

Innovation for Our Energy Future

### Technology Validation: Fuel Cell Bus Evaluations

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> Project ID# TV10

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## 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<sub>2</sub> 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

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# **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

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General Evalu Fleet Test & Evalua		Table 1. Data Collection Items						
A CONTRACTOR OF A CONTRACT OF	Type of Data	Frequency Recorded	Data Items					
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	Vehicle System Descriptions	Start of data collection and changes as needed	Data items shown in Appendix C					
Marchen 1975	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					

- Proprietary data
  - Collected from manufacturer
  - Protected in Secure Data Center at NREL
  - Only aggregate data products made public

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### 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<sub>2</sub> ICE



Hickam AFB, Honolulu, HI Hydrogenics, Enova: hybrid system



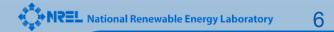




### Comparison of Hydrogen and Fuel Cell Buses to Conventional Technology

# 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



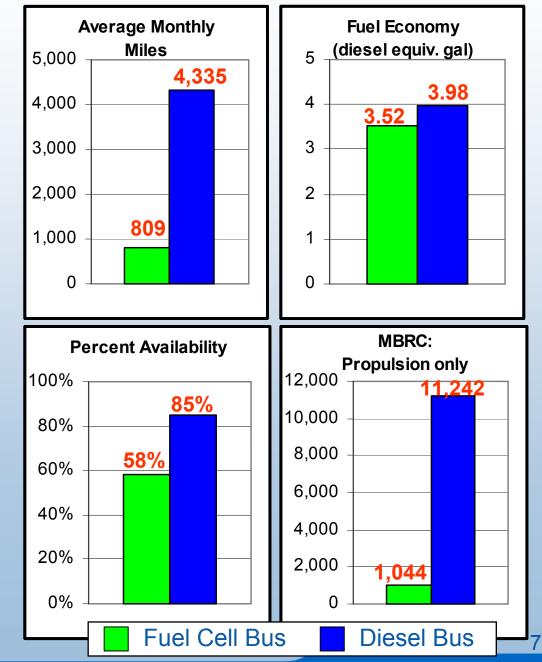
# Fleet Data Summary: Santa Clara VTA



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

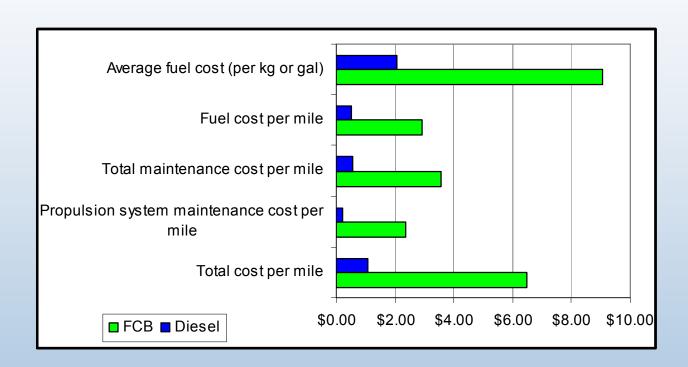


- 17 months operation of 5 diesel buses
- Total miles: 360,447



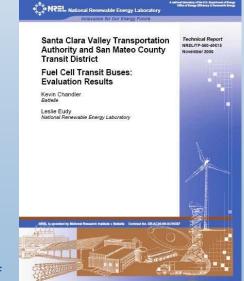
# Fleet Data Summary: Santa Clara VTA

#### **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

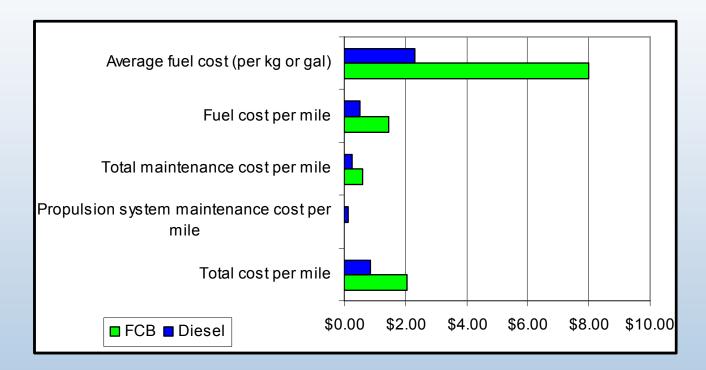


- 8 months operation of 6 diesel buses
- Total miles: 102,755



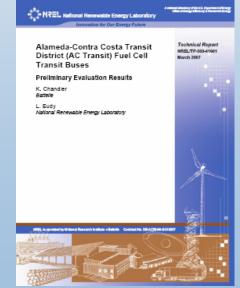
# Fleet Data Summary: AC Transit

#### **Summary of Costs**



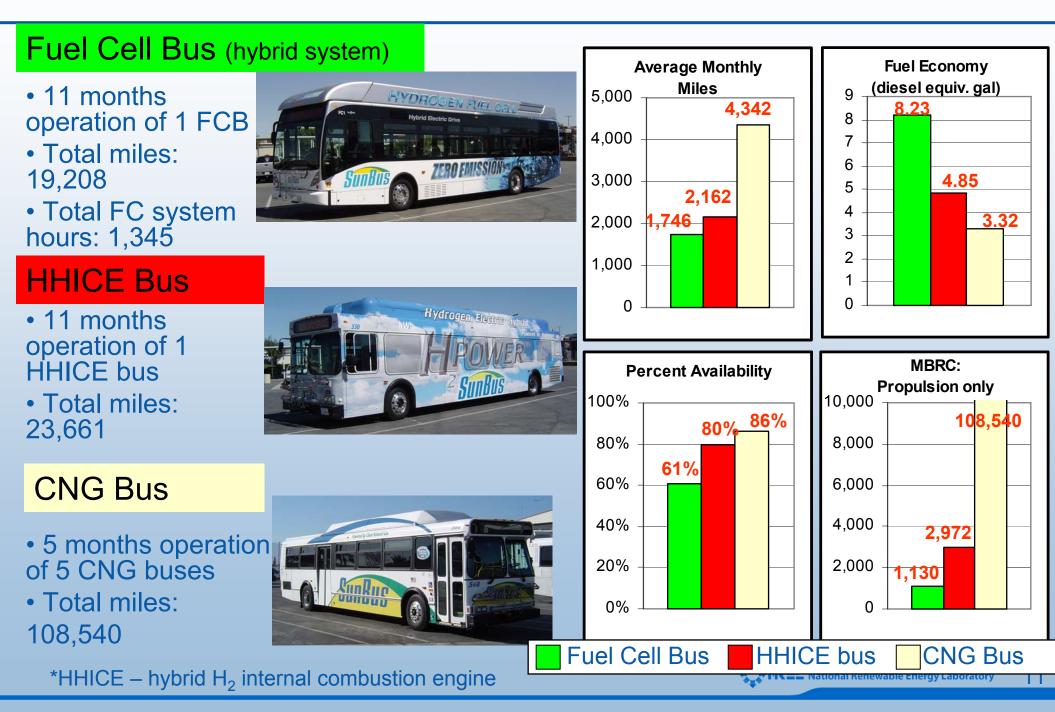
#### **Evaluation Status**

- Data collection ongoing
- Interim report published
- Second data report planned for fall 2007



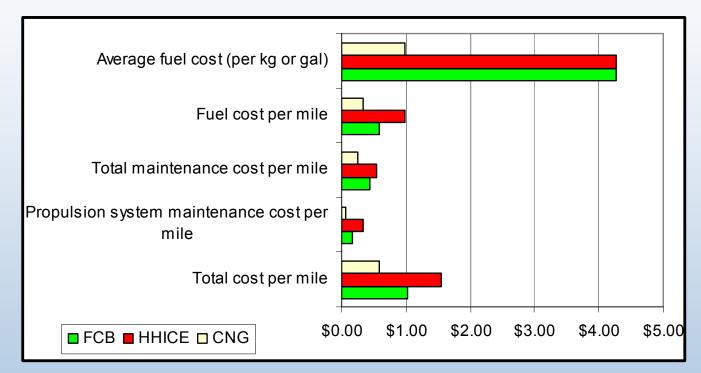
Report available online at www.nrel.gov/hydrogen/pdfs/41041.pdf

# Fleet Data Summary: SunLine



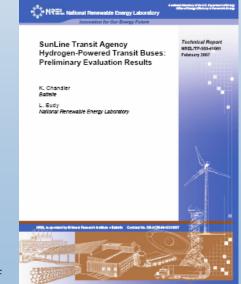
# Fleet Data Summary: SunLine

#### **Summary of Costs**



#### **Evaluation Status**

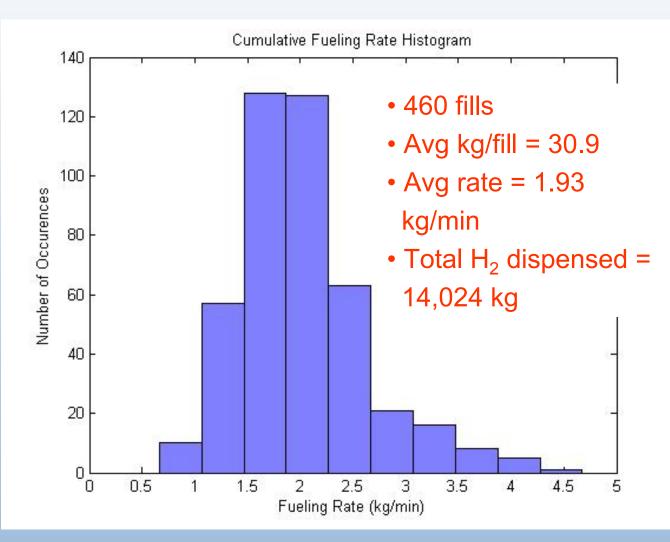
- Data collection ongoing
- Interim report published
- Second data report planned for fall 2007



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

### Infrastructure Data Summary: VTA

#### **VTA H<sub>2</sub> Fueling Station**



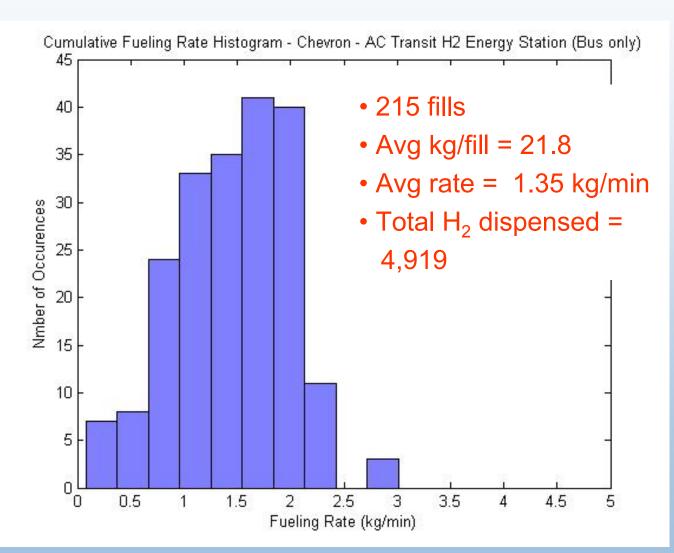


#### VTA fueling station:

- Air Products
- Liquid H<sub>2</sub> storage
- Dispenses compressed H<sub>2</sub>

### Infrastructure Data Summary: AC Transit

#### **Chevron - AC Transit H<sub>2</sub> Energy Station**





ACT fueling station:

- Chevron Technology
  Ventures
- Natural gas reformer
- 150 kg H<sub>2</sub> 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<sub>2</sub> 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**

- 4<sup>th</sup> 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



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### **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

