



U.S. DEPARTMENT OF  
**ENERGY**

# Technology Validation

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John Garbak

**2006 DOE Hydrogen Program  
Merit Review and Peer Evaluation Meeting**

**May 18, 2006**



# Technology Validation Team



## ● **Washington Team**

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# Objectives



*Validate integrated hydrogen and fuel cell technologies for transportation, infrastructure, and electric generation in a systems context under real-world operating conditions.*

- **By 2005, \$3.60/gge and 8¢/kWh.**
- **By 2008, 20,000 hour fuel-cell durability (stationary), 32% efficiency, \$1,500/kW**
- **By 2009, 250+ mile range, 2000 hour fuel-cell durability (vehicle), \$3.00/gge hydrogen (untaxed)**
- **By 2012, demonstrate biomass plant to produce hydrogen at \$1.75/gge and renewable electrolysis at \$2.85/gge at the plant gate (untaxed)**



# Summary of Technology Validation Tasks and Projects



Task No.	Description	Project	FY 2006 Available Funds	Earmarks
1	Vehicle & Infrastructure	GM/Shell * Ford/BP * DCX/BP * Chevron/Hyundai-Kia * LLNL – High-pressure cold hydrogen storage vehicle demo*	\$25,600K  \$290K	APCI – California Hydrogen Infrastructure Project NEXT Energy – Micro grid and hydrogen fueling facility Vehicle Projects LLC - Front end mine loader Santa Clara Valley Trans Auth - Bus demonstration
2	Natural Gas to H <sub>2</sub>	APCI – Development of a turnkey hydrogen fueling station * GTI – Development of a natural gas to hydrogen fueling station * APCI – Novel compression and fueling apparatus	\$960K \$230K ----	None
3	Energy Stations	APCI – Validation of an Integrated system for a H <sub>2</sub> fueled power park* APCI – Validation of a PEM fuel cell, H <sub>2</sub> reformer and vehicle refueling facility	\$980K  ----	City of Chattanooga – Fuel cell demonstration project

\* Oral Presentation



# Summary of Technology Validation Tasks and Projects



Task No.	Description	Projects	FY 2006 Available Funds	Earmarks
4	Power Parks	<p>DTE Energy – Hydrogen Technology Park *</p> <p>Hawaii – Hydrogen Center for Development and Deployment of distributed energy systems</p> <p>Arizona Public Service – Hydrogen Power Park for Business Concept Opportunities</p> <p>SNL – Power Parks System Simulation *</p>	<p>----</p> <p>\$400K</p> <p>\$65K</p> <p>\$250K</p>	
5	Renewable	Clark Atlanta University – Hydrogen from Biomass for Urban Transportation	\$50K	UNLV – Hydrogen filling station
6	Analyses	<p>NREL – Fleet and Infrastructure Analysis *</p> <p>NREL – Bus data collection and analysis</p>	<p>\$812K</p> <p>\$288K</p>	

\* Oral Presentation



# Task 1 Vehicle and Infrastructure Learning Demonstration and Validation



**Objective:** By 2009, 250+ mile range, 2000 hours fuel cell durability, \$3.00/gge hydrogen (untaxed)

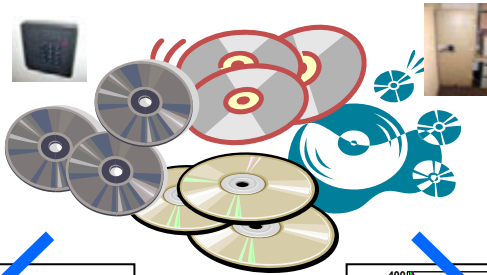
- 59 vehicles deployed, operating from 9 hydrogen stations
- 200,000 miles accumulated
- On-road fleet monitoring and data collection systems implemented
- Dynamometer testing conducted for all four teams
- Fuel cell voltage degradation is being analyzed statistically for durability prediction
- Advanced natural gas reformers are installed and others are being planned for installation this year and early '07
- Power park is operating and energy stations are being planned
- 700 bar stations being considered
- Completed Emergency Response and Hydrogen Safety Training
- 16 of 26 composite data products published



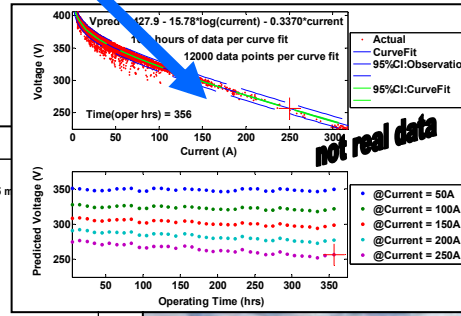
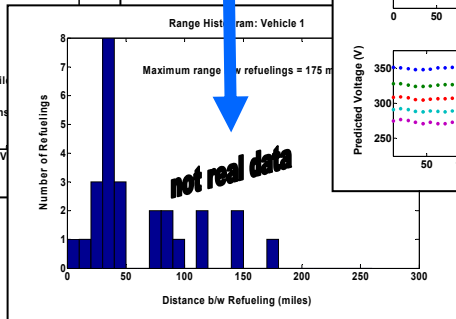
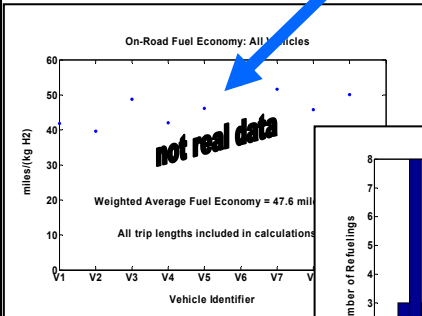
# Task 1 Learning Demonstration and Validation



Data is delivered to NREL's Hydrogen Secure Data Center (HSDC) on CD/DVDs



Data protected in HSDC for 5 years after data is developed under EPACT 2005, Sec. 810



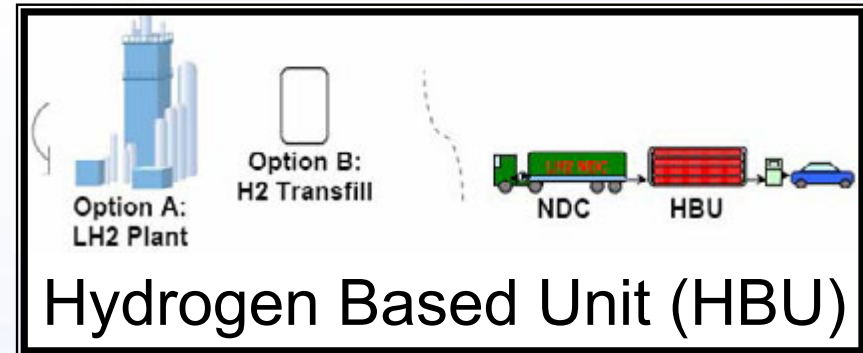


# Task 1 Vehicle and Infrastructure Learning Demonstration and Validation



**Objective:** By 2009, 250+ mile range, 2000 hours fuel cell durability, \$3.00/gge hydrogen (untaxed)

- Three Hydrogen Fuelers in fabrication
- Designed new LH<sub>2</sub> Delivery Concept and Hydrogen Based Unit to reduce costs and space requirements
- Equipment designed for station to operate from a hydrogen pipeline
- Demonstrated ultra-high purification system based on physical adsorption system
- Evaluated 4 operating bus fleets for 3 bus manufacturers and 3 fuel cell suppliers
- Designed, built and tested a horizontal cryogenic vessel that meets the 2010 DOE weight and 2007 DOE volume goals
- Performed detailed engineering design of power plant and metal hydride storage for fuel cell mine loader







## Task 2: Natural Gas to Hydrogen



**Objective:** By 2006, validate \$3.00/gge at \$5.00/MMBTU natural gas and 65% efficiency

- Completed system installation and checkout
- Integrated system operation is underway as of April 1, 2006
- Vehicles have been filled
- Achieved overall efficiency of 65.1%
- Projected \$3.03/gge using H<sub>2</sub>A for 1,500 kg/day station
- Composite storage tanks developed and installed on Mobile Refueler
- Efficient, compact fuel processor developed and tested
- Single stage 140:1 liquid compressor is built and undergoing testing (suitable for 700 bar dispensing system)



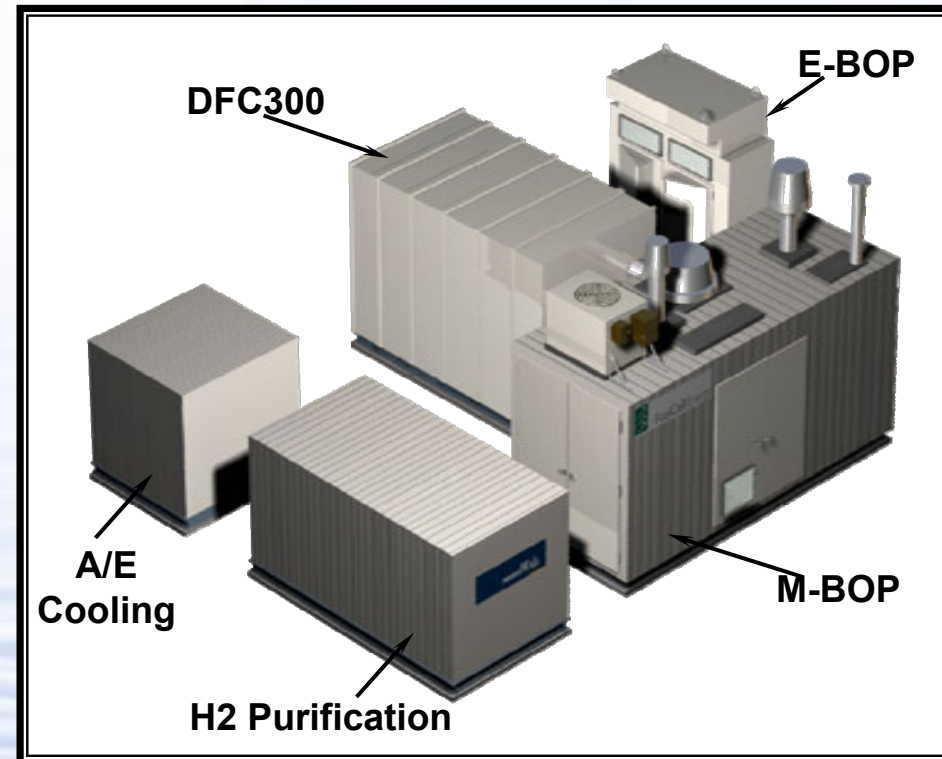


# Task 3: Energy Stations



**Objectives:** By 2005, \$3.60/gge and 8¢/kWh  
By 2008, 20,000 hour fuel cell durability (stationary),  
32% efficiency, \$1,500/kW

- Completed validation of \$3.60/gge hydrogen production and 8¢/kWh power production for PEM fuel cell energy station
- Peak PEM fuel cell efficiency – 44% for hydrogen fuel
- Completed engineering design and development of anode gas handling and hydrogen purification systems for Molten Carbonate Fuel Cell System
- Expected power efficiency 49%; expected overall fuel and power efficiency 66%
- Economic projection of \$2/kg using H2A assumptions
- Operated 5 kW planar Solid Oxide Fuel Cell energy station as of Feb. 5, 2006 – 2,255 hours of operation, 98% system availability
- Peak stack efficiency – 37.7%
- Peak system efficiency – 60.2%





## Task 4: Power Parks



**Objectives:**      **By 2005, 68% electrolyzer plus BOP efficiency (76% by 2010)**  
                         **By 2008, 20,000 hour fuel cell durability (stationary), 32% efficiency, \$1,500/kW**

- Alkaline electrolyzer and BOP achieved 59% efficiency over 8 months
- Compressor meets DOE target (2005) for the relative work in the electrolyzer system
- For 1,500 kg/day electrolyzer \$4.75/kg is achievable (2005) but innovation needed to achieve \$2.85/kg
- Polarization curve for PEM fuel cell determined from 3 sites (APS, DTE and HNEI) with excellent repeatability
- Fuel cell system peak efficiency is 44% for hydrogen fuel
- Fuel cell cost is \$3,000 / kW
- Fuel cell as peaking system had 1,500 hours durability



# Task 5: Renewable Systems



**Objective:** By 2012, demonstrate biomass plant to produce hydrogen at \$1.75/gge and renewable electrolysis at \$2.85/gge at the plant gate (untaxed)

- Completed design, construction and integration of reformer with pyrolyser
- Completed 100 hours of successful pilot unit operation
- Completed 1,000 hour test modifications
- Completed 1,100 psig electrolysis / compression / distribution system design
- Tested unit and it is delivered to site



# Future Work



## **Task 1** Vehicle and Infrastructure Learning Demonstration and Validation

- Complete composite data products for fuel cell durability, reliability, efficiency and start-up times
- Complete composite data products for hydrogen production costs, efficiency, maintenance and installation
- Complete installation of seven stations utilizing advanced delivery systems
- Install and test cryogas tank on Prius
- Continue to take operation and maintenance data for bus program

## **Task 2** Natural Gas to Hydrogen

- Planned six month operation on two fueling stations
- Install and operate liquid compressor at a fueling station

## **Task 3** Energy Station

- Install and operate high temperature energy station at test site and make decision to install at fueling station

## **Task 4** Power Park

- Install and operate a power park on Big Island of Hawaii

## **Task 5** Renewable

- Complete 1,000 hours biomass pyrolysis system test
- Complete installation and test of 1,100 psig electrolysis system and optimize its performance



# For More Information



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