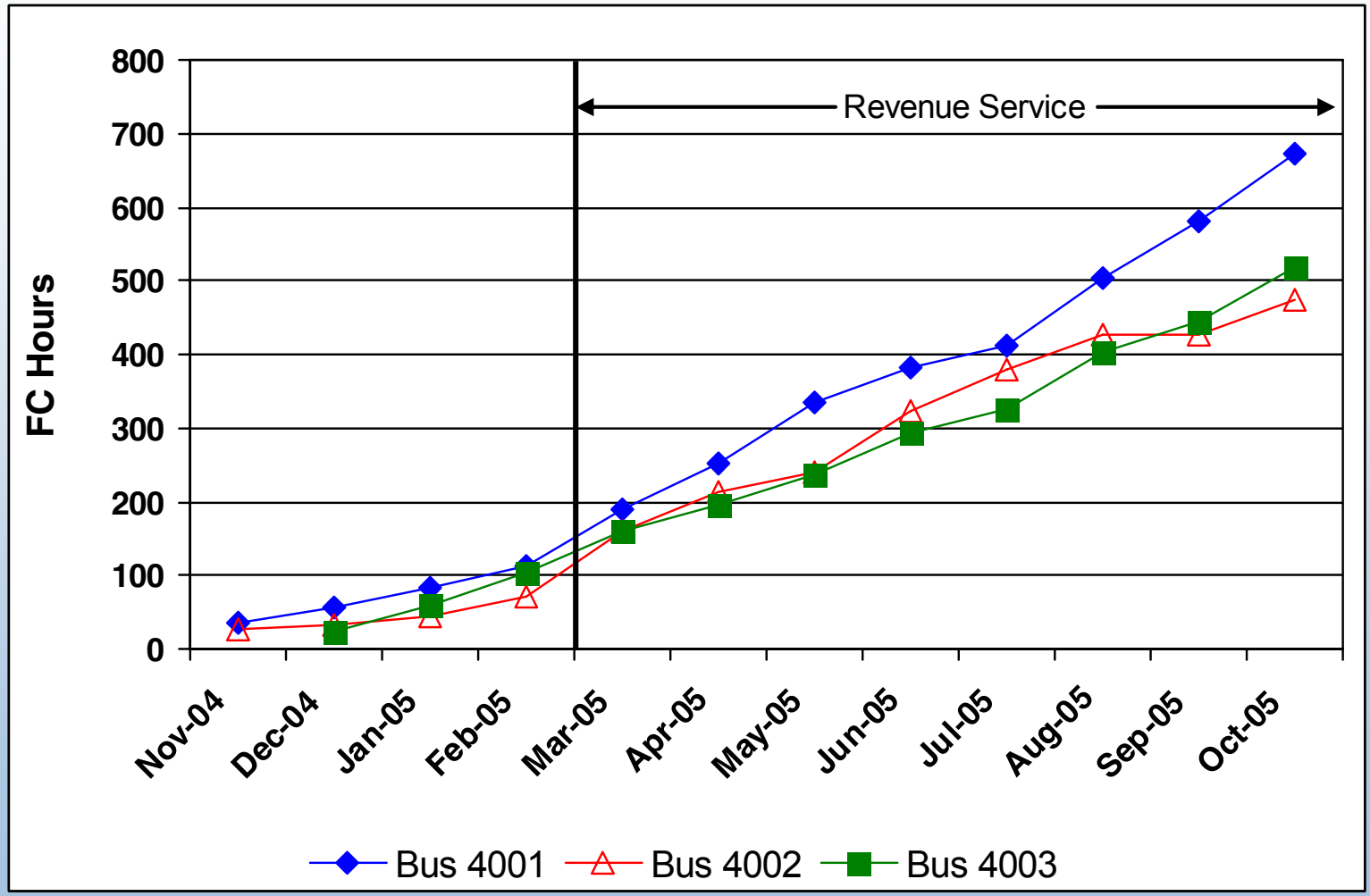


Cumulative FCB Mileage per Bus



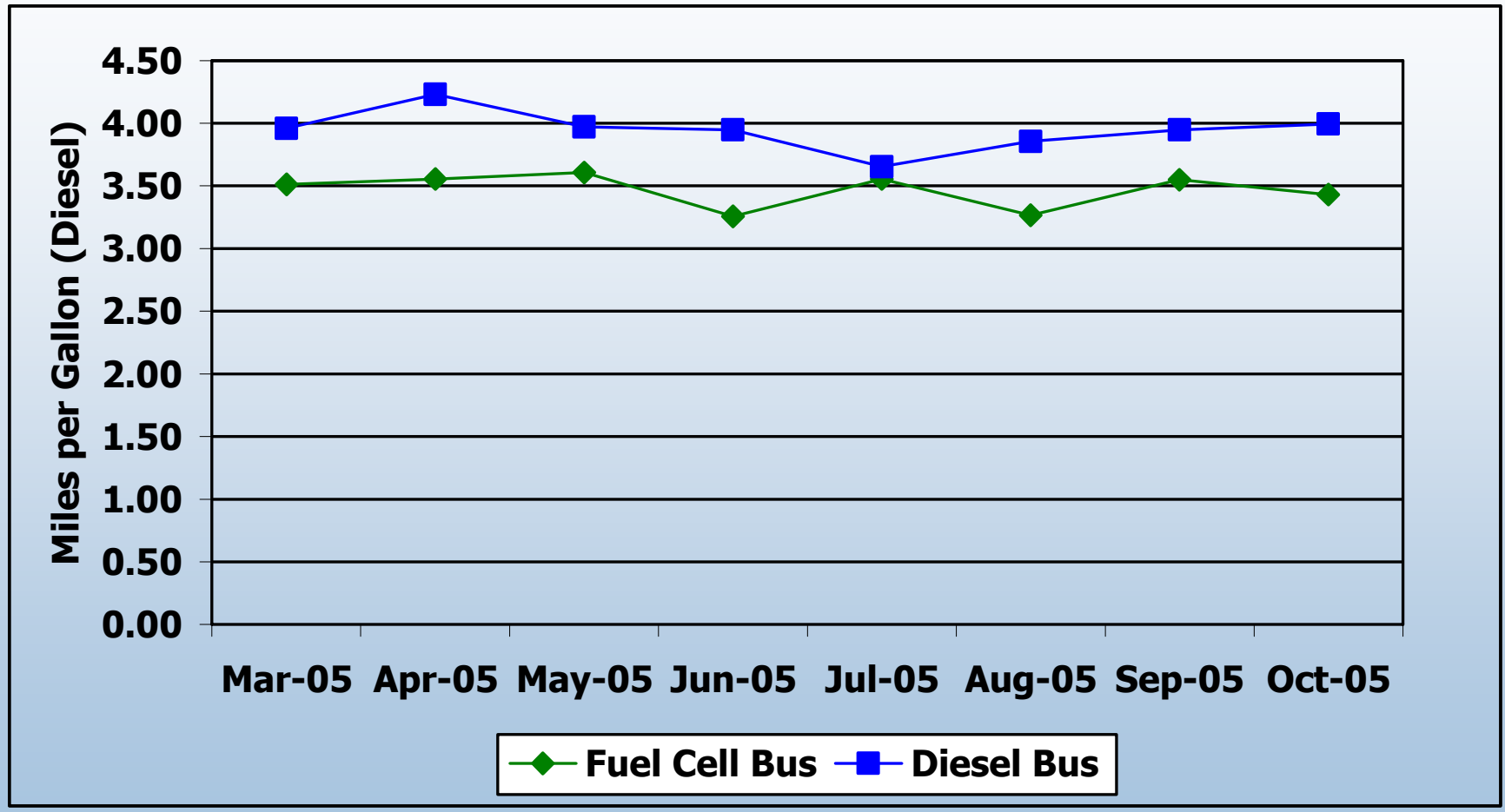
Total mileage for all 3 FCBs - over 19,000 miles

FC Hour Accumulation by Bus



Total FC hours accumulated for all buses 1,600 hrs.

Average Fuel Economy



Fuel Cell Buses have 13% lower energy equivalent fuel economy compared to diesel (FCB = 3.45, Diesel 3.95)

Reliability: Miles Between Road Calls

- Diesel Buses – 9,019 MBRC total; 11,424 MBRC propulsion related only
- Fuel Cell Buses – 983 MBRC total; 1,044 MBRC propulsion related only

Definition: A road call (RC) is a failure of an in-service bus that causes the bus to be replaced on route or results in a significant schedule delay. If the problem can be repaired during a layover and the schedule is not affected, this is not considered a RC. (from the National Transit Database)

Summary

- Bus duty-cycle allows fast accumulation of miles/FC hours
  - As of March 2006, highest mileage bus has accumulated over 17,000 miles
  - On-track to achieve over 1,000 FC hours/bus by end of demo
- Fuel Economy results show need for hybridization
- Collecting performance and cost data on conventional technology establishes a baseline for tracking progress
  - Use of prototype FCBs is much less than standard buses
  - High cost for maintaining current generation prototype technology

Reality Check – What Was Accomplished?

- Federal Level
  - Current status provided to Federal agencies (DOE, FTA, etc.)
  - Re-focus of R&D and new funding opportunities
- State Level
  - Provided results to State agencies (ARB, CEC, FTA Regional Office)
  - Regulations can be modified to aid in further development of the technology
- Local Level
  - Provided experience to fleet (and project partners)
  - Provided training to local officials (Fire, First Responders, etc.)
  - Increased public awareness – for both transit riders and general population

Special Thanks

- VTA
- SamTrans
- Ballard Power Systems
- Air Products & Chemicals
- U.S. Department of Energy

For More Information

Published Report:

Santa Clara Valley Transportation Authority and San Mateo County Transit District

Fuel Cell Transit Buses: Preliminary Evaluation Results

Report # NREL/TP-540-39365

www.eere.energy.gov/hydrogenandfuelcells/tech_validation/pdfs/vta_prelim_eval_results.pdf

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