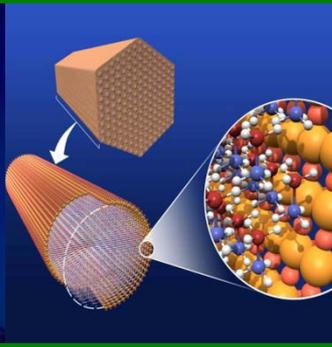
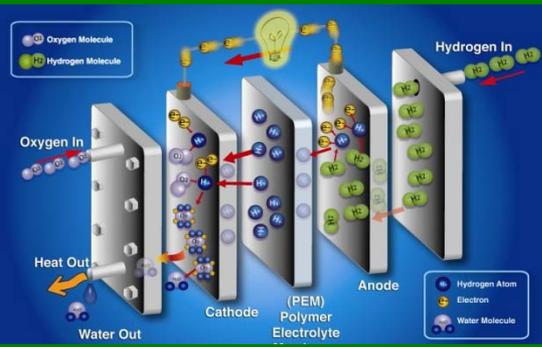




U.S. DEPARTMENT OF
ENERGY



Technology Validation

John Garbak

*2010 Annual Merit Review and Peer Evaluation Meeting
(8 June 2010)*

Goal: Validate complete systems of integrated hydrogen and fuel cell technologies for transportation, infrastructure and electricity generation applications under real-world operating conditions

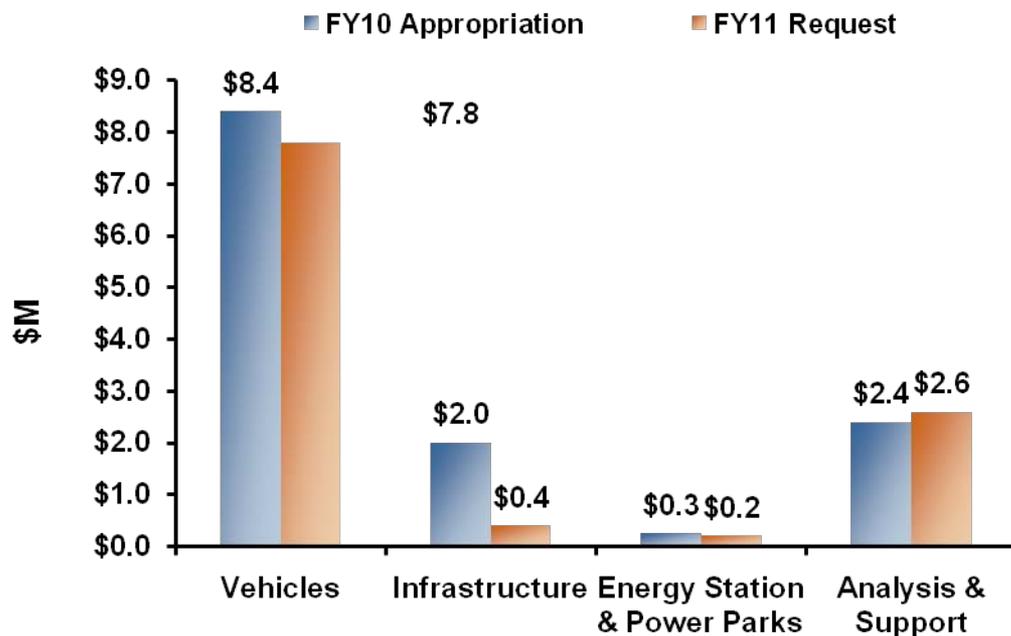
Objectives:

- Validate hydrogen and fuel cell technologies in parallel
- Identify current status of the technology
 - Assess progress toward technology readiness
 - Provide feedback to H₂ Research and Development

Key Targets

| Performance Measure | 2009 | 2015 |
|----------------------------|------------|------------|
| Fuel Cell Stack Durability | 2000 hours | 5000 hours |
| Vehicle Range | 250+ miles | 300+ miles |
| Hydrogen Cost at Station | \$3/gge | \$2-3/gge |

FY 2011 Request = \$11.0 M
FY 2010 Appropriation = \$13.1 M



EMPHASIS

- Final report from two learning demonstration teams to be completed
- Advanced fuel cell vehicles being introduced and data collection to continue in final two projects
- Collect operational and maintenance data at Combined Heat and Power site at Orange County Sanitation District in Fountain Valley, CA
- Continue data collection of fuel cell buses

Through data collection during the Learning Demonstration many challenges have been met

- **Lack of fuel cell vehicle performance and durability data**
 - Learning Demo and FC Bus evaluation have generated significant quantities of fuel cell vehicle data that have been analyzed and published
- **Lack of refueling infrastructure performance and availability data**
 - Tech Val projects have analyzed many aspects of H2 refueling infrastructure, including refueling rates, safety, maintenance, production efficiency, and availability
- **Assess fuel cell start-up and operation in 3 different climatic conditions and ability to start fuel cells in cold climates**
 - FCVs have demonstrated acceptable cold start performance and hot start durability
- **Evaluation of filling vehicles at 700 bar**
 - Over 5,500 fueling events performed at 700 bar, with an average fill rate of 0.63 kg/min
- **Need to address fuel cell vehicle and infrastructure interface issues**
 - Communication fills (vehicle talks to station during fill) have been evaluated, and on average communication fills are 30% faster than non-communication fills



- **Fuel cell durability**
 - 2,500 hours projected (nearly 75K miles)
- **Over 2.5 million miles traveled**
- **Over 106K total vehicle hours driven**
- **Fuel cell efficiency 53-59%**
- **Over 150,000 kg of hydrogen produced or dispensed**
- **144 fuel cell vehicles and 23 hydrogen fueling stations have reported data to the project**
 - There are 17 vehicles and 15 fueling stations active in the project

Summary – Key Performance Metrics

| Vehicle Performance Metrics | Gen 1 Vehicle | Gen 2 Vehicle | 2009 Target |
|---|----------------------|----------------------|-------------------|
| Fuel Cell Stack Durability | | | 2000 hours |
| Max Team Projected Hours to 10% Voltage Degradation | 1807 hours | 2521 hours | |
| Average Fuel Cell Durability Projection | 821 hours | 1062 hours | |
| Max Hours of Operation by a Single FC Stack to Date | 2375 hours | 1261 hours | |
| Driving Range | 103-190 miles | 196-254 miles | 250 miles |
| <i>Fuel Economy (Window Sticker)</i> | 42 – 57 mi/kg | 43 – 58 mi/kg | no target |
| <i>Fuel Cell Efficiency at ¼ Power</i> | 51 - 58% | 53 - 59% | 60% |
| <i>Fuel Cell Efficiency at Full Power</i> | 30 - 54% | 42 - 53% | 50% |

| Infrastructure Performance Metrics | | | 2009 Target |
|--|--|--|----------------|
| H₂ Cost at Station (early market)* | On-site natural gas reformation \$7.70 - \$10.30 | On-site Electrolysis \$10.00 - \$12.90 | \$3/gge |
| <i>Average H₂ Fueling Rate</i> | 0.77 kg/min | | 1.0 kg/min |

* DOE independent panels concluded at 500 replicate stations/year:
 Distributed natural gas reformation at 1500 kg/day: \$2.75-\$3.50/kg (2006)
 Distributed electrolysis at 1500kg/day: \$4.90-\$5.70 (2009)

2010 Progress & Accomplishments

NREL has collected data for DOE and FTA on 9 FCBs in service at 5 sites:

**AC Transit
SunLine
CTTRANSIT
VTA
Columbia, SC**

Traveled:

~ 395,000 miles

Dispensed:

80,304 kg H₂

| NREL Hydrogen Bus Evaluations for DOE and FTA | | | | | | | | | | | | | | | | | | | |
|---|--------|------------------------------------|------------------------|---|---|---|----------------------|---|---|---|------|---|---|---|------|---|---|---|--|
| Site/Location | State | Eval. Funding | 2009 | | | | 2010 | | | | 2011 | | | | 2012 | | | | |
| | | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| AC Transit/ SF Bay Area | CA | DOE Technology Validation | | | | | CA ZEB Advanced Demo | | | | | | | | | | | | |
| SunLine/ Thousand Palms | CA | | FCB | | | | | | | | | | | | | | | | |
| SunLine/ Thousand Palms | CA | | Advanced FCB Project | | | | | | | | | | | | | | | | |
| CTTRANSIT/ Hartford | CT | | FCB Demo | | | | | | | | | | | | | | | | |
| City of Burbank/ Burbank | CA | | Burbank FCB | | | | | | | | | | | | | | | | |
| AC Transit/ Oakland | CA | FTA National Fuel Cell Bus Program | Accel. Test | | | | | | | | | | | | | | | | |
| SunLine/ Thousand Palms | CA | | American FCB Demo | | | | | | | | | | | | | | | | |
| CTTRANSIT/ Hartford | CT | | Nutmeg Hybrid FCB Demo | | | | | | | | | | | | | | | | |
| USC, CMRTA/ Columbia UT/ Austin | SC, TX | | Hybrid FCB | | | | | | | | | | | | | | | | |
| Logan Airport / Boston | MA | | MA H2 FCB Demo | | | | | | | | | | | | | | | | |
| Albany / NY | NY | | Light-wt FCB | | | | | | | | | | | | | | | | |
| TBD / NY | NY | | NYPA H2 Powered FCB | | | | | | | | | | | | | | | | |
| SFMTA / San Francisco | CA | | FC APU Hybrid | | | | | | | | | | | | | | | | |

Demonstration sites color coded by geographic area:

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



Fuel economy results: 39% to 141% better than diesel and CNG buses

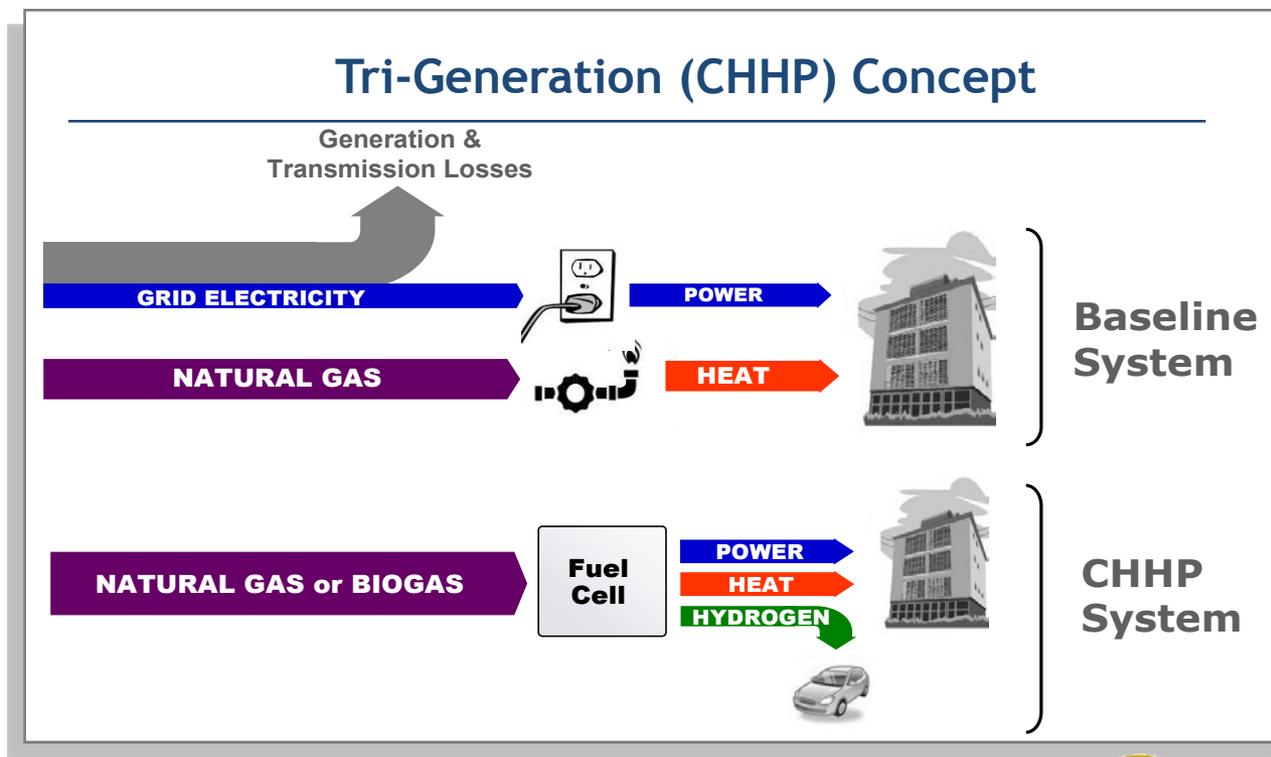
www.nrel.gov/hydrogen/proj_tech_validation.html

Estimate of data collection/evaluation - schedule subject to change based on progress of each project

2010 Progress & Accomplishments

We are participating in a project to demonstrate a combined heat, hydrogen, and power (CHHP) system using biogas.

- System has been designed, fabricated and shop-tested
- Improvements in design have led to higher H₂-recovery (from 75% to >85%)
- On-site operation and data-collection planned for FY10 – FY11



Combined heat, hydrogen, and power systems can:

- *Produce clean power and fuel for multiple applications*
- *Provide a potential approach to establishing an initial fueling infrastructure*

Public-Sector Partners:



South Coast Air Quality Management District



California Air Resources Board



Fuel Cell Energy & Air Products

- **Continue data collection of the advanced fuel cell vehicles in the Learning Demonstration**
- **Begin to collect data from the Fountain Valley Energy Station**
- **Continue data collection of fuel cell buses, stationary fuel cell and fork lifts**

- This is a review, not a conference
- Presentations will begin precisely at the scheduled times
- Talks will be **20 minutes** and **Q&A 10 minutes**
- Reviewers have priority for questions over the general audience
- Reviewers should be seated in front of the room for convenient access by the microphone attendants during the Q&A
- Please mute all cell phones, BlackBerries, etc.

- Deadline for final review form submittal is **June 18th**
- ORISE personnel are available on-site for assistance. A reviewer lab is set-up in room 8216 and will be open Tuesday –Thursday from 7:30 AM to 6:00 PM and Friday 7:30 AM to 3:00 PM.
- Reviewer feedback session – **Thursday, at 1:30pm, (after lunch) in the room of the last session.**

Technology Validation

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