

Technology Validation: Fuel Cell Bus Evaluations



**2010 DOE Annual
Merit Review**

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**Project ID#
TV008**

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Overview

Timeline

- Project started in FY03
- First-generation FCB completed in FY09
- Second-generation FCBs began 4th Qtr 2009

Budget

- FY 2010: \$200K
- FY 2009: \$205K
- FY 2008: \$300K
- Additional funding from DOT/Federal Transit Admin.

Tech. Val. Barriers

- A. Lack of fuel cell vehicle performance and durability data
- C. Lack of H₂ fueling infrastructure performance and availability data
- D. Need for maintenance and training facilities

Partners

- Fleets: Operational data, fleet experience
- Manufacturers: Vehicle specs, data and review
- Fuel providers: Fueling data and review

Objectives - Relevance

- Overall: Validate fuel cell technologies in transit applications
 - Analyze fuel cell bus (FCB) performance and cost compared to conventional technologies to measure progress toward commercialization
 - Provide “lessons learned” on implementing fuel cell systems in transit operations to address barriers to market acceptance
 - Harmonize data collection efforts with other fuel cell bus demonstrations worldwide (in coordination with FTA and other U.S. and international partners)
- 2010
 - Complete analysis and report results on first generation FCBs
 - Begin data collection and analysis for next-generation fuel cell buses at Burbank, SunLine, and AC Transit
 - Conduct crosscutting analysis of FCB status at all sites

Evaluation Approach

- Data collection & analysis at transit sites
 - Follows existing, standard protocol
 - Uses cost-effective process utilizing data already collected by agency
 - Includes data on baseline vehicles in same service
 - Builds database of evaluations/results
- Annual FCB Status report
 - Includes summary of data across all sites
 - Assesses progress and needs for continued success
- Expansion of data collected and analyzed as resources allow

Approach – Milestones

- Complete evaluations of 1st generation FCBs:
 - Santa Clara VTA: completed in FY07
 - AC Transit: completed in FY09
 - SunLine: completed in FY09
 - **CTTRANSIT**: completed in FY10
 - Overall assessment of 1st gen: Sep 10
- Begin evaluations of 2nd generation FCBs
 - SunLine: March 2010
 - City of Burbank: April 2010
 - AC Transit: May 2010



Comparison of Fuel Cell Buses to Conventional Technology Baseline

Metrics for assessing progress toward commercialization

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



Fleet Data Summary: SunLine

Fuel Cell Bus (hybrid system)

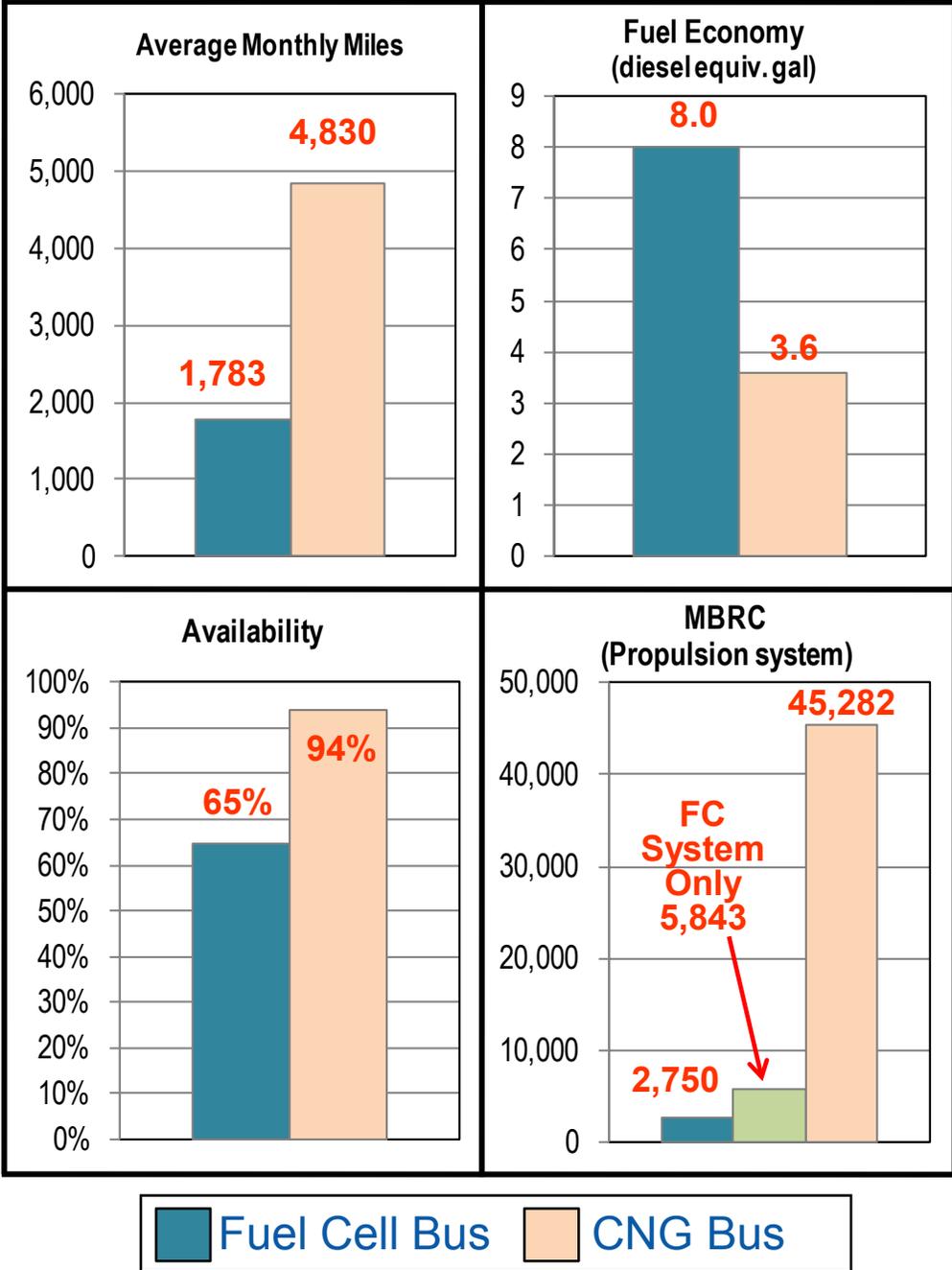


- 22 months operation of 1 FCB
- Total miles: 39,236
- Data with new version of fuel cell installed
- Total FC system hours: 2,937

CNG Bus



- 15 months operation of 5 CNG buses
- Total miles: 362,259



Fleet Data Summary: CTTRANSIT

Fuel Cell Bus (hybrid system)

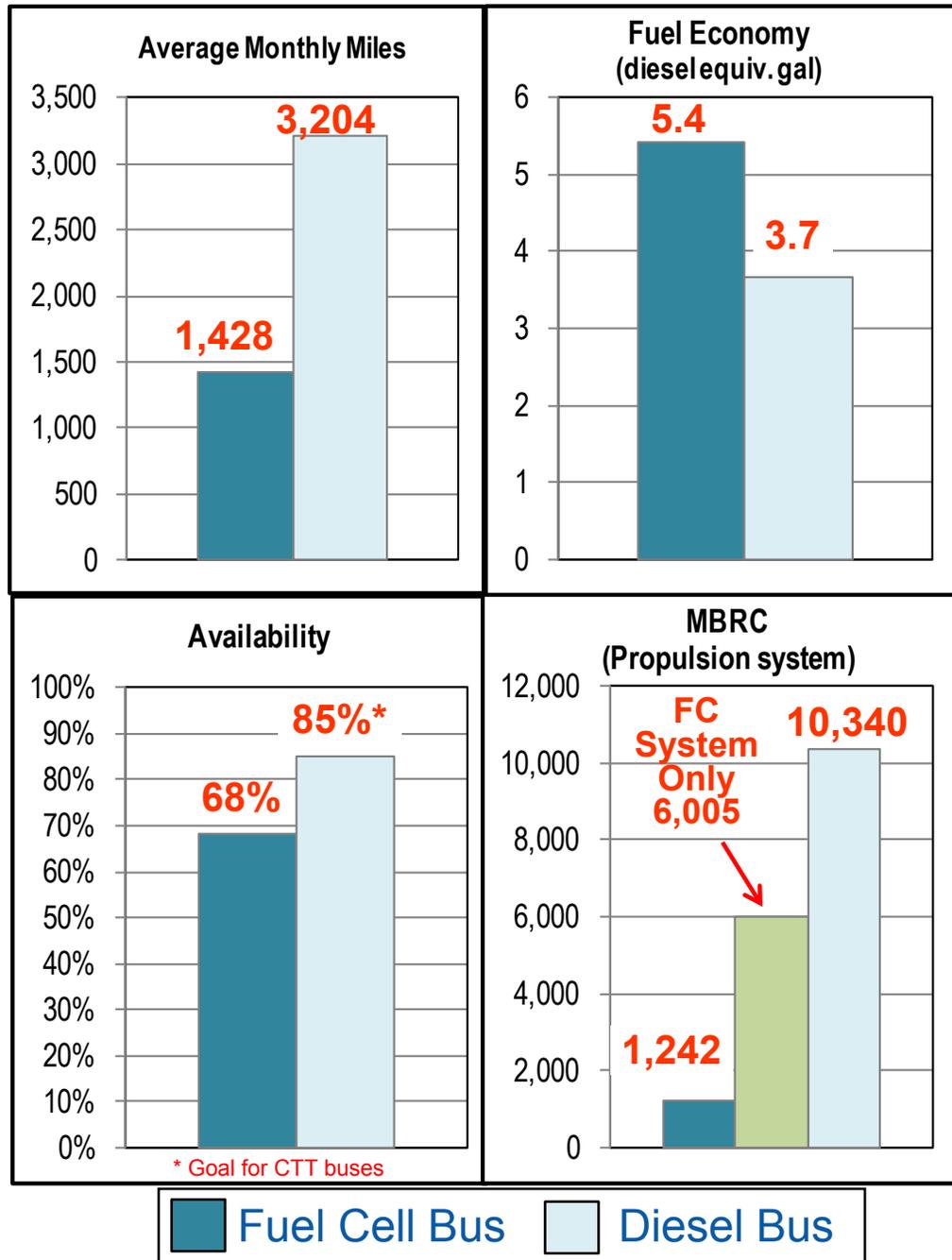


- 25 months operation of 1 FCB
- Total miles: 35,690
- Data with new version fuel cell installed
- Total FC system hours: 5,424

Diesel Bus (baseline)



- 27 months operation of 3 diesel buses
- Total miles: 259,547



Fleet Data Summary: AC Transit

Fuel Cell Bus (hybrid system)

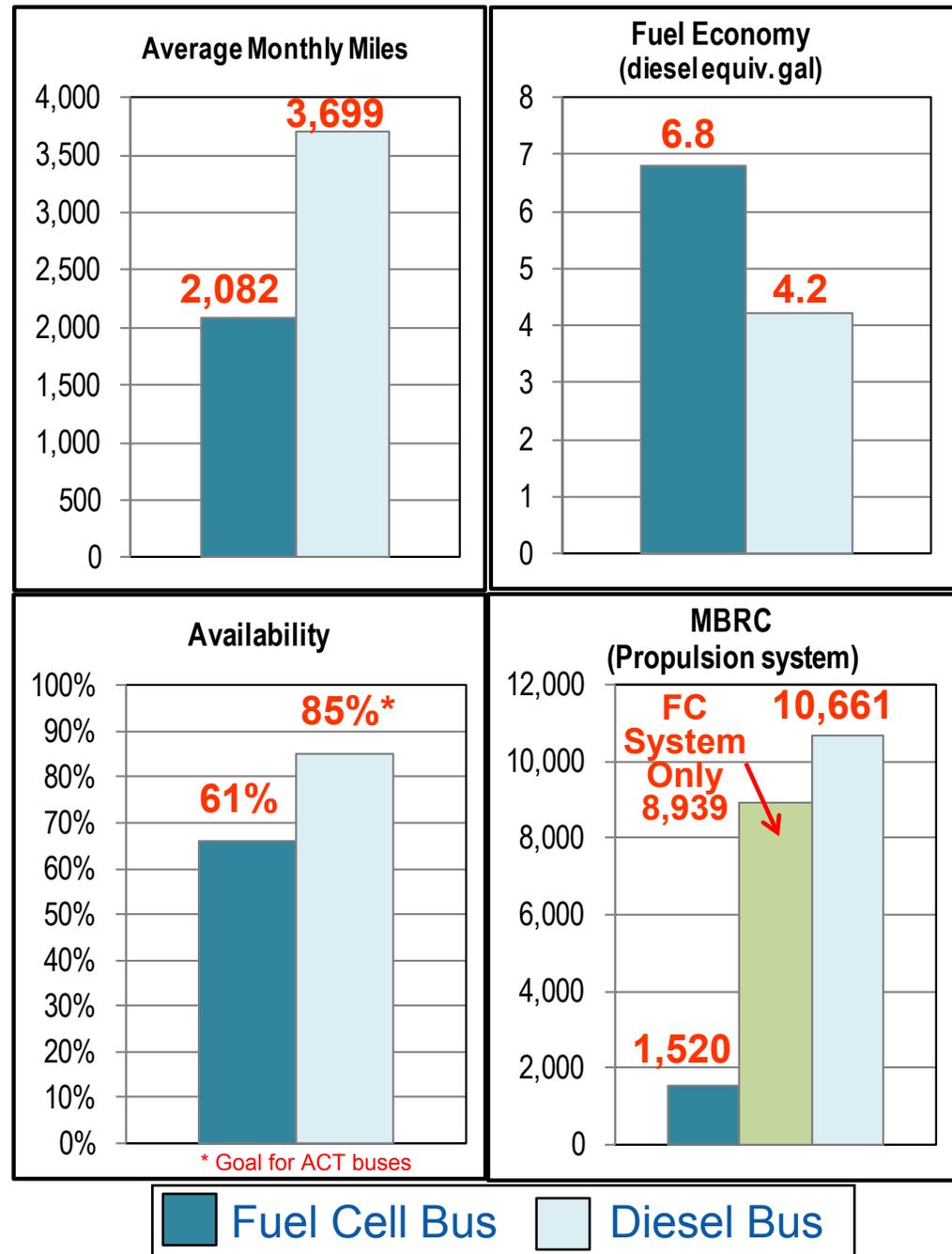


- ~26 months operation of 3 FCBs
(Data with new version FC systems)
- Total miles: 151,950
- Total FC system hours: 16,058
- 2 FC systems over 5,000 hrs

Diesel Bus (baseline)

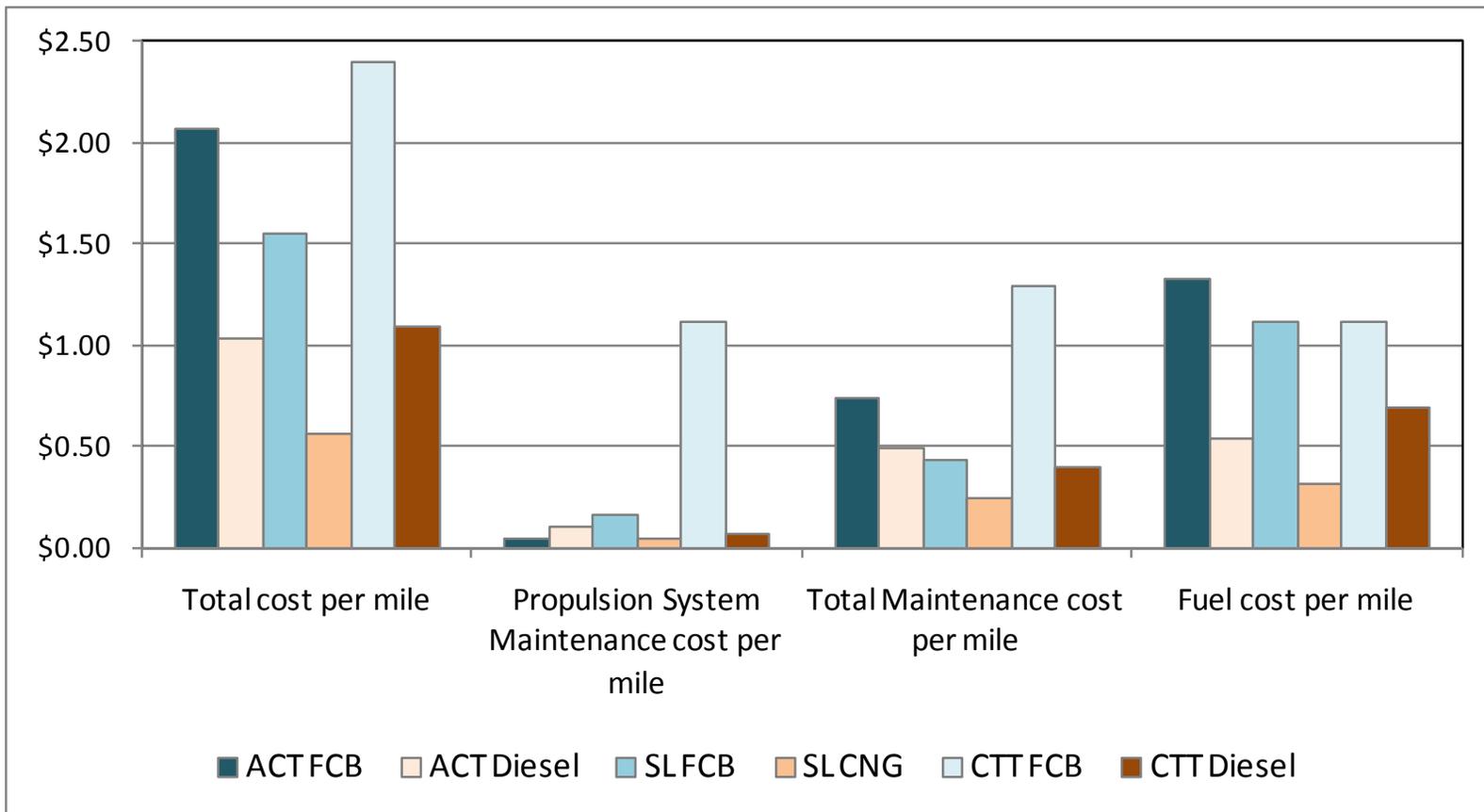


- 12 months operation of 6 diesel buses
- Total miles: 266,514



Data Summary: Costs

- Capital costs of buses dropping; larger quantity orders should help
- Fuel costs remain higher
- Operational costs still higher



Fuel Costs (per kg or gallon)

ACT H2	\$8.00
ACT Diesel	\$2.29
CTT H2	\$5.29
CTT Diesel	\$2.70
SL H2	\$8.00
SL CNG	\$1.07

H2 Infrastructure Data Summary

Hydrogen Fueling Data Summary

Fleet	Dates covered	# Months	Total Fuel (kg)	Total Time (min)	Avg. Fill (kg)	Rate (kg/min)	Number Fills
VTA*	Nov 2004 - Jun 2007	32	20,102	9,711	30.0	2.07	670
ACT	Apr 2006 - Jan 2010	46	35,001	26,077	21.8	1.34	1,605
SunLine	Jan 2006 - Jan 2010	49	17,060	16,281	20.1	1.05	847
CTT	Apr 2007 - Jan 2010	34	7,767	11,693	22.5	NA	345
Totals		161	79,931			1.39	3,467

Hydrogen Station Descriptions

VTA

- Air Products
- Liquid H₂ storage
- Dispenses compressed H₂

SunLine

- HyRadix
- Natural gas reformer

AC Transit

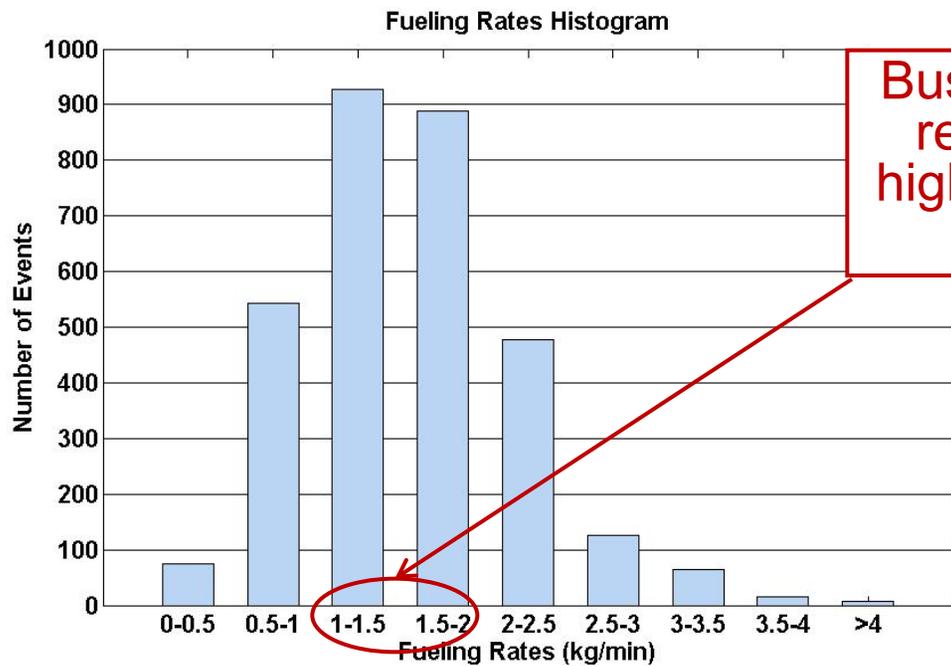
- Chevron
- Natural gas reformer

CTTRANSIT

- UTC Power station
- Praxair
- Liquid H₂ storage
- Dispenses compressed H₂

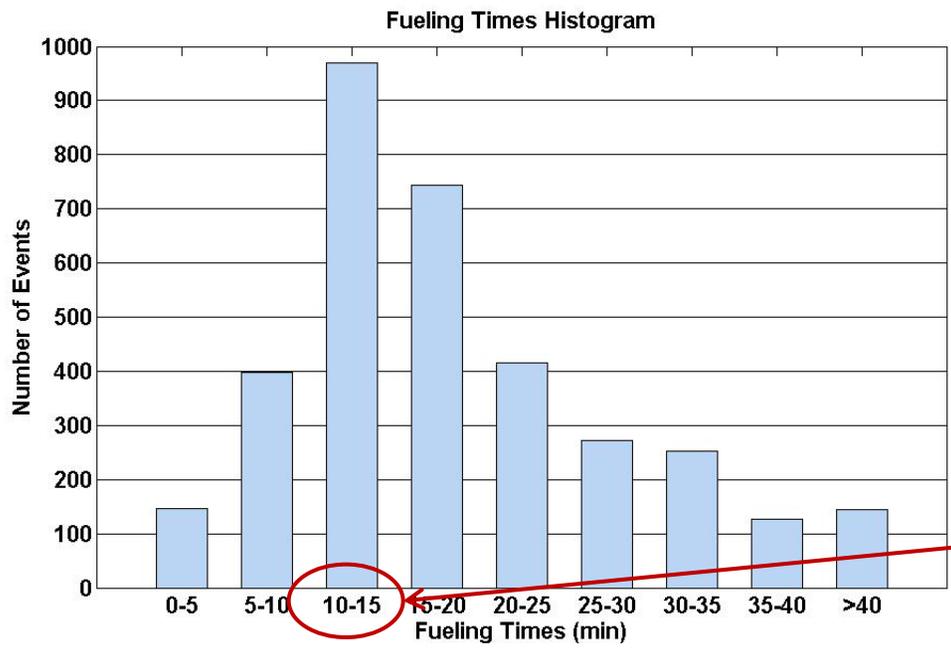
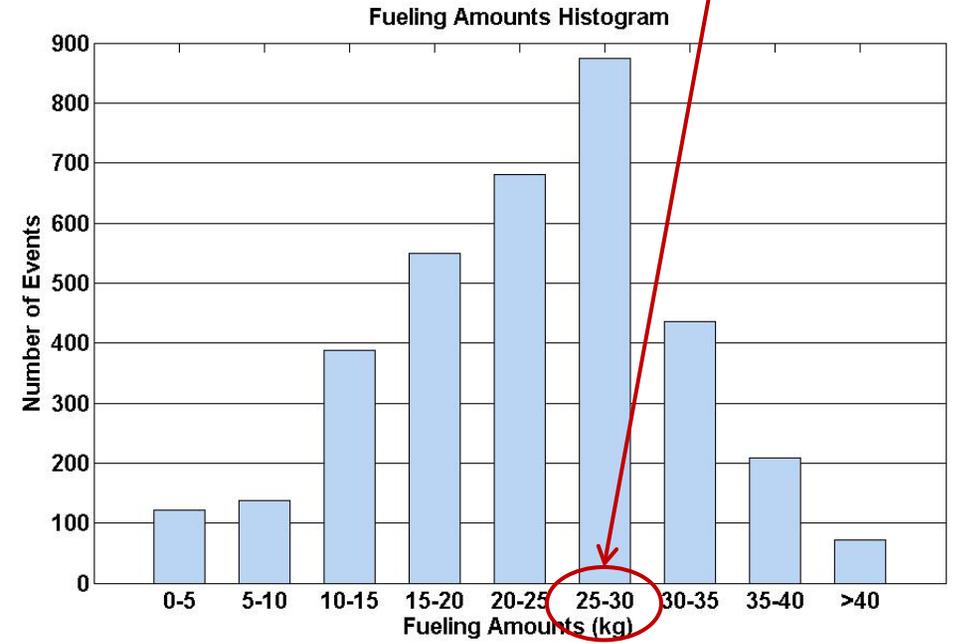
* VTA data reported previously – included to show total fuel dispensed

H2 Infrastructure Data Summary



Bus fueling requires high fueling rates

Bus H2 fuel capacity ~50 kg, require larger quantity fills



Transit agency targets for filling time: under 10 minutes

Collaborations

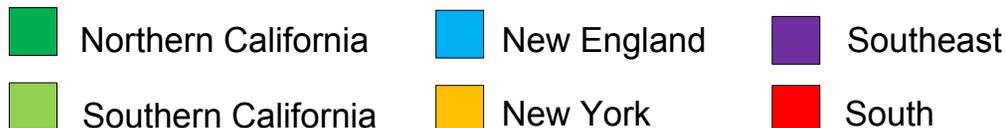
- Transit agencies provide data on buses, fleet experience & training, and review reports
 - California: AC Transit, Golden Gate Transit, Santa Clara VTA, SamTrans, SunLine, San Francisco MTA
 - Connecticut: CTTRANSIT
 - South Carolina: Columbia Midlands RTA, USC
- Manufacturers provide some data on buses and review reports
 - Bus OEMs: Proterra, Van Hool
 - FC OEMs: Ballard, Hydrogenics, UTC Power
 - Hybrid system OEMs: BAE Systems, ISE
- Other organizations share information and data
 - National: CARB, NAVC, CTE, Calstart, EDTA
 - International: Various organizations from Germany, Iceland, Brazil, Canada, China, Japan, England, Australia

Planned FCB Evaluations for DOE and FTA

NREL Hydrogen Bus Evaluations for DOE and FTA

Site/Location	State	Eval. Funding	2009				2010				2011				2012				
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
AC Transit/ SF Bay Area	CA	DOE Technology Validation						CA ZEB Advanced Demo											
SunLine/ Thousand Palms	CA		FCB																
SunLine/ Thousand Palms	CA						Advanced FCB Project												
CTTRANSIT/ Hartford	CT		FCB Demo				← June 2010												
City of Burbank/ Burbank	CA						Burbank FCB												
AC Transit/ Oakland	CA	FTA National Fuel Cell Bus Program	Accel. Test																
SunLine/ Thousand Palms	CA										American FCB Demo								
CTTRANSIT/ Hartford	CT						Nutmeg Hybrid FCB Demo												
USC, CMRTA/ Columbia UT/ Austin	SC, TX						Hybrid FCB												
Logan Airport / Boston	MA										MA H2 FCB Demo								
Albany / NY	NY						Light-wt FCB												
TBD / NY	NY										NYPA H2 Powered FCB								
SFMTA / San Francisco	CA						FC APU Hybrid												

Demonstration sites color coded by geographic area:



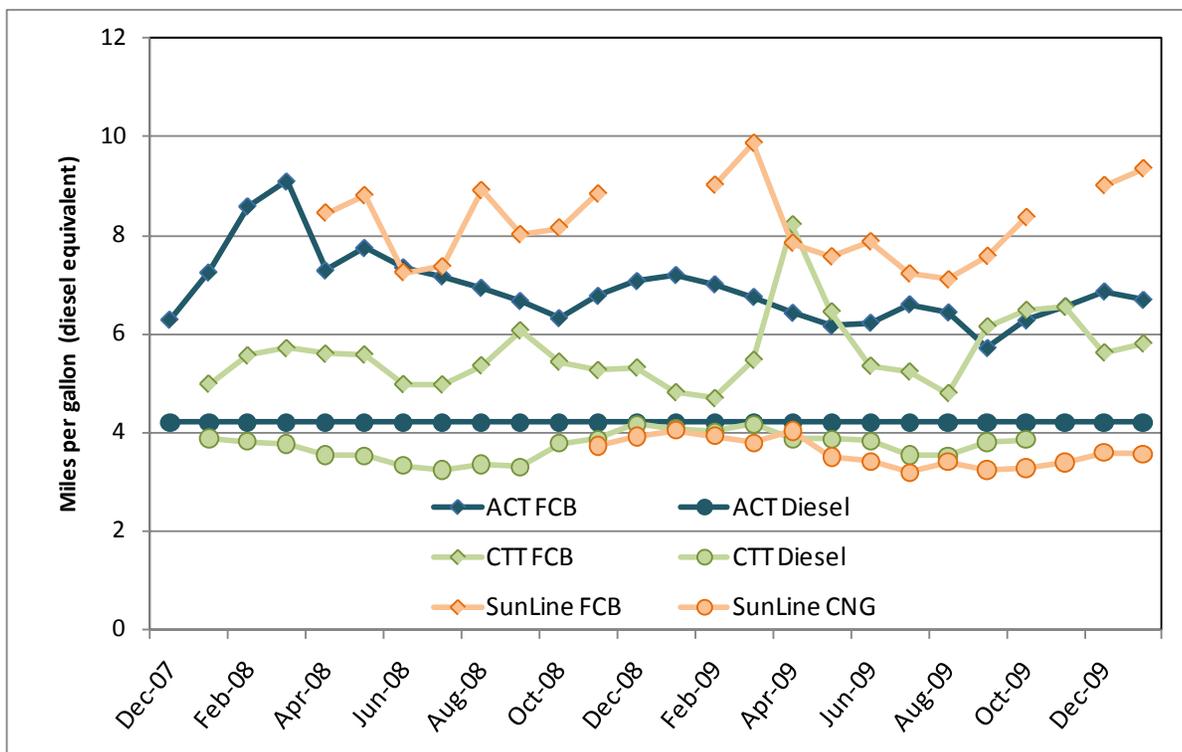
Future Work

- Remainder of FY 2010
 - Initiate data collection on next-generation fuel cell buses at AC Transit, SunLine, and City of Burbank
 - Initiate detailed data collection on FCBs developed under the FTA program
 - Complete final crosscutting analysis of 1st generation FCBs at all sites
- FY 2011
 - Analyze data and report on new FCBs at Burbank, SunLine, and AC Transit
 - Complete annual crosscutting analysis across sites
 - Continue coordinating data collection activities with FTA

Summary

Progress

- Continued data collection & analysis of five FCBs in real-world service at three transit agencies
- Documented fuel economy improvement over conventional technology as high as 2 times (depending on duty cycle)
- Manufacturer has modified FC based on early results to increase durability and reliability. New version installed in all 5 buses beginning in late 2007.



Monthly Fuel Economy

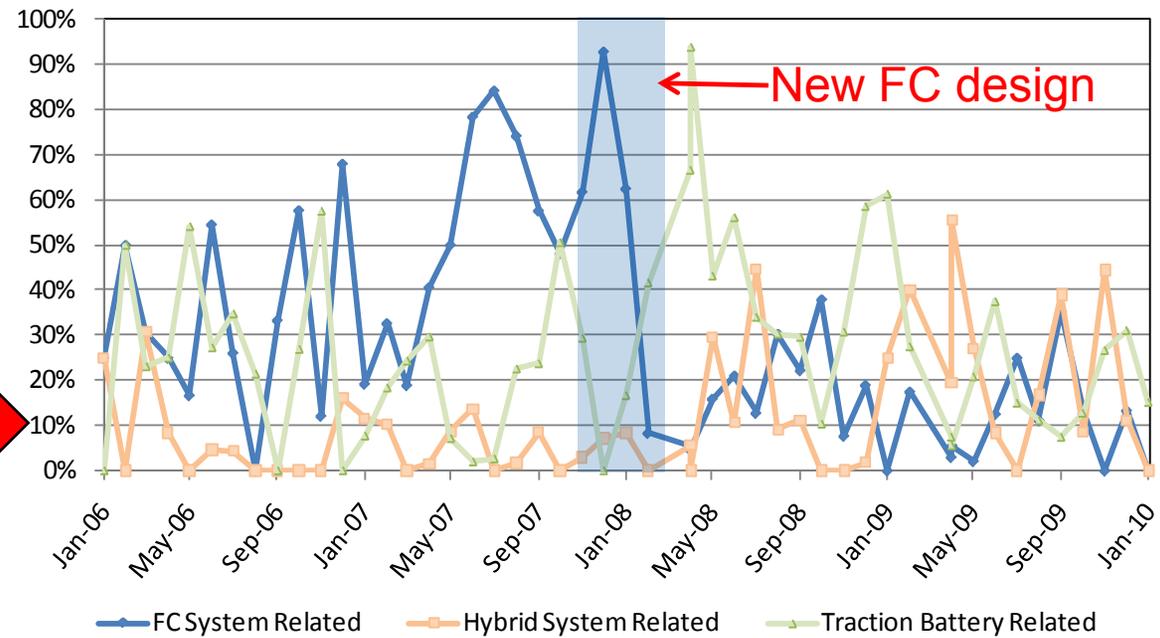
- Clean point with new design FC System
- Two new FC systems have surpassed 5,000 hours without any repairs (routine maintenance only)

Summary (continued)

Progress

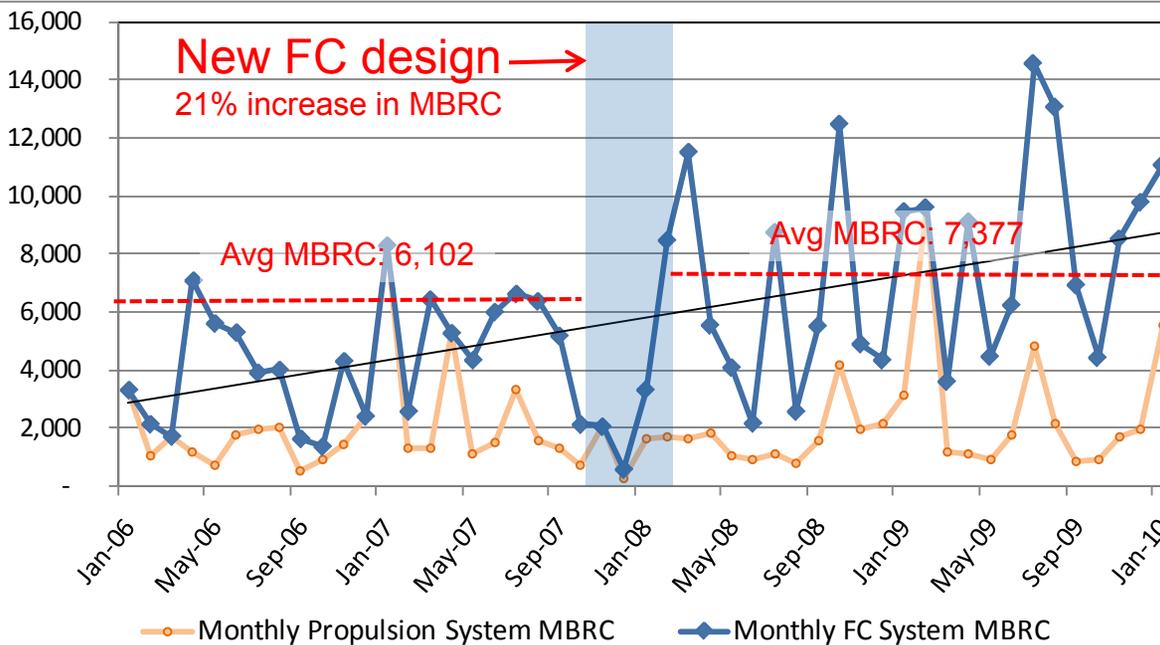
- Improvement seen in availability with new fuel cell system

Unavailability by Category →



- Results show increase in reliability

Monthly MBRC →



- New generation designs expected to show marked improvement