

# Fuel Cell Bus Evaluation Results

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# Hydrogen Fuel Cell Technology Validation

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## Objectives:

- Validate H<sub>2</sub> fuel cell vehicles and infrastructure in parallel
- Identify current status and evolution of the technology
  - Assess progress toward technology readiness
  - Provide feedback to H<sub>2</sub> 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?

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- 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

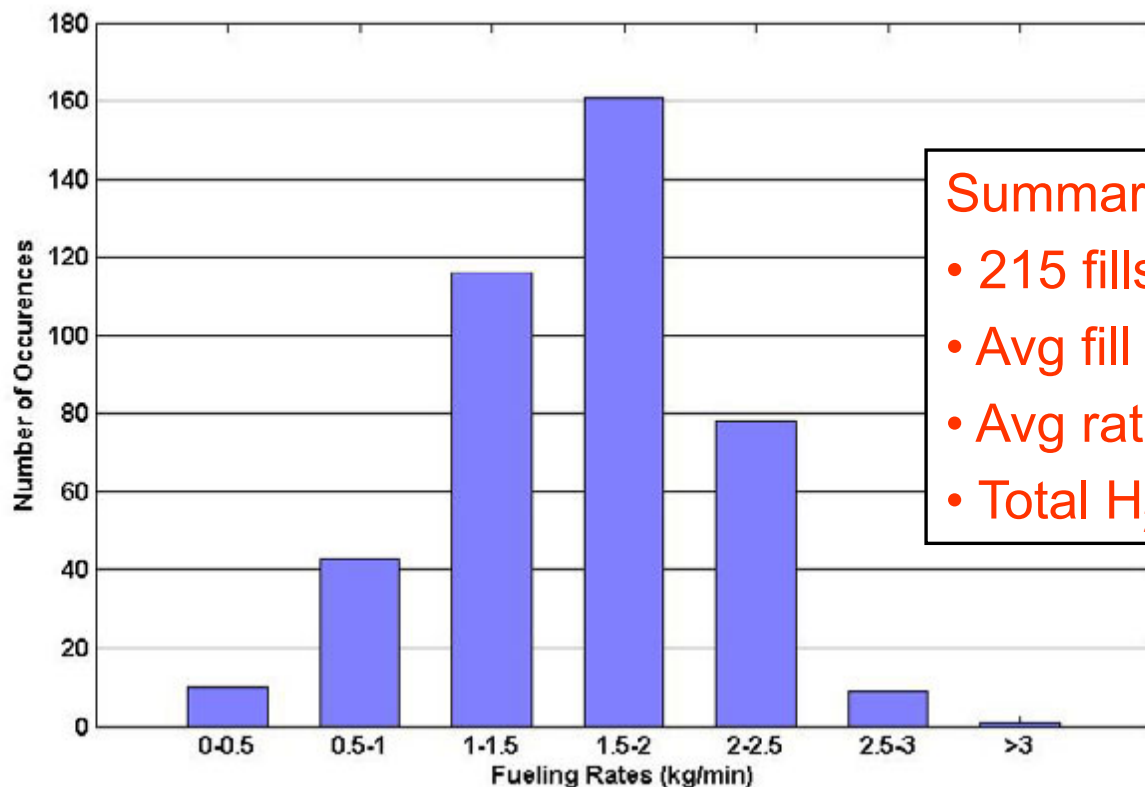
## Hydrogen Fueling Facility

- Chevron Technology Ventures
- Natural gas reformer
- 150 kg H<sub>2</sub> per day
- 366 kg storage



# AC Transit: Infrastructure

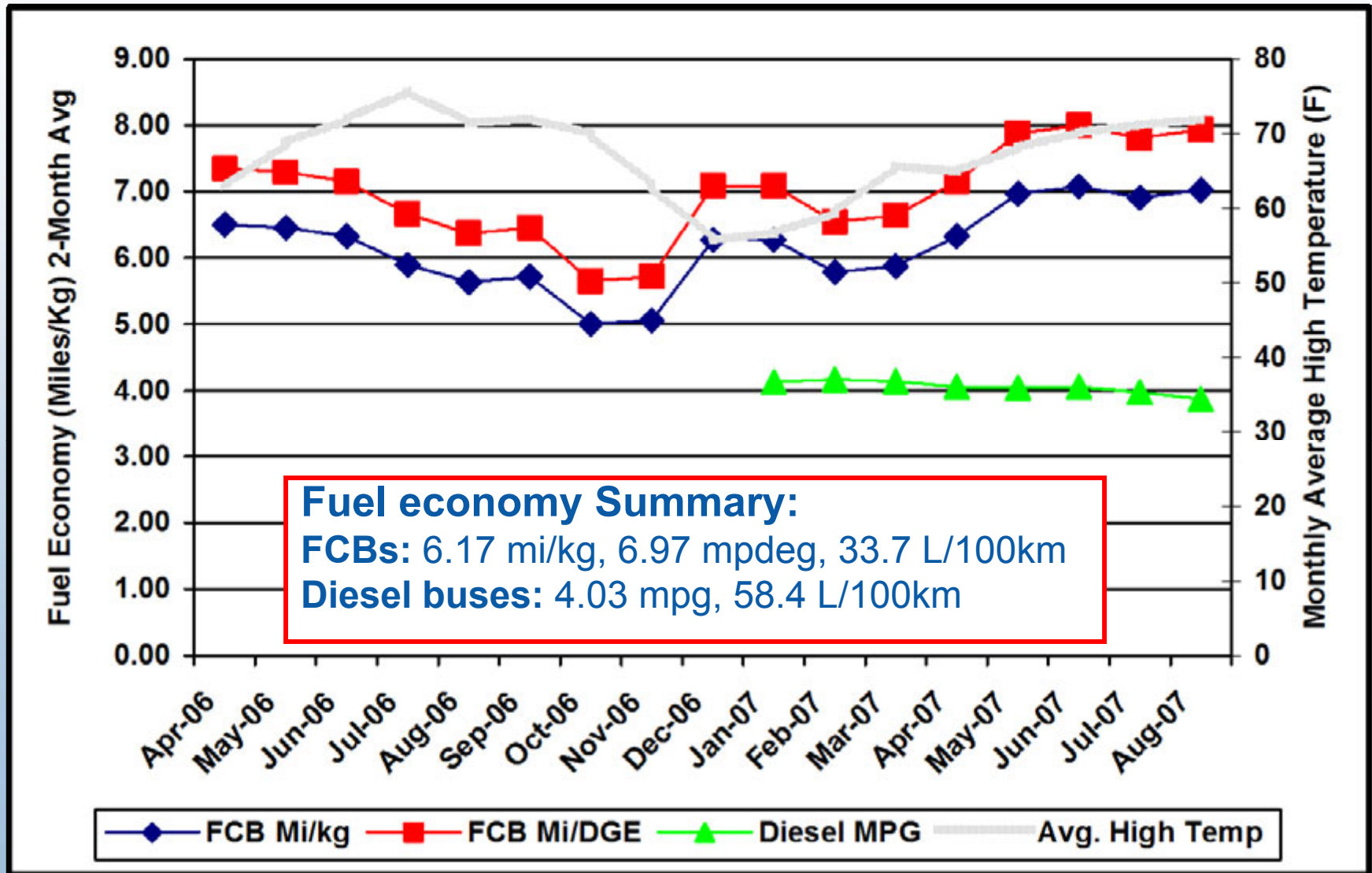
## Chevron – AC Transit Hydrogen Energy Station Cumulative Fueling Rate Histogram (Apr 06 – Aug 07)



### Summary

- 215 fills
- Avg fill = 21.8 kg
- Avg rate = 1.35 kg/min
- Total H<sub>2</sub> dispensed = 4,919 kg

# AC Transit: Fuel Economy

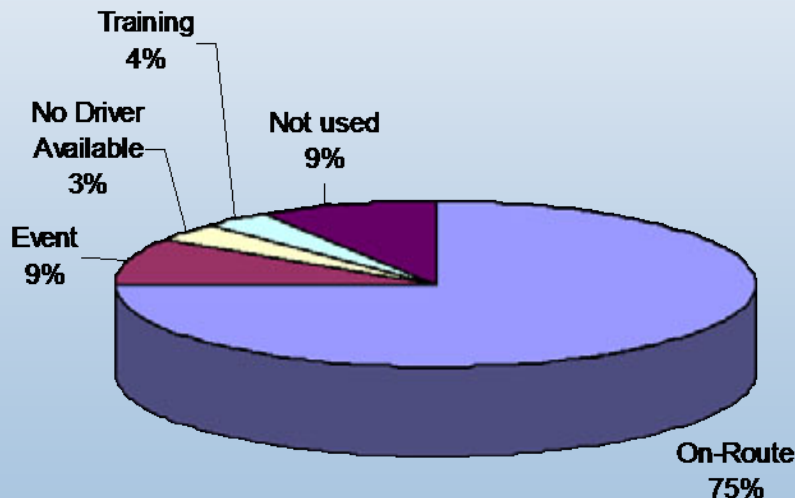


# AC Transit: Availability

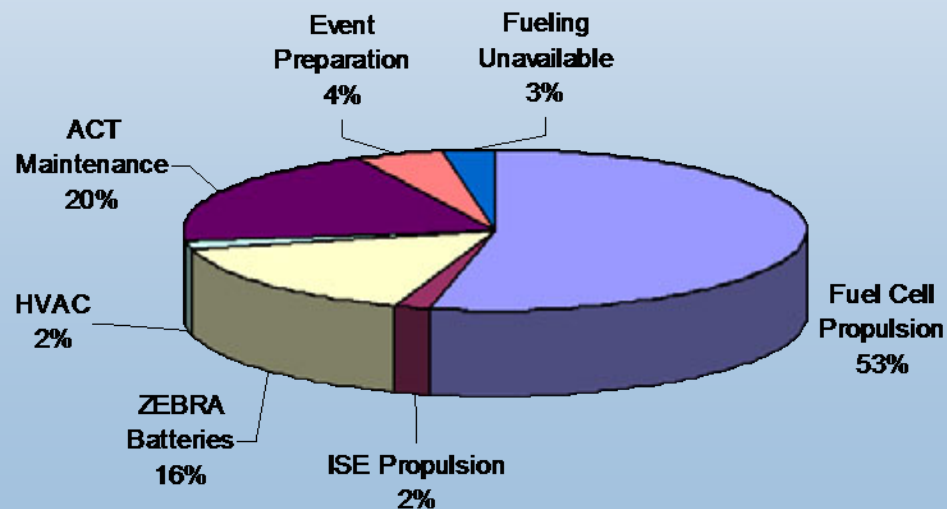
Availability during evaluation period: 61%

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

## Availability by Category:



## Reasons for unavailability:



# AC Transit: Reliability

## Miles Between Road Calls

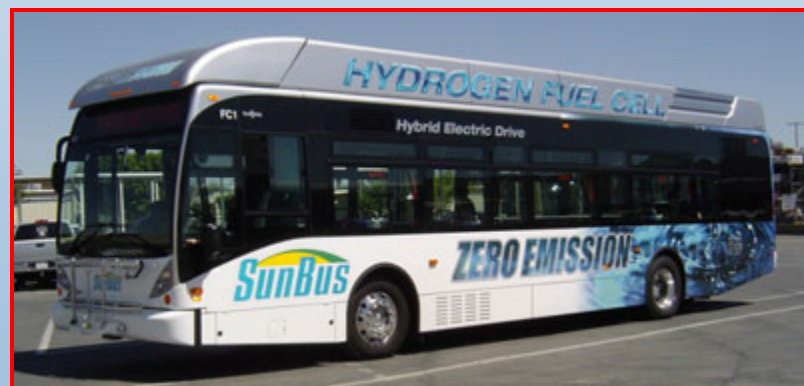
- Diesel Buses – 4,474 MBRC total;  
10,670 MBRC propulsion related only
- Fuel Cell Buses – 1,395 MBRC total;  
1,649 MBRC propulsion related only





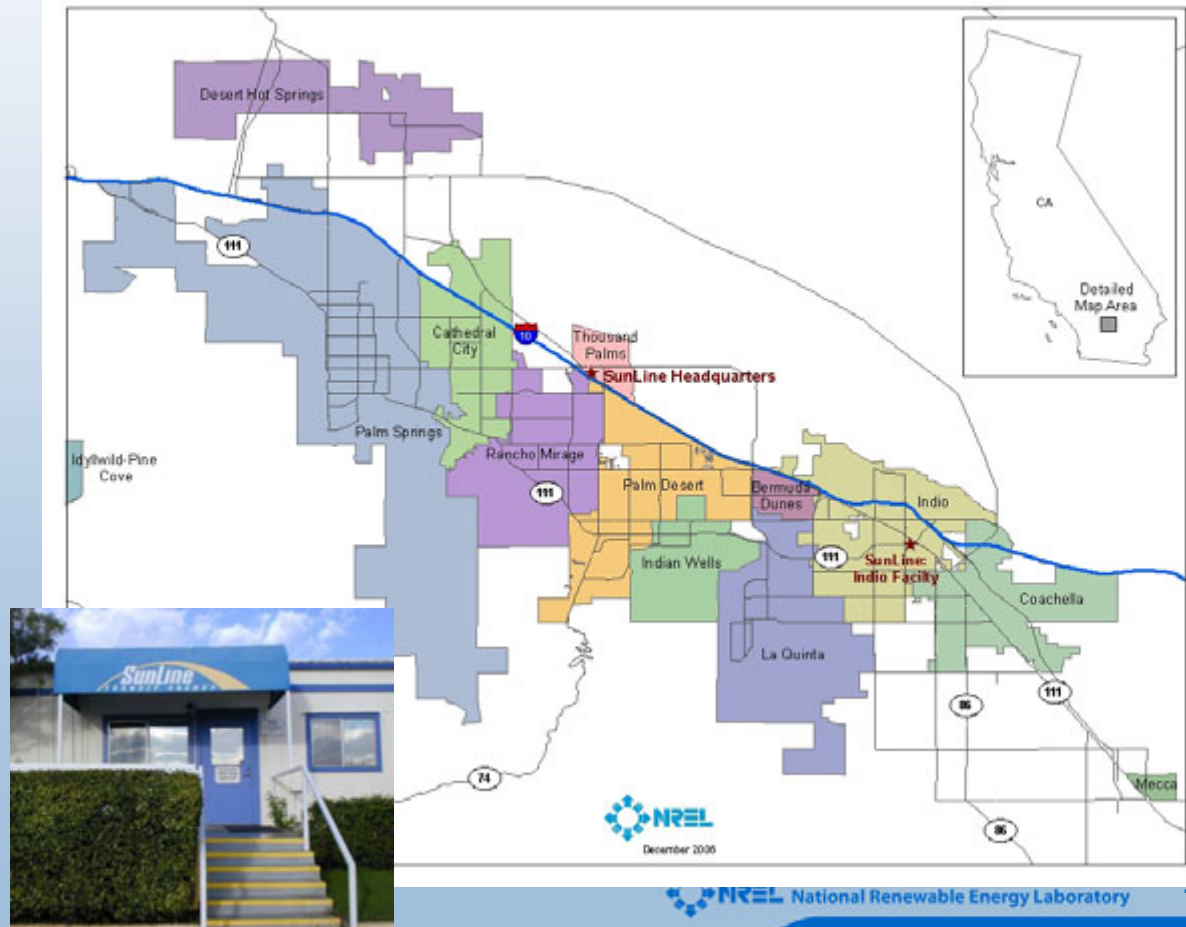
# SunLine: Data Results

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

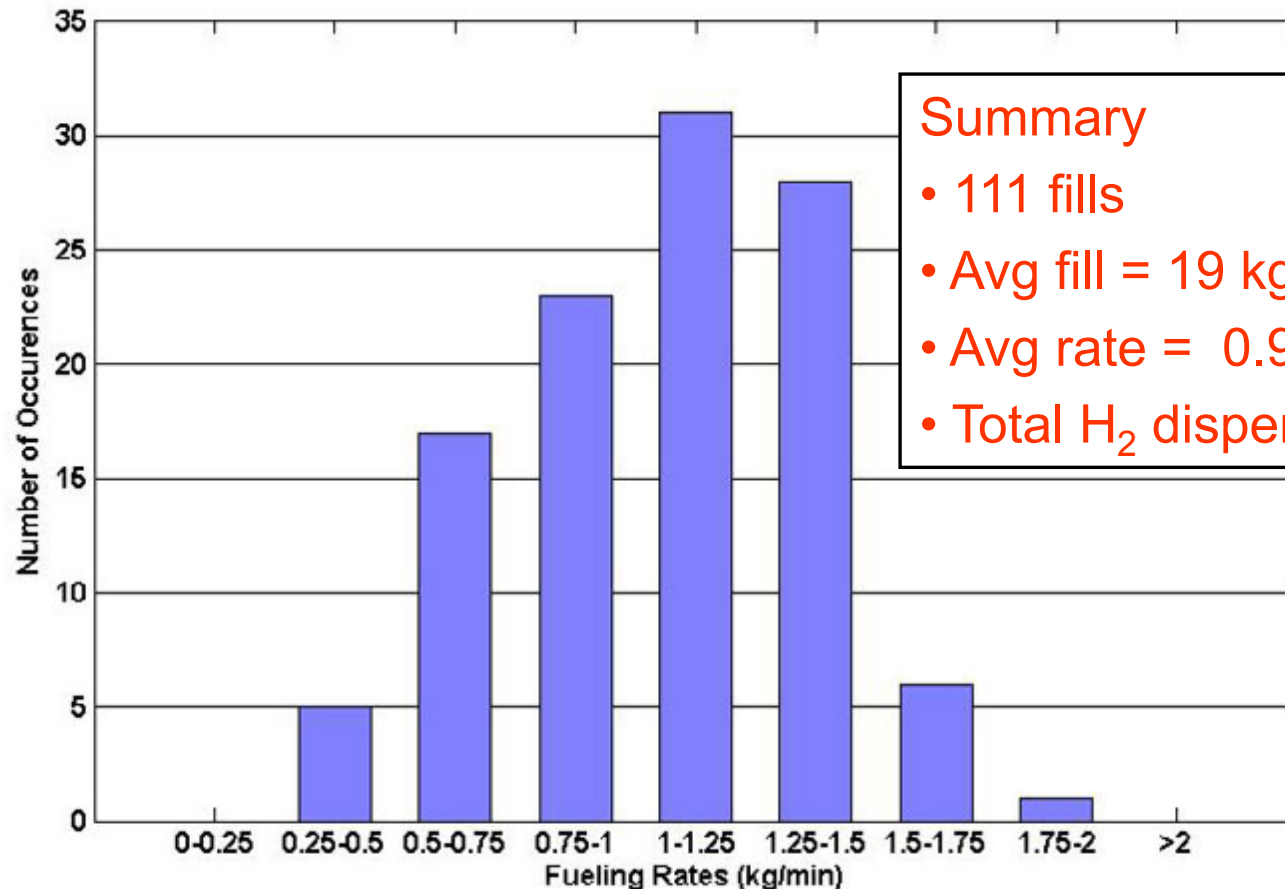
## Hydrogen Fueling Facility

- Hyradix
- Natural gas reformer
- 9 kg H<sub>2</sub> per hour max
- 180 kg storage



# SunLine: Infrastructure

## Cumulative Fueling Rate Histogram (Mar – Jun 2007\*)



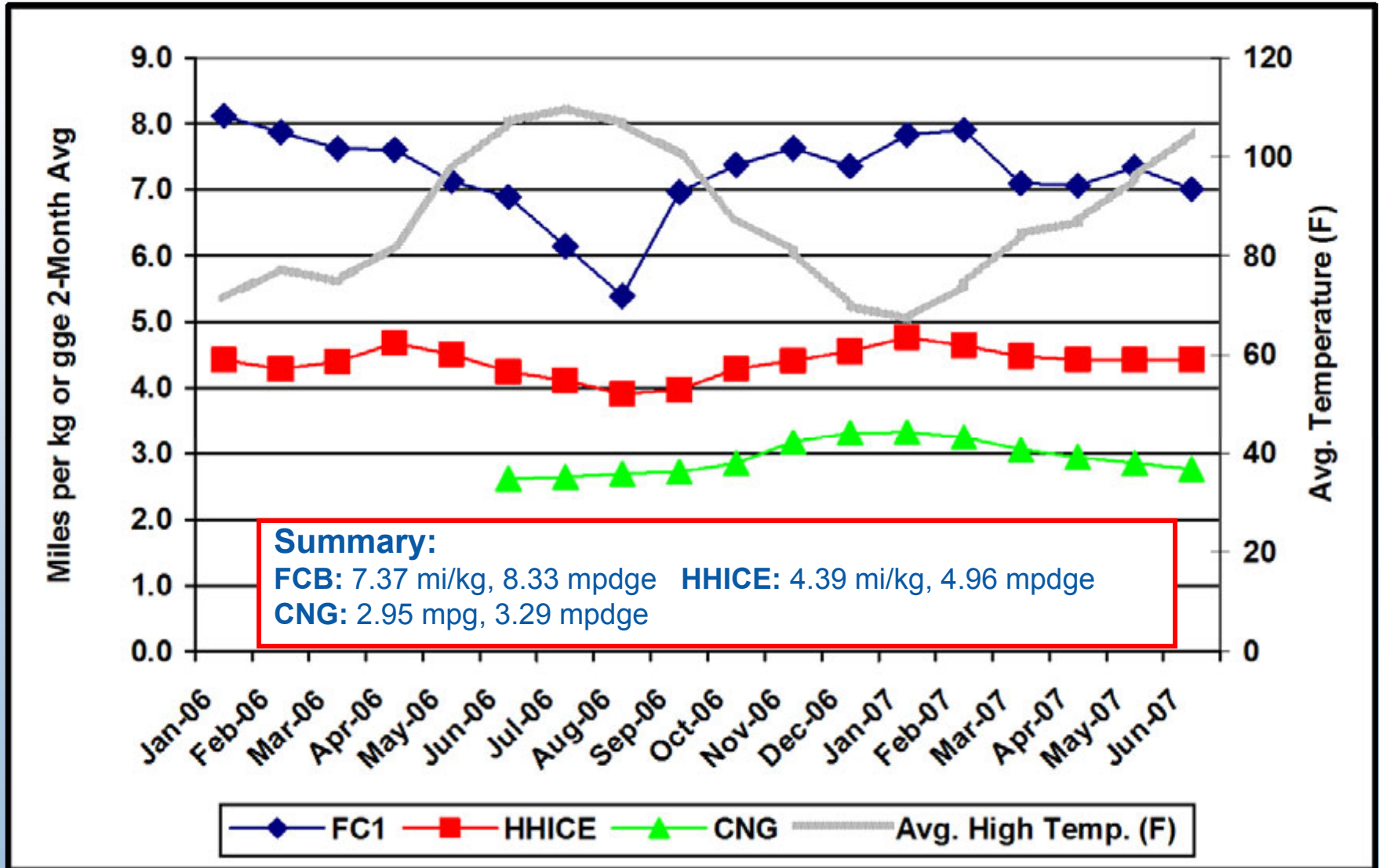
### Summary

- 111 fills
- Avg fill = 19 kg
- Avg rate = 0.97 kg/min
- Total H<sub>2</sub> 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
<b>Available</b>	<b>293</b>	<b>100</b>	<b>357</b>	<b>100</b>	<b>1,475</b>	<b>100</b>
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
<b>Unavailable</b>	<b>156</b>	<b>100</b>	<b>108</b>	<b>100</b>	<b>222</b>	<b>100</b>
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
- H<sub>2</sub> Fueling
  - More than 14,000 kg H<sub>2</sub> safely dispensed
- Technology progress
  - Lessons learned with bus and H<sub>2</sub> 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](http://www.nrel.gov/hydrogen/proj_tech_validation.html)

