

Fuel Cell Bus Evaluation Results

TRB 87th Annual Meeting

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Hydrogen Fuel Cell Technology Validation

Objectives:

- Validate H₂ fuel cell vehicles and infrastructure in parallel
- Identify current status and evolution of the technology
 - Assess progress toward technology readiness
 - Provide feedback to H₂ research & development and policy decision makers
 - Provide “lessons learned” on implementing next generation fuel cell systems into bus operation

DOE/NREL Technology Validation

Light-Duty Vehicle/Infrastructure Learning Demonstration Project



Fuel Cell/Hydrogen Bus Evaluations



Current NREL FCB Evaluation Status

Fleet	Vehicle/Technology	Number of buses	Evaluation Status
VTA and SamTrans	Gillig/Ballard fuel cell transit bus	3	Evaluation complete; report Nov 06
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 in process; Report Oct 07
	Delivery van: Hydrogenics and Enova, fuel cell hybrid	1	Van in service, data collection in Process; Report Oct 07
AC Transit	Van Hool/UTC Power fuel cell hybrid transit bus integrated by ISE Corp.	3	Buses in service; evaluation in process; Reports Mar & Oct 07
CTTRANSIT	Van Hool/UTC Power fuel cell hybrid transit bus integrated by ISE Corp.	1	Buses in service; evaluation in process
SunLine Transit Agency	Van Hool/UTC Power fuel cell hybrid transit bus integrated by ISE Corp.	1	Bus in service, evaluation in process, Reports Feb & Sep 07
	New Flyer ISE Corp. hybrid hydrogen internal combustion engine transit bus	1	Bus in service, evaluation in process, Interim report Feb & Sep 07

FTA/NREL Fuel Cell Bus Evaluations

- Evaluate fuel cell buses developed under the National Fuel Cell Bus Program
 - Up to 14 FCBs in service around the U.S.
 - Niagara, NY; Hartford, CT; Boston, MA; Columbia, SC; Birmingham, AL; San Francisco, Oakland, Palm Springs, CA
 - Four different fuel cell manufacturers represented: Ballard, Hydrogenics, Nuvera, UTC Power
- Support to national and international FCB work groups to collaborate and share data

Why Evaluate Prototype Technology?

- Measure progress toward FCB commercialization
- Provide credible and consistent data collection & analysis for comparison
- Provide information to the transit industry and government
- Provide a “reality check”

AC Transit: Data Results

Data Period:
April 2006 – August 2007



AC Transit: Partners/Service Area

- Fleets:
 - AC Transit in Oakland, CA
 - Golden Gate Transit in San Rafael, CA
- Manufacturers
 - UTC Power
 - ISE Corp.
 - Van Hool
- Infrastructure
 - Chevron Technology Ventures



AC Transit: Study Buses

**Evaluation Period: April 2006 -
Aug 2007 (17 months)**

- Buses
 - 3 fuel cell buses
 - 6 diesel buses (baseline)
- Mileage accumulation
 - FCB: 54,404 miles total, fuel cell system hours: 4,938
 - Diesel: 277,408 miles total
- Average monthly miles
 - FCB: 1,067 miles/month
 - Diesel: 2,720 miles/month

Fuel Cell Bus (hybrid system)



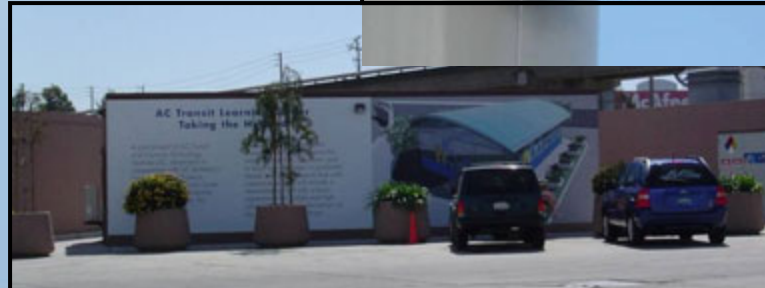
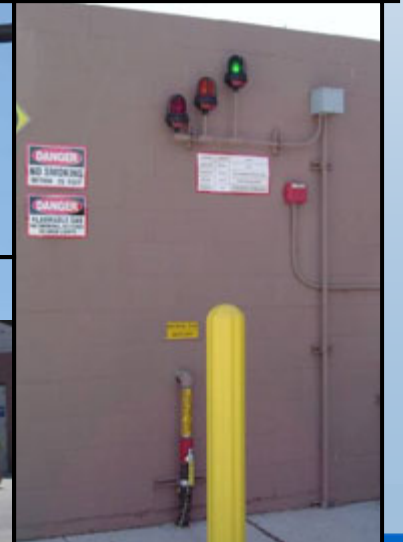
Diesel Bus (baseline)



AC Transit: Infrastructure

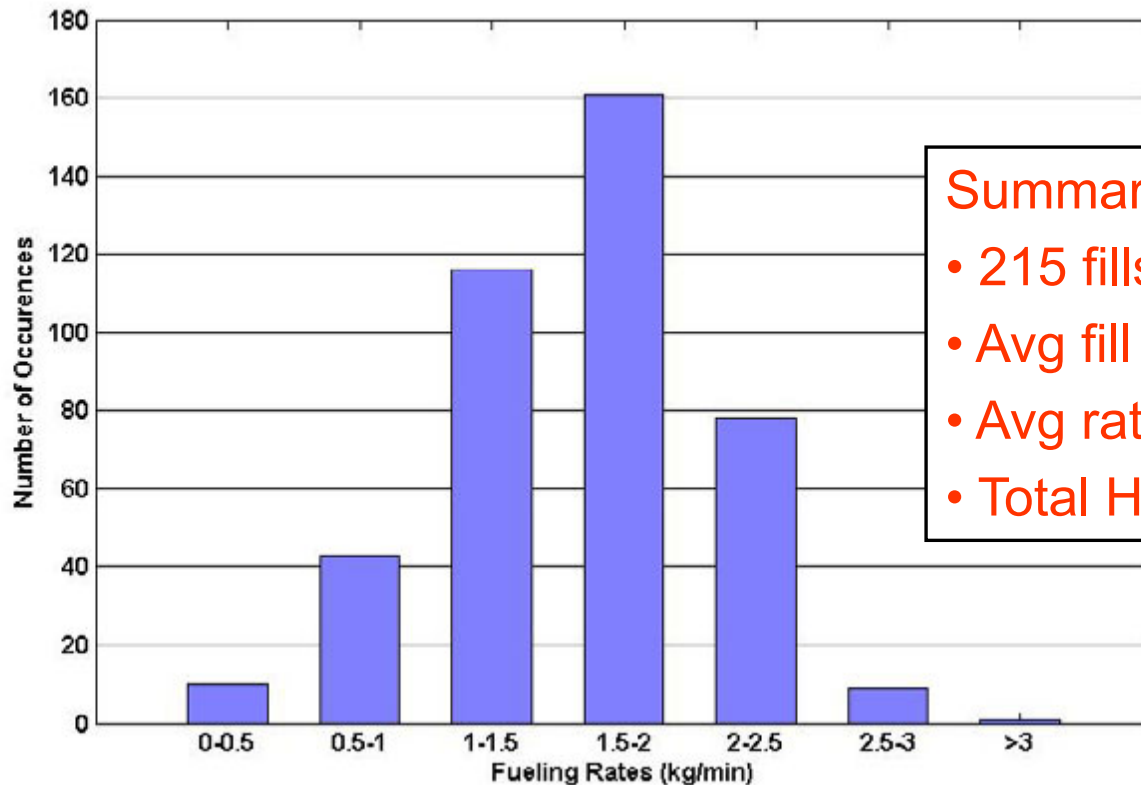
Hydrogen Fueling Facility

- Chevron Technology Ventures
- Natural gas reformer
- 150 kg H₂ per day
- 366 kg storage



AC Transit: Infrastructure

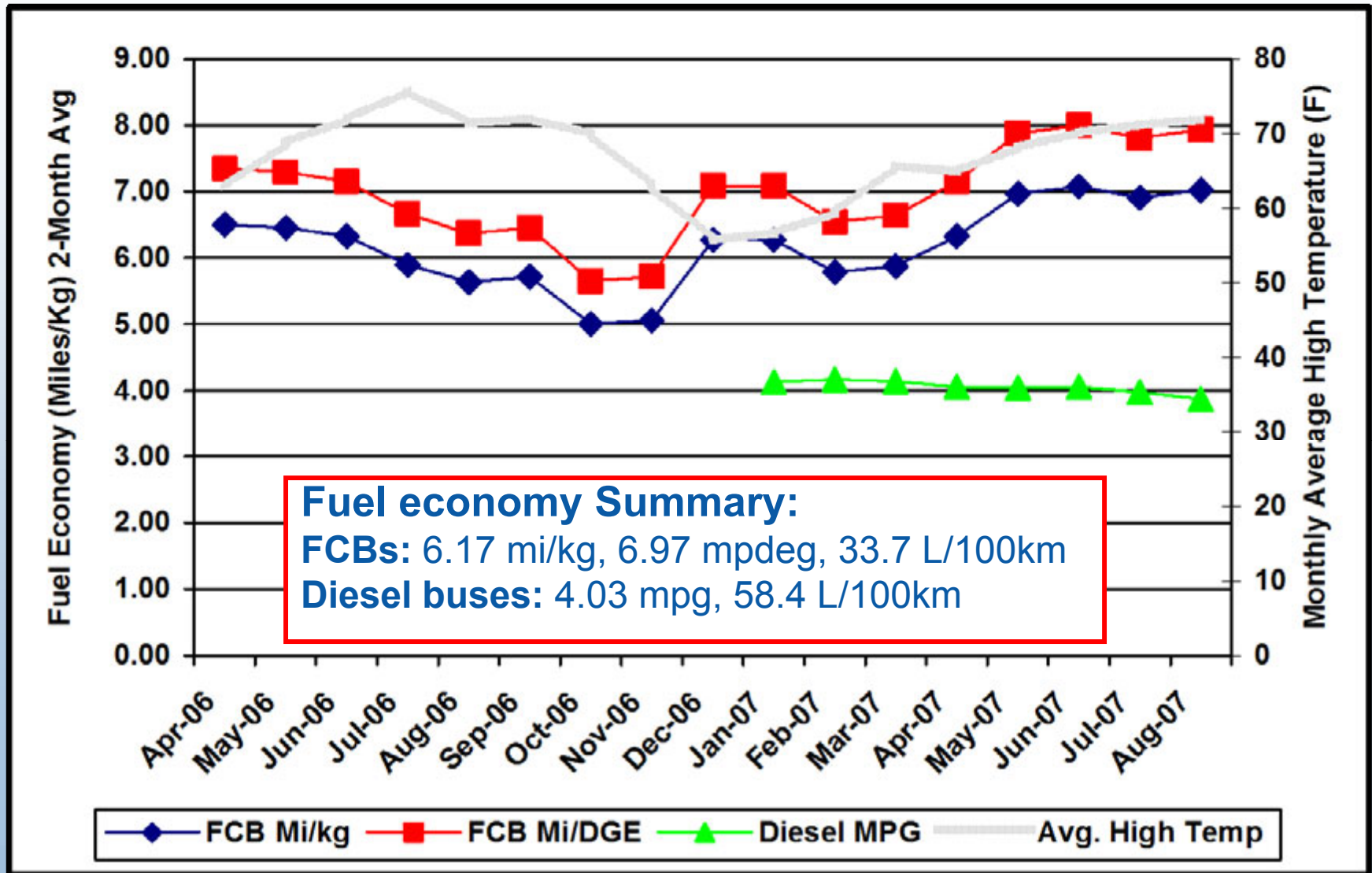
Chevron – AC Transit Hydrogen Energy Station Cumulative Fueling Rate Histogram (Apr 06 – Aug 07)



Summary

- 215 fills
- Avg fill = 21.8 kg
- Avg rate = 1.35 kg/min
- Total H₂ dispensed = 4,919 kg

AC Transit: Fuel Economy

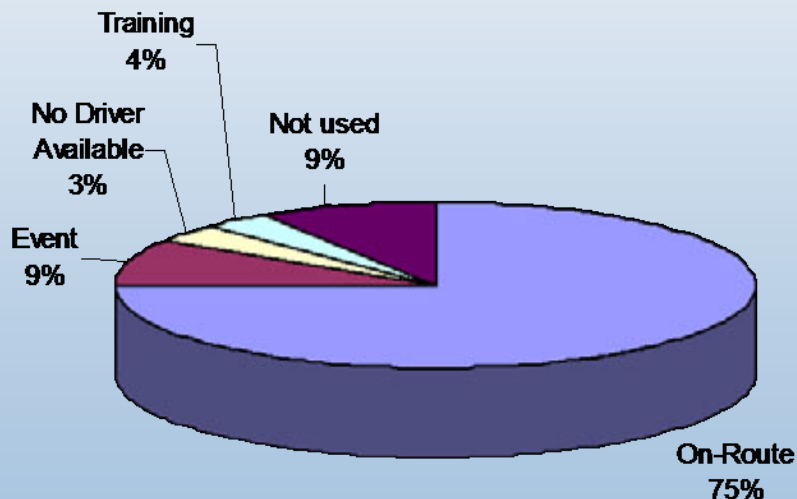


AC Transit: Availability

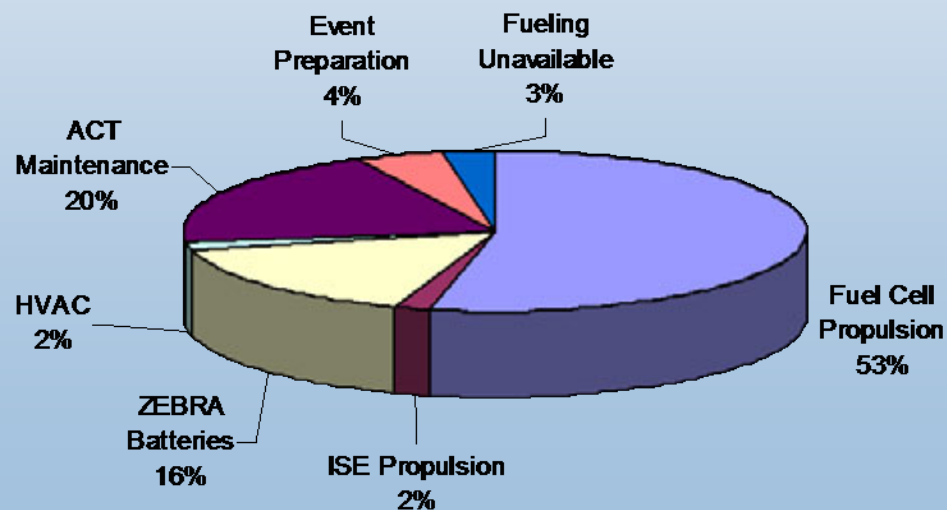
Availability during evaluation period: 61%

- Buses were available 655 out of a possible 1,087 days

Availability by Category:



Reasons for unavailability:



AC Transit: Reliability

Miles Between Road Calls

- Diesel Buses – 4,474 MBRC total;
10,670 MBRC propulsion related only
- Fuel Cell Buses – 1,395 MBRC total;
1,649 MBRC propulsion related only



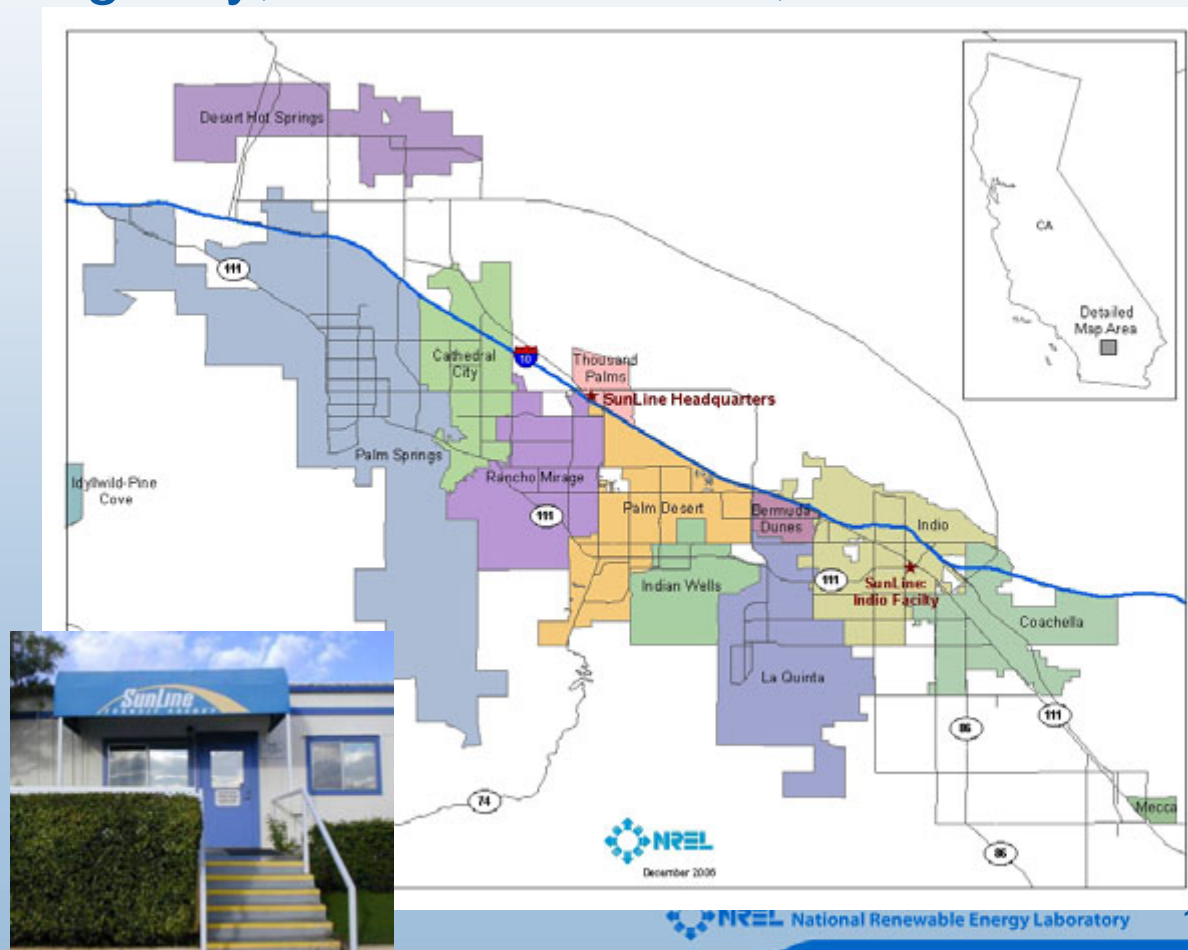
SunLine: Data Results

Data Period:
Jan 2006 – Jun 2007



SunLine: Partners/Service Area

- Fleet
 - SunLine Transit Agency, Thousand Palms, CA
- Manufacturers
 - UTC Power
 - ISE Corp.
 - Van Hool
 - Ford
 - New Flyer
- Infrastructure
 - HyRadix



SunLine: Study Buses

Evaluation Period:

Jan 2006 - Jun 2007 (18 months)

- Buses
 - 1 fuel cell bus
 - 1 HHICE bus
 - 5 CNG buses (baseline)
- Mileage accumulation
 - FCB: 37,005 miles, fuel cell system hours: 2,822
 - HHICE: 38,853 miles
 - CNG: 265,107 miles total
- Average monthly miles
 - FCB: 2,056 miles/month
 - HHICE: 2,159 miles/month
 - CNG: 4,418 miles/month

Fuel Cell Bus (hybrid system)



HHICE Bus



CNG Buses (baseline)



SunLine: Infrastructure

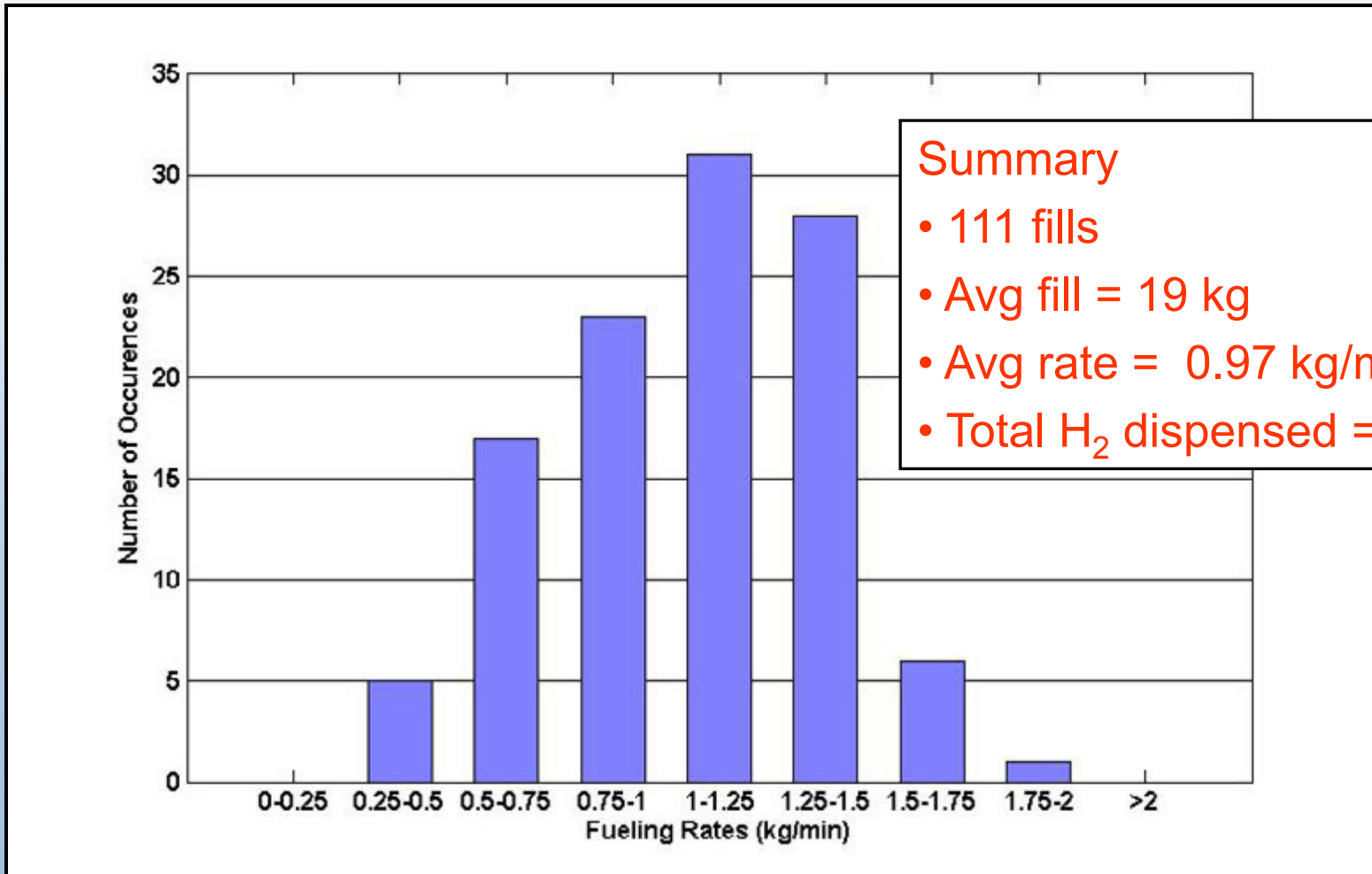
Hydrogen Fueling Facility

- Hyradix
- Natural gas reformer
- 9 kg H₂ per hour max
- 180 kg storage



SunLine: Infrastructure

Cumulative Fueling Rate Histogram (Mar – Jun 2007*)

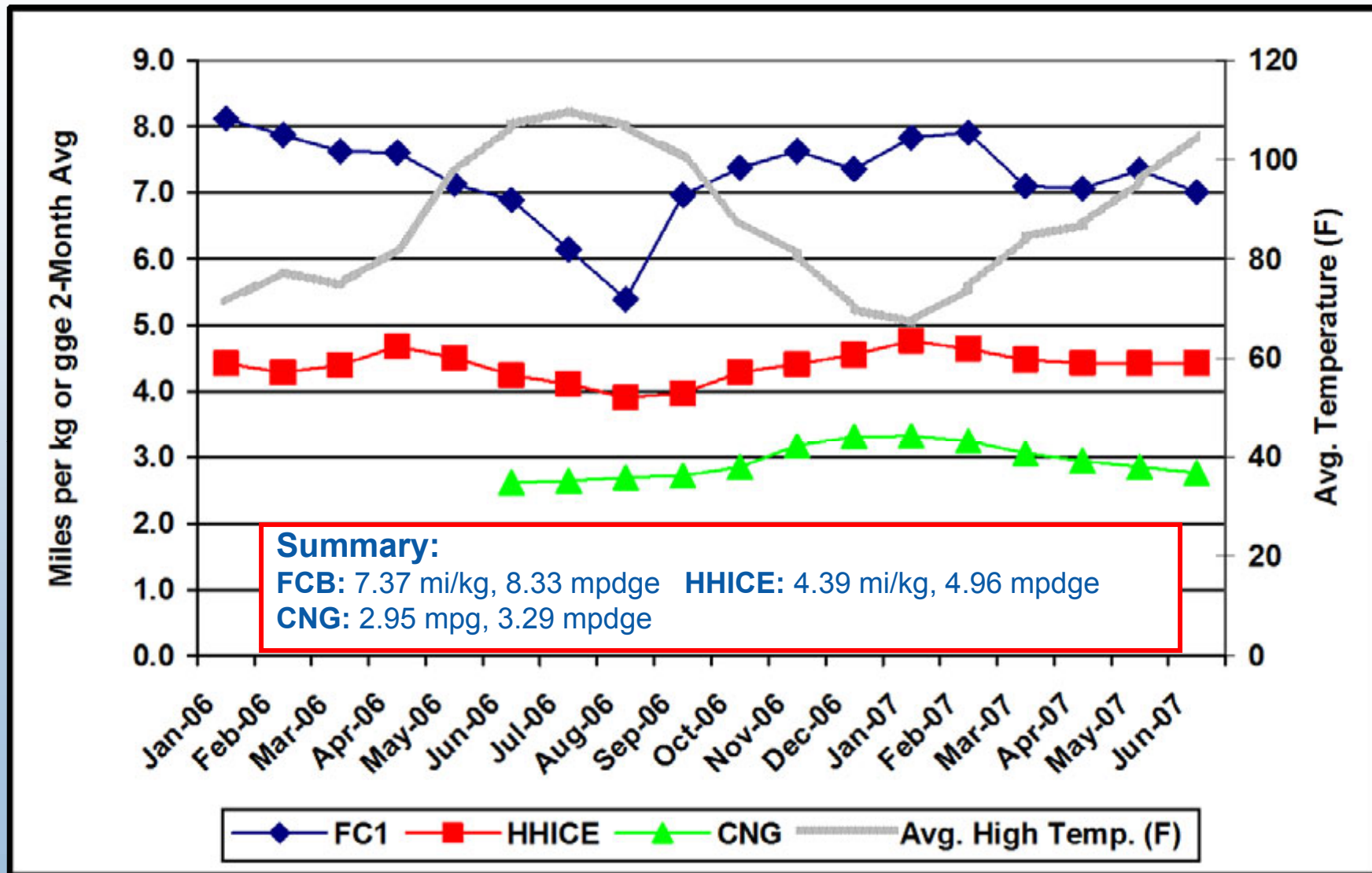


Summary

- 111 fills
- Avg fill = 19 kg
- Avg rate = 0.97 kg/min
- Total H₂ dispensed = 2,358 kg

* Prior to March 2007, this data was not available

SunLine: Fuel Economy



SunLine: Availability

Category	Fuel Cell Bus		HHICE Bus		CNG Buses	
	Number	Percent	Number	Percent	Number	Percent
Planned Work Days	449		465		1,697	
Days Available	293	65	357	77	1,475	87
Available	293	100	357	100	1,475	100
On-Route	283	97	334	93	1,462	99
Event/Demonstration	3	1	6	2	5	0
Training	6	2	13	4	0	0
Not Used	2	0	4	1	8	1
Unavailable	156	100	108	100	222	100
Fuel Cell Propulsion	45	29				
Hybrid Propulsion	9	6	68	63		
ZEBRA Battery	29	19				
Air Conditioning	35	22	0	0	18	8
Headsign	7	4				
SunLine Maintenance	0	0	9	8	204	92
Fueling Unavailable	31	20	31	29		

SunLine: Reliability

Miles Between Road Calls

- CNG Buses – 10,604 MBRC total;
37,872 MBRC propulsion related only
- Fuel Cell Bus – 1,194 MBRC total;
1,322 MBRC propulsion related only
- HHICE Bus – 2,428 MBRC total;
2,775 MBRC propulsion related only



Achievements

- Successful demonstration of FCBs in several locations
- H₂ Fueling
 - More than 14,000 kg H₂ safely dispensed
- Technology progress
 - Lessons learned with bus and H₂ station are being incorporated into the next designs
- Information Dissemination
 - Results shared with industry
 - Training for fire officials and first responders
 - Public awareness

Industry's Needs for Continued Successful FCB Implementation

- **Costs:** optimize the initial cost for buses and infrastructure
- **Performance & Reliability:** further optimize systems and increase availability
- **Durability:** control maintenance costs by addressing durability and analyze overall operational costs
- **Fleet Personnel Training:** focus on full fleet integration and training of staff
- **Continued Data Collection & Analysis:** more data is needed to fully understand all aspects and costs


For More Information

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NREL Hydrogen Technology Validation web page:
www.nrel.gov/hydrogen/proj_tech_validation.html






Atameda-Contra Costa Transit District (AC Transit)

Technical Report
NREL/TP-460-42346
October 2007

**Fuel Cell Transit Buses:
Evaluation Results Update**




Kevin Chandler, Battelle
Leslie Eudy, National Renewable Energy Laboratory



SunLine Transit Agency

**Hydrogen-Powered Transit Buses:
Evaluation Results Update**



Kevin Chandler, Battelle
Leslie Eudy, National Renewable Energy Laboratory



**Fuel Cell Buses in U.S. Transit Fleets:
Summary of Experiences and Current
Status**

Technical Report
NREL/TP-460-41967
September 2007

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Battelle
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Federal Transit Administration



Hickam Air Force Base

**Fuel Cell Vehicles:
Early Implementation Experience**

Leslie Eudy, National Renewable Energy Laboratory
Kevin Chandler, Battelle

