National Renewable Energy Laboratory
Innovation for Our Energy Future

Overview of U.S. Fuel Cell Bus Technology Validation Activity

Leslie Eudy,
NREL

Joint 12th IPHE
ILC & SC Meeting
December 2, 2009

Presentation Outline

- Overview of NREL FCB Evaluations
- Evaluation Objectives
- Evaluation Approach
- Current Evaluation Projects
  - Summary of recent results
- Planned Evaluation Projects
- Status of FCB development in North America
- Needs for Continued Success

Evaluation Objectives

Evaluations of Fuel Cell Buses in Revenue service:
- FTA: National Fuel Cell Bus Program
- DOE: Hydrogen Fuel Cell Technology Validation

Follows a standardized protocol to harmonize data collection and allow comparisons across projects

Objectives

- Assess progress toward technology readiness
- Provide feedback to H_2 research & development and policy decision makers
- Provide “lessons learned” on implementing next generation fuel cell systems into bus operation

Overview of NREL FCB Evaluations

NREL Hydrogen Bus Evaluations for DOE and FTA

Site/Location	State	Eval. Funding	2008	2009	2010	2011
AC Transit/ SF Bay Area	CA	DOE Technology Validation	CA ZEB Advanced Demo			
SunLine/ Thousand Palms	CA		FCB Extended Testing			
SunLine/ Thousand Palms	CA				Advanced FCB Project	
CTTRANSIT/ Hartford	CT		CTTRANSIT FCB Demo			
City of Burbank/ Burbank	CA		Burbank FCB			
AC Transit/ Oakland	CA	FTA National Fuel Cell Bus Program	Accelerated Testing			
SunLine/ Thousand Palms	CA				American FCB Demo	
CTTRANSIT/ Hartford	CT		Nutmeg Hybrid FCB Demo			
Columbia / Site 2	SC		Dual Variable Output Hybrid FCB			
Logan Airport / Boston	MA				MA H2 FCB Demo	
Albany / NY	NY				Lightweight FCB Demo	
TBD / NY	NY				NYPA H2 Powered FCB	
SFMTA / San Francisco	CA				FC APU Hybrid	

National Fuel Cell Bus Program

Demonstration sites color coded by geographic area:

- Northern California
- New England
- Southeast
- Southern California
- New York
- South

Estimate of NREL data collection/evaluation schedule
Subject to change based on progress of each project

Evaluation Approach

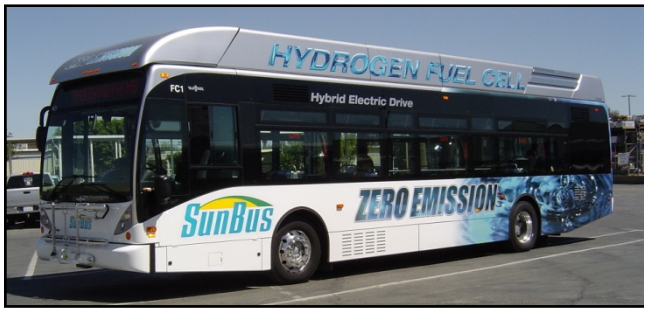
Comparison of hydrogen and fuel cell buses to conventional technology baseline (diesel, CNG)

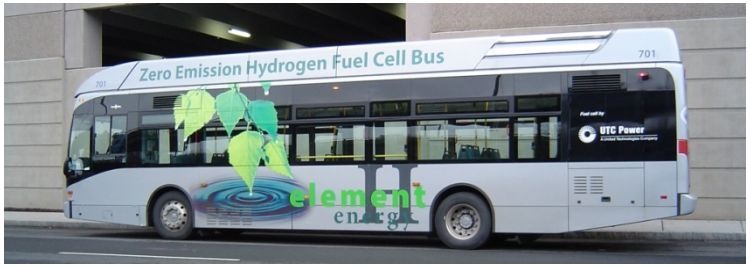
Data Include:

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

Current Evaluations

- **Transit Agencies:**
  - SunLine, Thousand Palms, CA
  - CTTRANSIT, Hartford, CT
  - AC Transit, Oakland, CA & fleet partner Golden Gate Transit, San Rafael, CA
- **Manufacturers**
  - UTC Power: Fuel Cell Power System
  - ISE: Hybrid System
  - Van Hool: Chassis



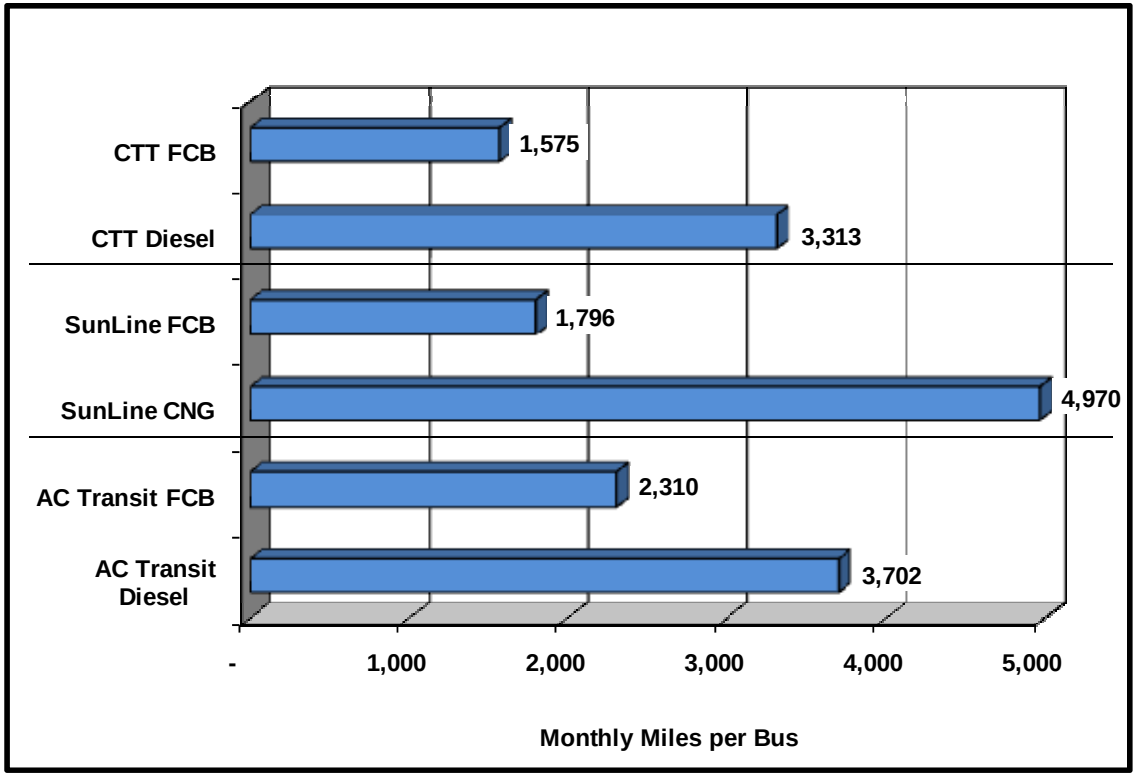


Summary Results: Bus Use

Total Miles and Average Monthly miles per bus

Site	No. of Buses	No. Months	Total Miles	FC Hours	Avg. Speed Mph
AC Transit	3	12	83,156	8,636	9.6
SunLine	1	12	21,556	1,559	13.8
CTTRANSIT	1	12	18,900	2,738	6.9

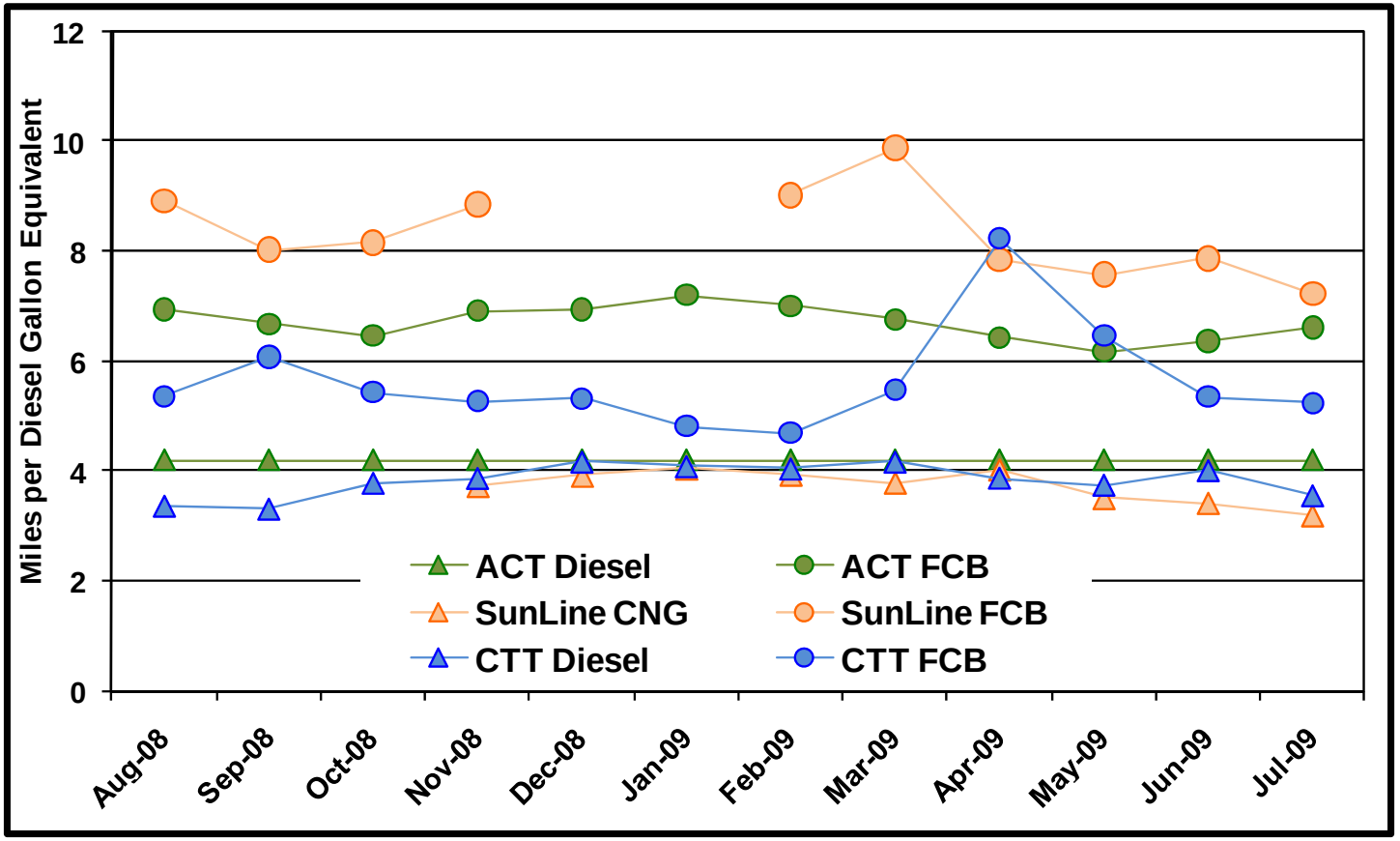
Data summary: 12 months, Aug 2008 – Jul 2009



Summary Results: Fuel Economy

Summary

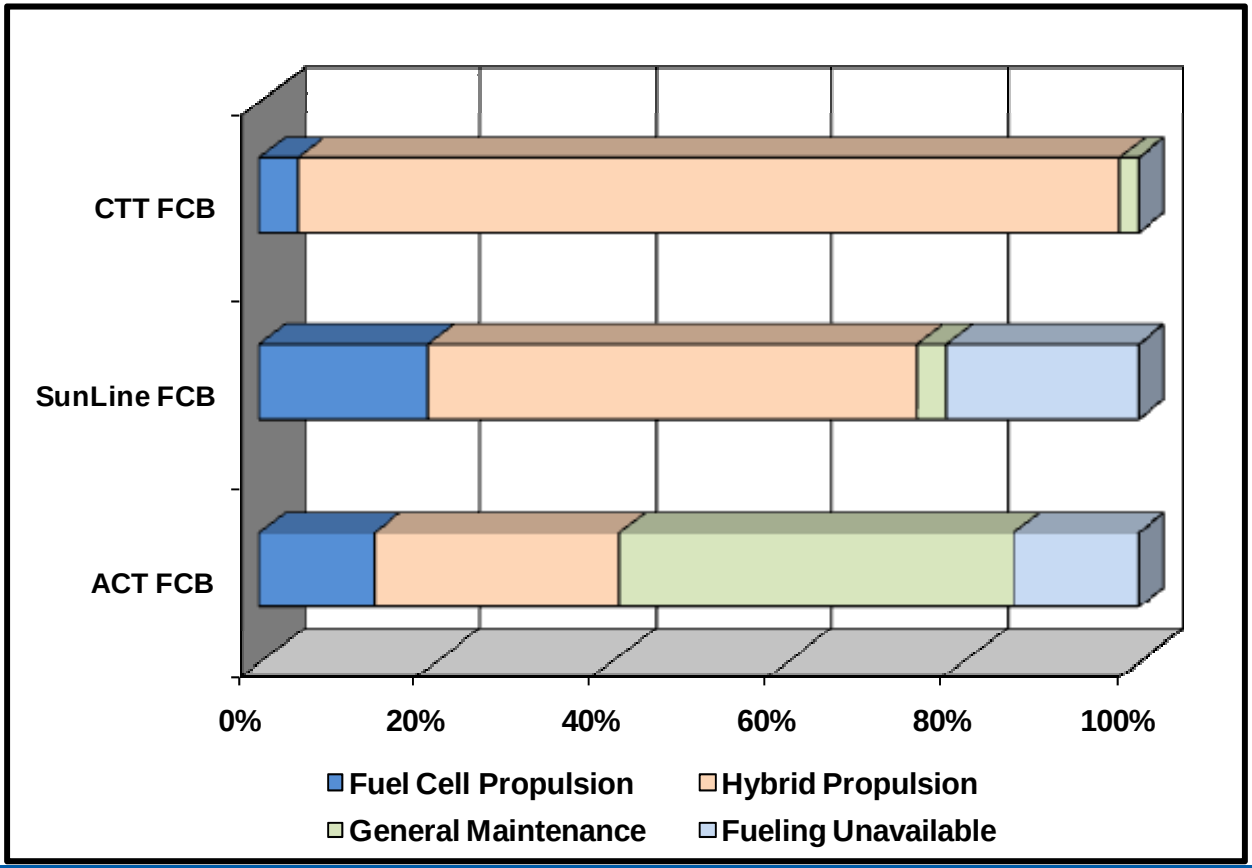
	ACT Diesel	ACT FCB	SunLine CNG	SunLine FCB	CTT Diesel	CTT FCB
Miles/kg		5.92	3.32	7.05		4.78
Mpdeg	4.2	6.69	3.71	7.96	3.81	5.4
kg/100 km		10.5		8.81		13.0



Summary Results: Availability

Summary

	Days Available	Days Planned	% Availability	Baseline (Target)
ACT	602	1878	69%	85%
SunLine	195	310	63%	85%
CTT	198	290	68%	85%



Reasons why the buses were not available

Planned Evaluations

- Columbia, South Carolina (FTA funded)
  - Dual-Variable Output Hybrid FCB developed under FTA NFCBP
  - Bus went into service in Nov. 2009
  - Proterra battery-dominant, plug-in hybrid bus
  - 35-foot composite body
  - Two 16 kW Hydrogenics fuel cells
  - Altairnano Lithium Titanate battery pack
  - Data collection includes detailed, on-road data
- Burbank, CA (DOE funded)
  - 2nd Proterra bus for City of Burbank

Planned Evaluations

Remaining Projects funded by DOE

- SF Bay Area ZEB Demo (AC Transit lead agency)
  - 12 buses on order: new fuel cell hybrid system by UTC Power and Van Hool
  - First buses scheduled for delivery December 2009
- SunLine
  - New generation FCB project primarily funded by CARB
  - Details of bus TBD

Planned Evaluations

Remaining projects funded by FTA

- Massachusetts Hydrogen FCB Demo
  - Demonstration primarily at Logan airport
  - Nuvera fuel cell
  - Advanced batteries
  - Data collection includes detailed, on-road data
  - Expected to begin in early 2010
- Lightweight Fuel Cell Hybrid Bus
  - GE hybrid system
  - Lightweight bus body
  - Advanced batteries

Planned Evaluations

FTA funded

- Compound Hybrid FCB
  - FC APU to operate auxiliary loads on a BAE Systems diesel hybrid bus
  - Hydrogenics 16kW FC
  - Lithium ion batteries (A123 Systems)
  - SF MTA demonstration site

- NY FCB
  - Team led by New York Power Authority
  - Very few details released

Status of FCB in North America

Steps to introducing advanced propulsion systems for transit:

1. Operational field testing and design shakedown (1 to 3 buses)
2. Full-scale operational demonstration and fleet-ready reliability testing (10 to 20 buses at several locations)
3. Limited production and full operation (50 to 100 buses at a small number of locations)

Status:

- Current demonstrations are in step 1
- The NFCBP will complete most of the research for step 1
- New demos beginning this year will move the technology into step 2
  - BC Transit: 20 buses for Whistler, BC
  - Bay Area ZEBA (led by AC Transit) : 12 FCBs in California

Needs for Continued Success

- Bus Performance
  - FC Reliability & Durability
  - Hybrid System Optimization, Reliability & Durability
- Hydrogen Stations
  - Increase availability of fuel
  - Optimization of station size and scalability for larger fleets
  - Investigating ‘green’ sources of H2
- Preparation for Market Introduction
  - Demonstrations of larger fleets (50+ buses in various locations)
  - Fleet Personnel Awareness & Training
  - Continued Data Collection & Analysis
- Cost reduction

For more information

Contact Info: Leslie Eudy

Phone: 303-275-4412

Email: leslie.eudy@nrel.gov

NREL Hydrogen Technology Validation web page:

www.nrel.gov/hydrogen/proj_tech_validation.html