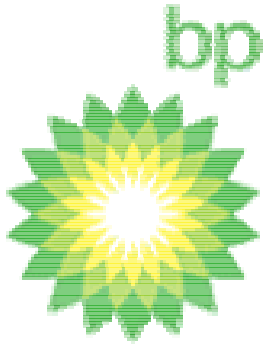


Hydrogen Fuel Cell Vehicle & Infrastructure Demonstration Program Review

Ford Motor Company
Research & Advanced Engineering

May 19, 2006

Overview

Timeline

- Project start:
  Nov. 17, 2004
- Project end:
  Jun. 2009
- 35 % complete

Barriers Addressed

- Vehicles
- Storage
- Hydrogen Refueling Infrastructure
- Maintenance and Training Facilities
- Codes & Standards

Budget

- $88 mil project
  - DOE $44 mil
  - Ford $44 mil
- FY05: $34.2 mil
- FY06: $24.9 mil

Partners

- BP America
- Ballard
- States of California & Florida
- Cities Ann Arbor & Taylor
- SMUD, Progress Energy & NextEnergy

Vehicle Project Objectives

To gain FCV operational data in differing climate conditions to direct and augment future design efforts

Since Last Review

- **Complete Vehicle Deliveries**
- **Implement Data Collection Process**
- **Service Fleet**
- **Begin Phase II Vehicle Build**
- **Begin data submissions to NREL**

Infrastructure Project Objectives

Project

- Provide safe, reliable user friendly hydrogen infrastructure
- Install technology to meet cost targets
- Establish an initial infrastructure network to fuel small fleets across a metropolitan area

Since Last Review

- Construct and operate 3 new stations (COT, Jamestown, Sacramento Airport)
- Select compact reformer and novel electrolysis technology for 2007 upgrades
- Decide on feasibility of Energy Station concept for validation program

Vehicle Approach

- Two demonstration components
  - Phase 1: developed technology installed in contemporary (Focus) vehicles for real world use
  - Phase 2: controlled in-house demonstration of extended range, durability and operating temperature
- Fleet vehicles in three differing geographic/climatic regions
- Automated data collection methodologies for effective data analysis

Vehicle Approach

Program Elements	Phase 1	Phase 2
Real World Data	Underway	
Maintenance & Training	Complete	
Hydrogen Storage & Interface	Underway	☑
Durability	Underway	☑
Economy	Underway	☑
Weight		☑
Cost		☑

Technical Accomplishments/ Progress/Results

- **Delivery: Completed delivery of 18 program vehicles**
- **Dynamometer: Completed procedures, data collection and reporting**
- **Data: Implemented data collection with PDA's and weekly reports**
- **Training: Completed all training**
- **Phase II: Built first two Phase II vehicles**

Technical Accomplishments/ Progress/Results

Phase I Fleet

- Accumulated 78,000 miles vs. (125,000 mile) target
- Operated 3200 hours (5000 hr) target
- Dyno tested four vehicles
- Encouraging operators to drive more !
- Mid year vehicle re-allocation being considered

Robustness Improvement

Significant Reliability Improvements

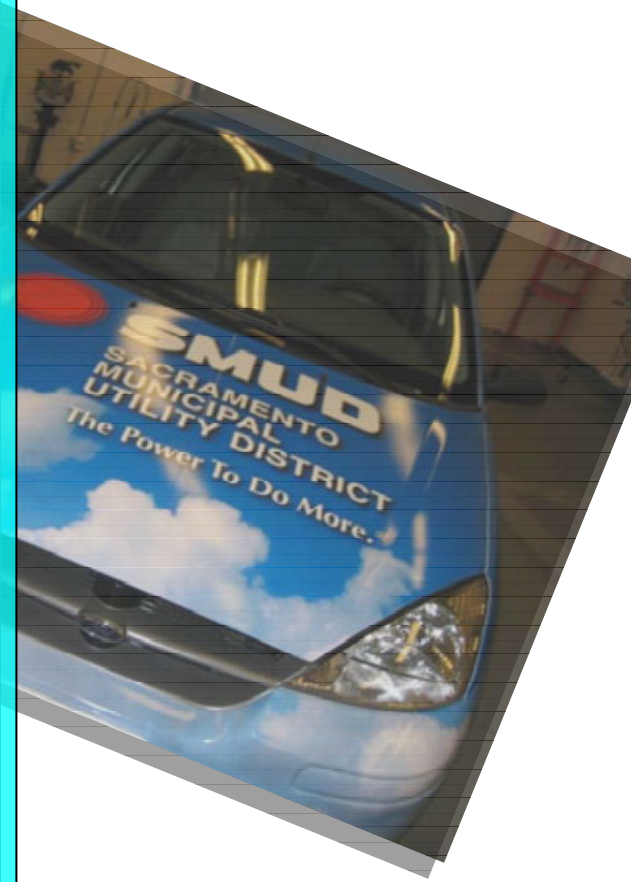
- **Systems Control Software updated**
- **Improved availability to 93%**
- **Average 36 days between service stops**

Vehicle Data Collection

Data acquisition, transfer, and analysis using PDAs and weekly downloads. Also implementing monthly on-road data submission to NREL

Vehicle Placements Activities

- Maintenance Issues
  - Fuel Cell water build-up: temperature related, software corrected
  - False H2 Sensor signals: humidity related
  - HV Battery State of Charge: usage dependent, software corrected
  - Systems Module Valve contamination: under investigation
- Safety Issues
  - None



Lessons Learned- Vehicles

- **Need to design components for flexibility**
  - Change component performance with controls software
- **Most operational issues are addressed with controls software**
- **Tradeoffs in fuel economy vs. performance can be significant**
- **Fuel storage capacity appears to be a larger challenge than originally perceived, perhaps as challenging as fuel cell technology development**

Lessons Learned- Vehicles (cont)

- **There are benefits from hybridization that make sense for some H2 vehicles**
  - Hybrids H2 concepts will benefit from the growing volume of production hybrid vehicles being sold today through component standardization, production volumes and technology development
- **"Production" level programs tax resources and significantly reduced the rate of technological development**
- **18 vehicles generate a tremendous level of data and information**
  - Larger study fleets not likely to produce more
  - Larger fleets may be counter-productive in industry and government resource use

Infrastructure Approach

- **Employ Two Phase Approach**
  - Phase I: Test Infrastructure Deployment
    - Install H2 Delivered Stations
    - Include electronic data collection for select sites
  - Phase II: Meet Cost Targets
    - Install onsite H2 Production and 700 bar Fueling at Select Sites
- **Station Locations**
  - Orlando Florida (1)
  - Sacramento (up to 4)
  - Taylor, Michigan (up to 2)

Station Opening Timeline

Fiscal Year	2005			2006											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Florida															
APCI Mobile Refueler	**Opened 9/16/05**														
Florida Permanent Station											**07/31/06 Planned**				
Michigan		**Opened 10/19/'05**					**Open 03/31/06**								
City of Taylor	**BOC Partial Refueler**						**BP/BOC Perm. Station**								
Sacramento															
CaFCP Station	**In-Place: BP/Shell Control June 5, '05**														
SMUD Temp & Permanent Station						**APCI Mobile Refueler Open 03/20/06**							**Perm. Station Open Jan. '07**		
Sacramento Airport												**Open Sept '06**			
Sacramento Sation S2													**Station TBD?**		

Integrated OEM/Energy Partner Approach

- Ford/BP conduct bi-weekly teleconferences to communicate changes and address issues for overall Program.
- Ford and BP work closely together with BP's station suppliers to ensure that stations meet our guidelines, for example:
  - Fuel quality sampling
  - Grounding: must confirm that station provides adequate grounding for H2 refueling.
  - Vehicle-to-station communications: wireless is being installed on permanent stations; defaults to non-communication if wireless fails.
  - Data collection system
- Ford/BP have implemented a Station Signoff Checklist for each station to document what requirements are met (or not met).

Technical Accomplishments

- Completed permitting and construction of 9000 gallon storage capacity liquid hydrogen station in Taylor Michigan
- Permitted and operated two mobile refuelers
- Completed Emergency Response and Hydrogen Safety training for over 150 individuals
- Completed Hazardous Identification Reviews for three permanent stations
- Completed 8 community engagement events
- Updated assessment of Energy Station and compact reformer technology

Commercial Compact Reformer Technology

H2 GEN REFORMER

APCI Harvester Unit

H2 Generator

Utility “Island”

HYRADIX REFORMER

Safety Implementation

Hydrogen for Transport is committed to no accidents, no harm to people, no damage to the environment

- **Project Management**
  - ✓ Managerial Gate Approvals
  - ✓ Management of Change
  - ✓ Pre-Construction Safety Induction for Contractors and Suppliers (Injury and Incident Free training)
  - ✓ Advanced Safety Audits
  - ✓ Integrity Management Standard
- **Adherence to relevant safety codes for example:**
  - ✓ NFPA 52
  - ✓ SAE J2600
  - ✓ SAE J2601(planned)
  - ✓ ASME B31.3
- **Collaborative system safety assessments and reviews**
  - ✓ HAZID / QRA
  - ✓ HAZOP
  - ✓ pHSSEr approach
  - ✓ BP-Global Alliance safety training for contractor and supplier
- **H2 Safety Training**
  - ✓ Contractors
  - ✓ Fleet operators
  - ✓ Station operators
  - ✓ Emergency Responders

Lessons Learned

- **Permitting**
  - Municipalities in Florida and Michigan very hydrogen friendly
  - Sacramento area has mixed results (depends on which agency you are dealing with)
- **Equipment Acquisition**
  - Installed equipment costs contribute about 35% to total cost to build station
  - Equipment costs have increased 2-3x since 2003
  - Small companies are vulnerable to bankruptcy
  - Monitor more closely key codes and standards (e.g. NFPA 52 surprised by specification of gas and leak detectors)
  - Expect delays in equipment delivery timing (e.g. externalities such as inconsistent funding impact technology development and delivery)
- **Station Construction**
  - Construction Costs contribute 60% to the overall station build
- **Hydrogen Purity**
  - Force fitting inadequate set of analytical test methods
  - No round robin so if two labs give different results unclear as to who is right
  - A lot of time and financial commitment to just do the minimum

Future Work: 2006 Work Plan

Upcoming Events:

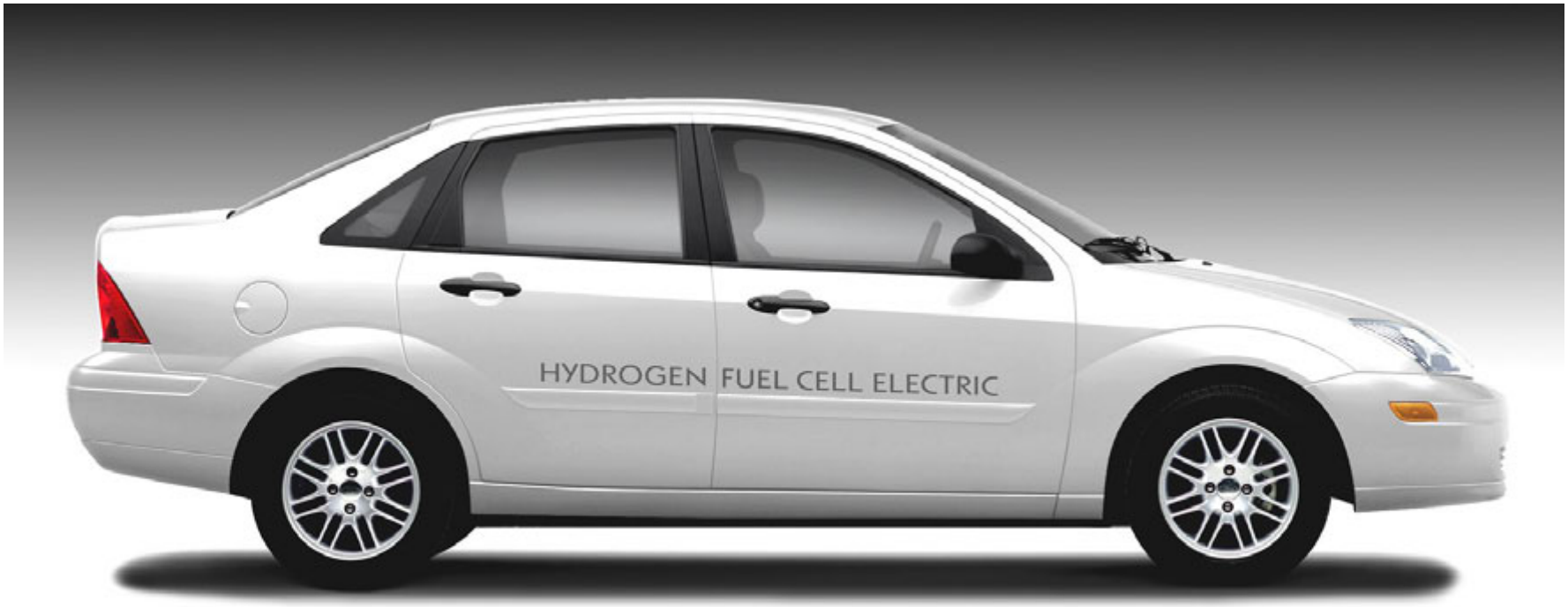
- Install and operate Taylor, MI Hydrogen Fueling Station
- Install and operate Orlando area partial renewable station
- Install and operate Sacramento Airport Hydrogen Station
- Complete third Phase II vehicle
- Install SMUD Renewable Hydrogen Station
- Begin Monthly on-road data submission

2006 Work Plan Phase II Ford Controlled Engineering Prototypes

Vehicle Attributes	H2 Storage Upgrade	Robustness Demonstrator	Designed Around Hydrogen Demonstrator
Fuel Cell Generation	Gen 1	Gen 2 (Stage 1)	Gen 2 (Stage 2)
Number of Vehicles	2	1	5
Timing	1Q '07	1Q '06	4Q '06
Range (miles)	240	200	>300
Hydrogen Storage (bar)	700	350	350
Unassisted Cold Start	2 °C	2 °C	< 0 °C
Assisted Cold Start	2 °C	2 °C	-15 °C
Fuel Efficiency (mpg) (*normalized to Focus)	50	50	50

Summary

- Program is on track, Phase I vehicles performing well
- Infrastructure implementation has been more difficult than anticipated
- Geographic deployments have highlighted key requirements in software controls development
- Phase II vehicles are underway



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Back-up Slides

Responses to 2005 Reviewer's Comments

- "An important part of technology demonstration is the economic viability. The project must address the efforts to reduce technology costs (vehicle and fuel cell price reduction strategy, total cost per mile, etc.)".
  - Too early in the development to report on this issue
  - Working with component suppliers to develop details
  - Considerable published studies already available
- "Detailed project results, failure modes, root cause, etc. data needs to be fully shared with all DOE participants".
  - We are following the program design, submitting relevant data to NREL
- "This project could be improved by developing a detailed plan describing how the 18 vehicles in this project will interface with the 12 additional vehicles being built".
  - These are separate programs, each with their own agreements
  - Engineering vehicle data will be shared with the DOE

Publications & Presentations

- None

Critical Assumptions & Issues

- Fuel Cell System Operational Limits: high frequency start/stop operations appears to have significant adverse affect on projected fuel cell life
  - Studying actual fuel cell state on key vehicles to identify cause of degradation
- Funding: The flow of government funds to support this program lags company expenditures. The current business environment makes company funding very difficult without timely matching funds.
  - Communicating with DOE program personnel

2006 Deployments