



U.S. DEPARTMENT OF  
**ENERGY**

# Results from the Vehicle/Infrastructure Learning Demonstration Project

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National Renewable Energy Laboratory



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

**May 18, 2006**

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# Project Objectives and Targets

## ● Objectives

- Validate H<sub>2</sub> FC Vehicles and Infrastructure in Parallel
- Identify Current Status of Technology and its Evolution
- Re-Focus H<sub>2</sub> Research and Development
- Support Technology Readiness Milestone by 2015



### 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

\* To verify progress toward 2015 targets

\*\* Subsequent projects to validate 2015 targets

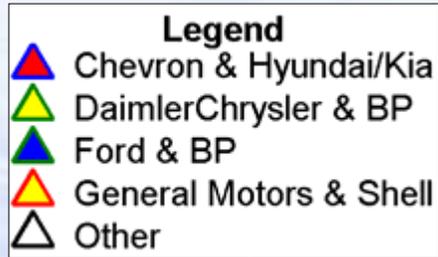
# Teams are Fielding Four Main Types of Vehicles



# Representative Hydrogen Refueling Infrastructure Supporting Vehicles



# Refueling Stations from All Four Teams Test Vehicle/Infrastructure Performance in Various Climates



# Project Produces Results for Both the Public and the Industry Project Teams

## Hydrogen Secure Data Center (HSDC)

Raw Data,  
Reports



- Located at NREL: Strictly Controlled Access
- Detailed Analyses, Data Products, Internal Reports



## Composite Data Products

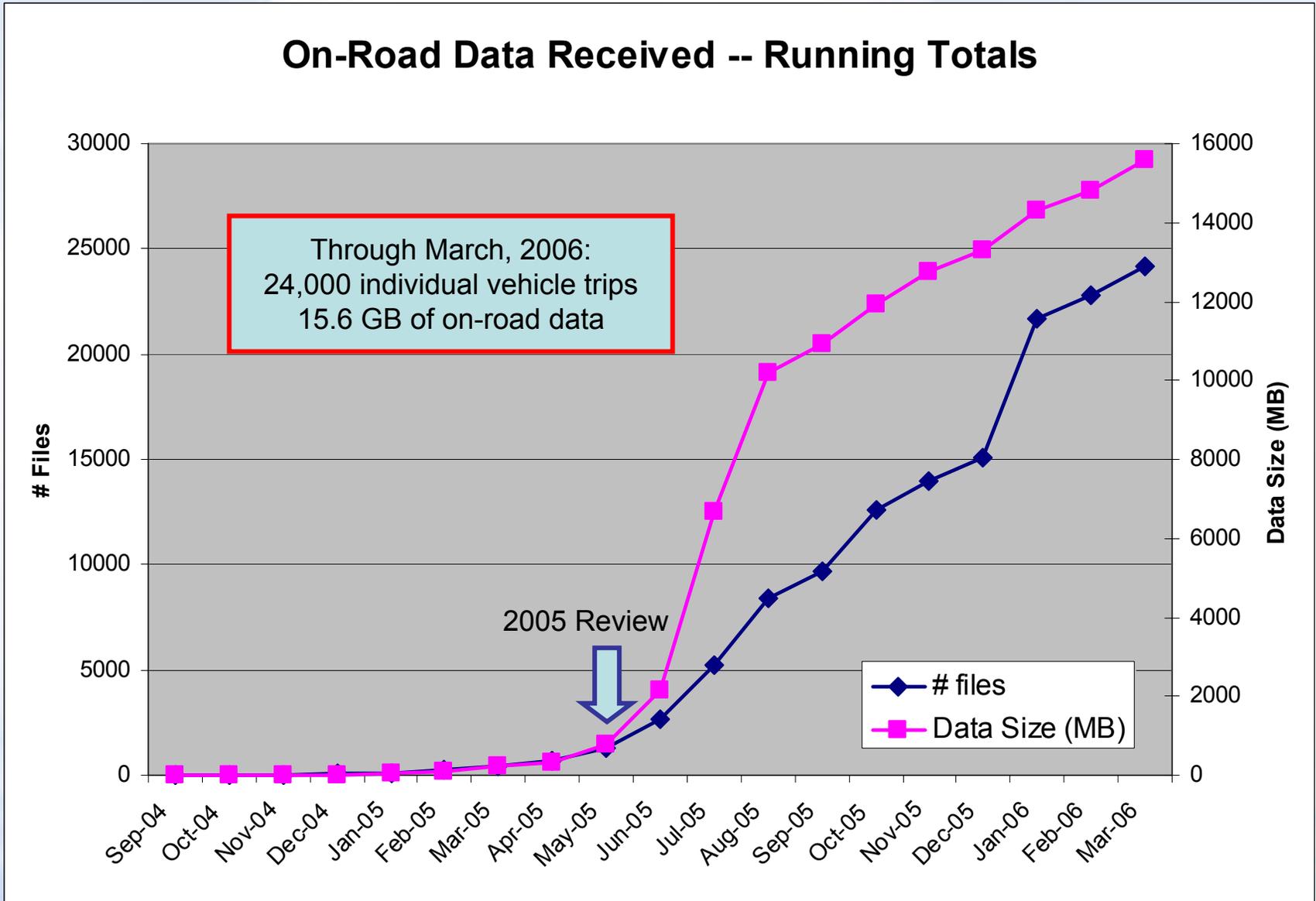
- Pre-agreed upon aggregate data results for public
- No confidential information

## Detailed Data Products

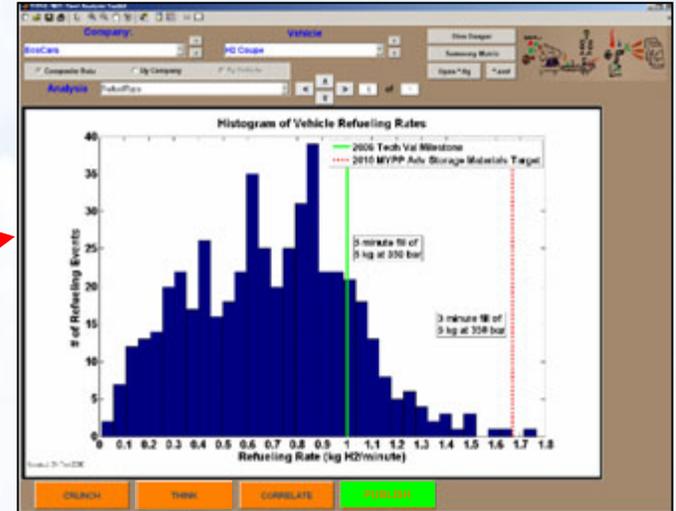
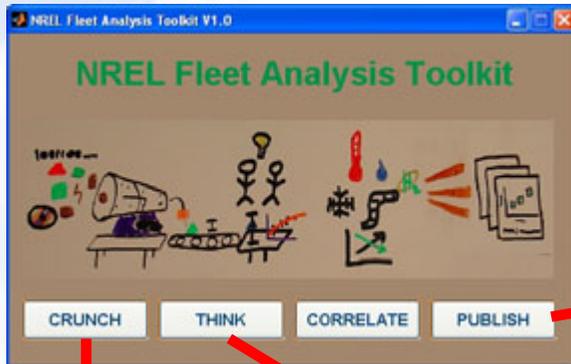
- Only shared with company which originated the data

# Project Now Well Underway: 1<sup>st</sup> Year of Data Analyzed

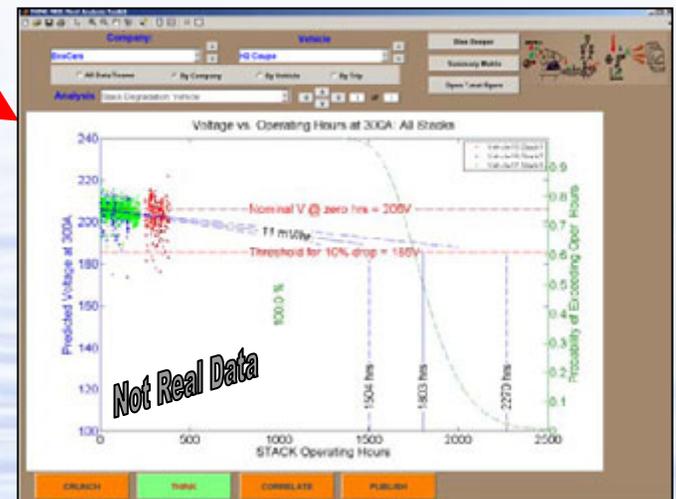
## Current Status of Data Reporting to the Hydrogen Secure Data Center at NREL



# New Fleet Analysis Toolkit (FAT) Helps Automate the Analysis



This screenshot shows the main interface of the NREL Fleet Analysis Toolkit. The title bar reads "CRUNCH NREL Fleet Analysis Toolkit". The interface is divided into several sections: "Company:" with a dropdown menu set to "EcoCars"; "Vehicle:" with a dropdown menu set to "HQ Coupe"; "Processing to Perform" with options for "New CD" and "Selected Below"; "Raw Data Conversion" with a checkbox for "Convert to Matlab" and a file browser; "Fuel Economy" with checkboxes for "Create Raw", "Vehicle", "Fleet", and "Trip Length Effect"; "Range" with checkboxes for "Create Raw", "Vehicle", and "Fleet"; "Stack Degradation" with checkboxes for "Create Raw", "Vehicle", "Fleet", "Combined Fleet", and "Hours Accum"; "Geographic" with checkboxes for "Create Raw" and "Fleet"; and "Fuel Cell System Efficiency" with a checkbox for "Curve Calc". A large green "GO" button is located at the bottom left. At the bottom of the window are four buttons: "CRUNCH", "THINK", "CORRELATE", and "PUBLISH".



# First 16 of 26 Composite Data Products Published Earlier This Year

## A. Critical Program Metrics:

1. Fuel Cell Durability, Actual vs. DOE Targets, All OEM's
2. Vehicle Ranges, Actual vs. DOE Targets, All OEM's
3. H2 Production Cost. Actuals/Projections vs. DOE Targets

Highlighted CDPs Have Been Completed

## B. Composite Performance Tracking:

### *Vehicles*

4. Reliability (FC System & Powertrain, MTBF)
5. Start Times vs. DOE Target
6. Fuel Economy: Dyno, On-Road
7. Normalized Vehicle Fuel Economy
8. Fuel Cell System Efficiency
9. Safety Incidents - Vehicle Operation
10. Weight % Hydrogen
11. Energy Density of Hydrogen Storage
12. Vehicle Hydrogen Tank Cycle Life

### *Hydrogen Infrastructure*

13. H2 Production Efficiency vs. Process
14. Combined Heat and Power (CHP) Efficiencies
15. H2 Production Cost vs. Process
16. H2 Purity vs. Production Process
17. Hydrogen Impurities - Range for Production Process A
18. Histogram: Refueling Rate
19. Average Maintenance Hours - Scheduled and Unscheduled
20. Safety Incidents - Infrastructure

## C. High Level Program Progress:

### *Vehicles*

21. Range of Actual Ambient Temperatures During Vehicle Operation – All Vehicle Teams
22. Histogram: # Vehicles vs. Operating Hours to Date
23. Histogram: # Vehicles vs. Miles Traveled to Date
24. Cumulative Vehicle Miles Traveled - All Teams
25. Progression of Low to High Pressure On-board H2 Storage

### *Hydrogen Infrastructure*

26. Cumulative Hydrogen Production – All Teams

Composite Data Products are Main Output to Public and Hydrogen Community

# Dynamometer Testing Completed to Evaluate Fuel Economy Under Controlled Conditions

- One vehicle per team per geographic region
- 11 vehicles tested using SAE J2572

Chevron/Hyundai-KIA



DaimlerChrysler/BP



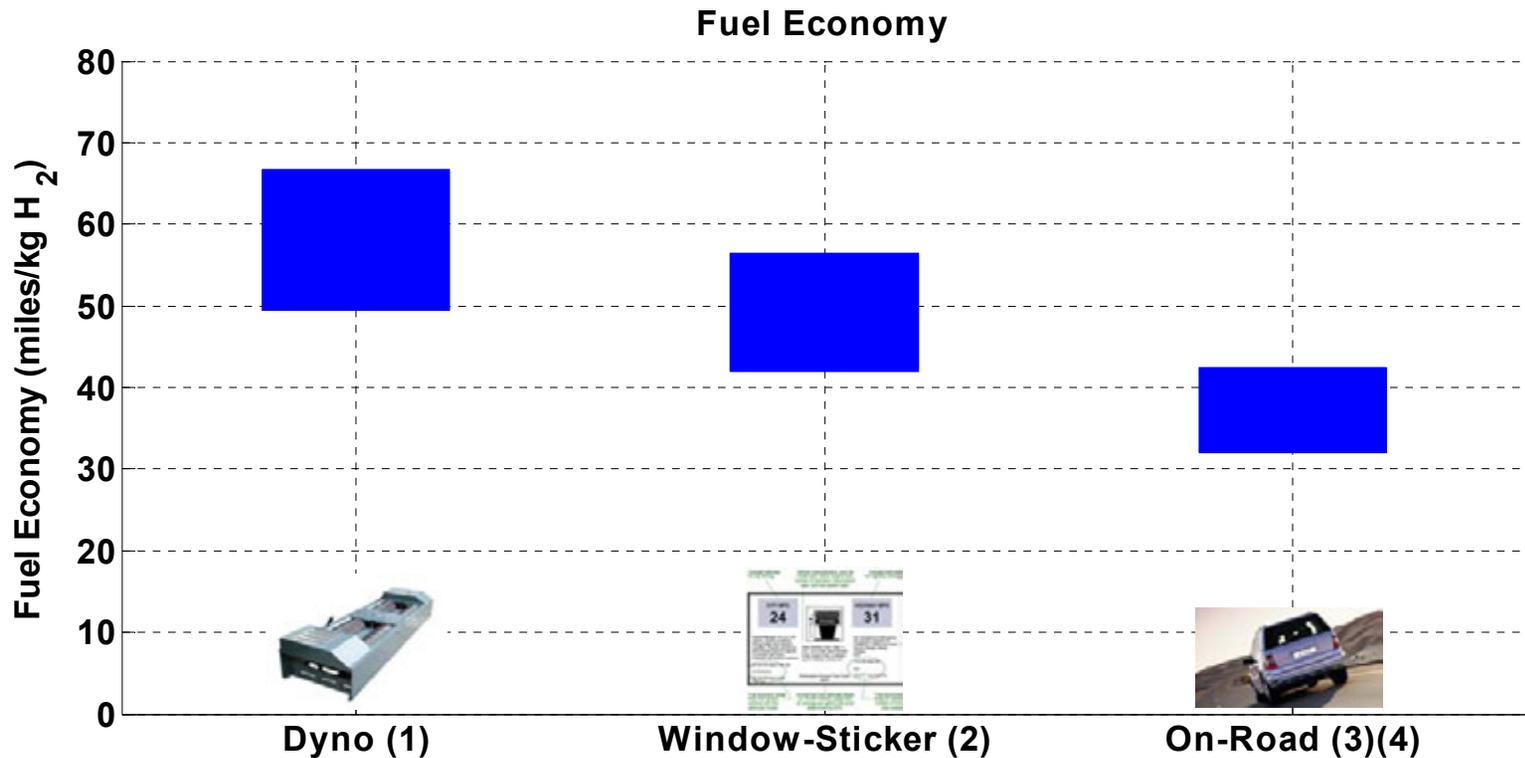
GM/Shell



Ford/BP



# Dynamometer and On-Road Fuel Economy



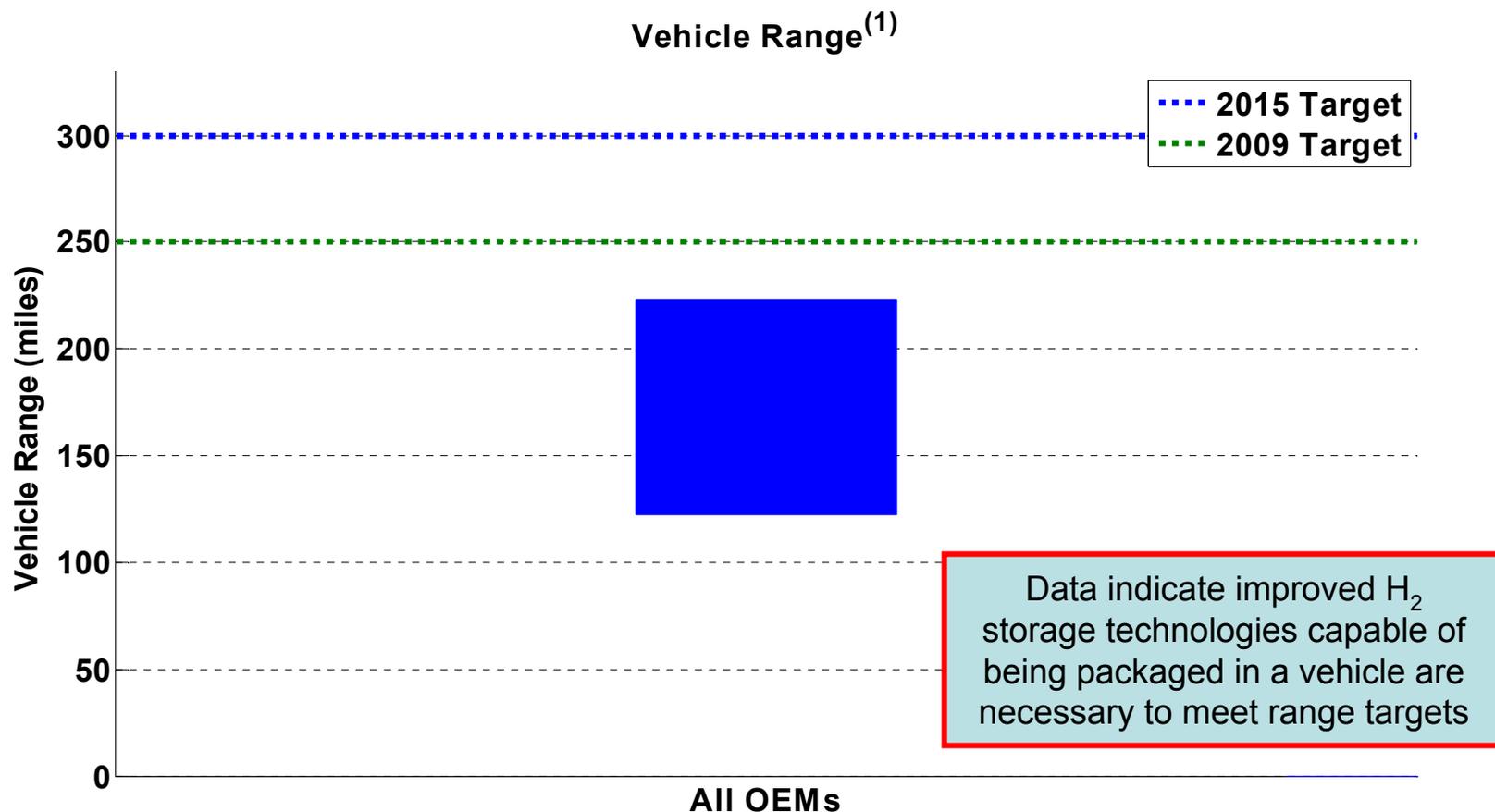
(1) One data point for each make/model. Combined City/Hwy fuel economy per DRAFT SAEJ2572.

(2) Adjusted combined City/Hwy fuel economy ( $0.78 \times \text{Hwy}$ ,  $0.9 \times \text{City}$ ).

(3) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.

(4) Calculated from on-road fuel cell stack current or mass flow readings.

# Vehicle Range Based on Dyno Results and Usable H<sub>2</sub> Fuel Stored On-Board

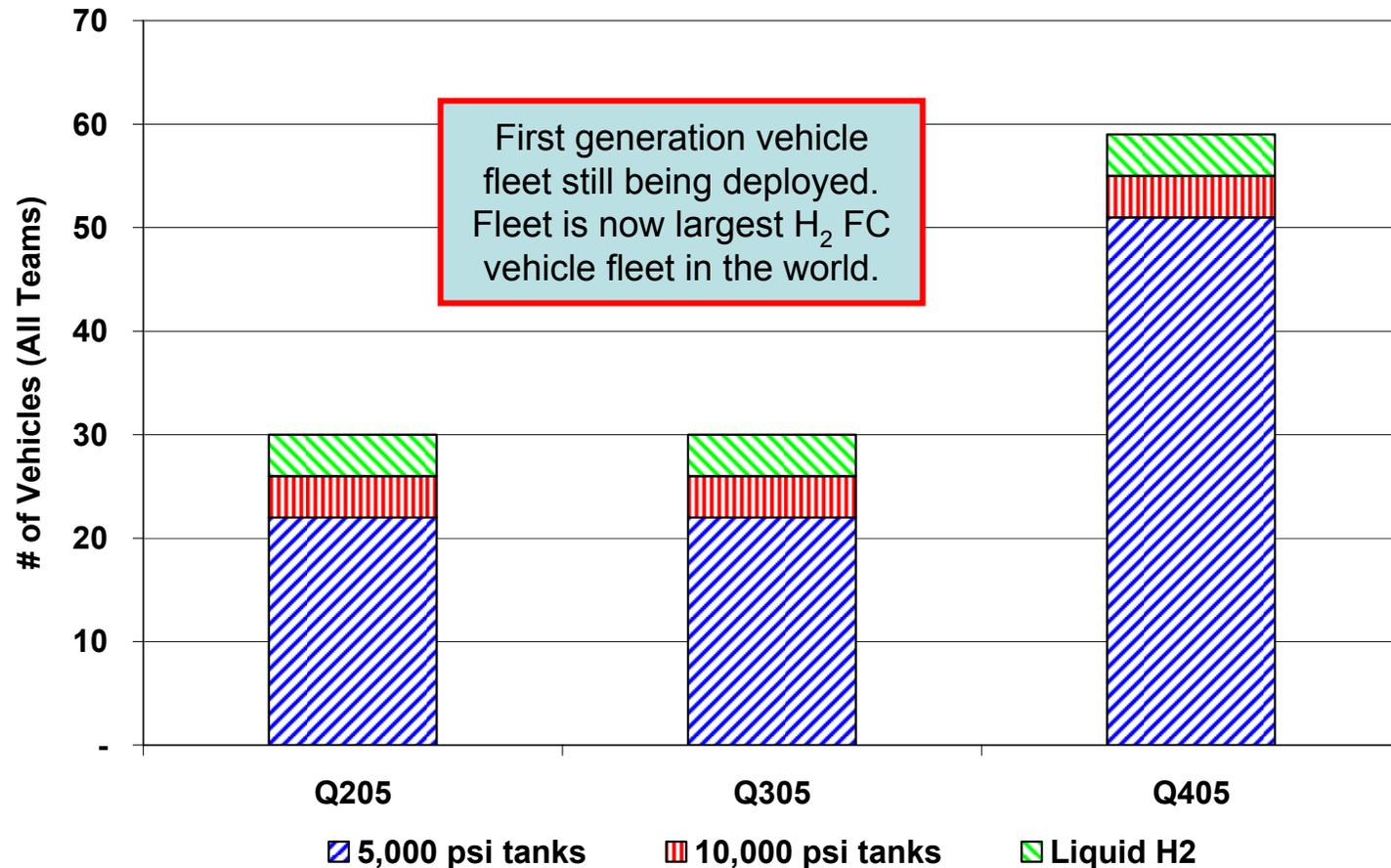


Created: 21-Feb-2006

(1) Calculated from combined City/Hwy fuel economy (dyno test) per DRAFT SAE J2572 and usable fuel on board.

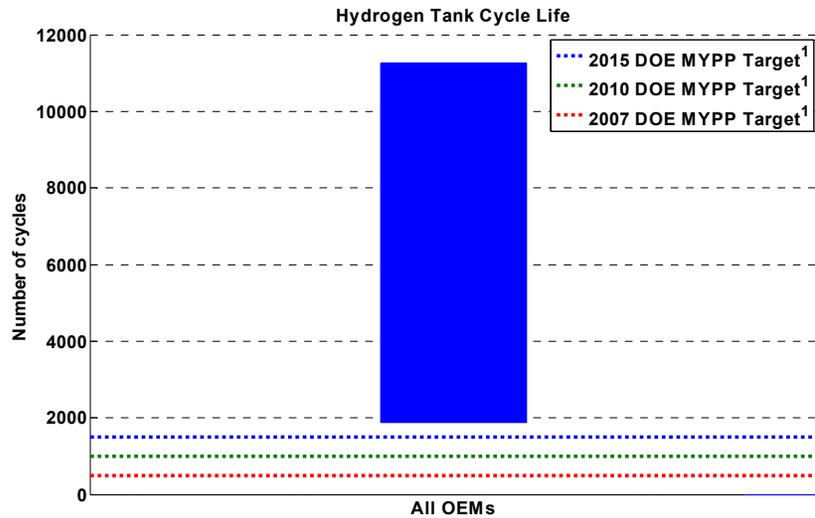
# Vehicle H<sub>2</sub> Storage Technologies Include 350 bar, 700 bar, and Liquid H<sub>2</sub>

On-Board Hydrogen Storage Methods



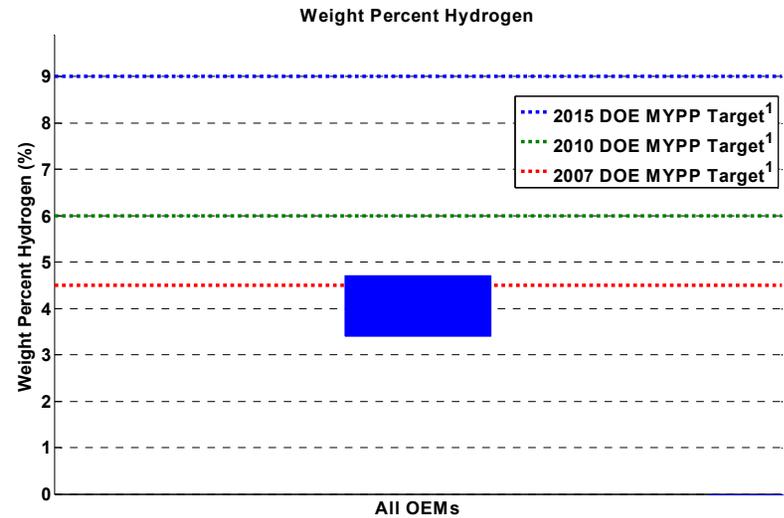
First generation vehicle fleet still being deployed. Fleet is now largest H<sub>2</sub> FC vehicle fleet in the world.

# Technical Status of On-Board H<sub>2</sub> Storage Technologies Being Validated



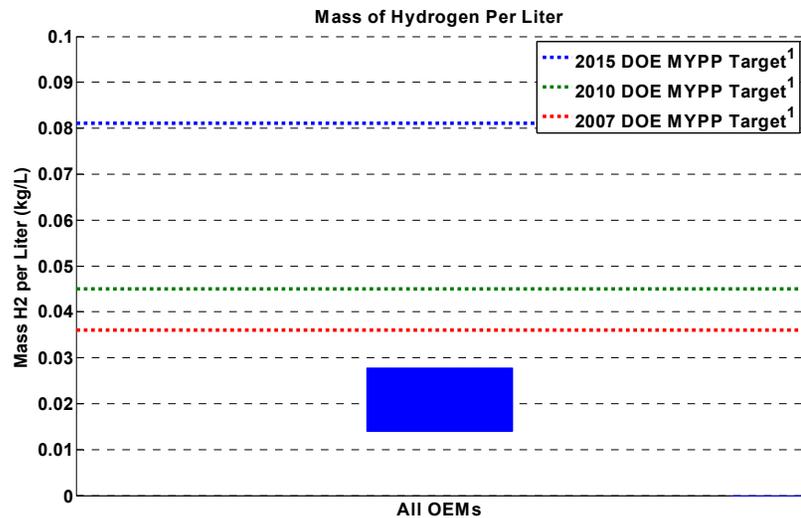
Created: 23-Feb-2006

<sup>1</sup>Some near-term targets have been achieved with compressed and liquid tanks. Emphasis is on advanced materials-based technologies.



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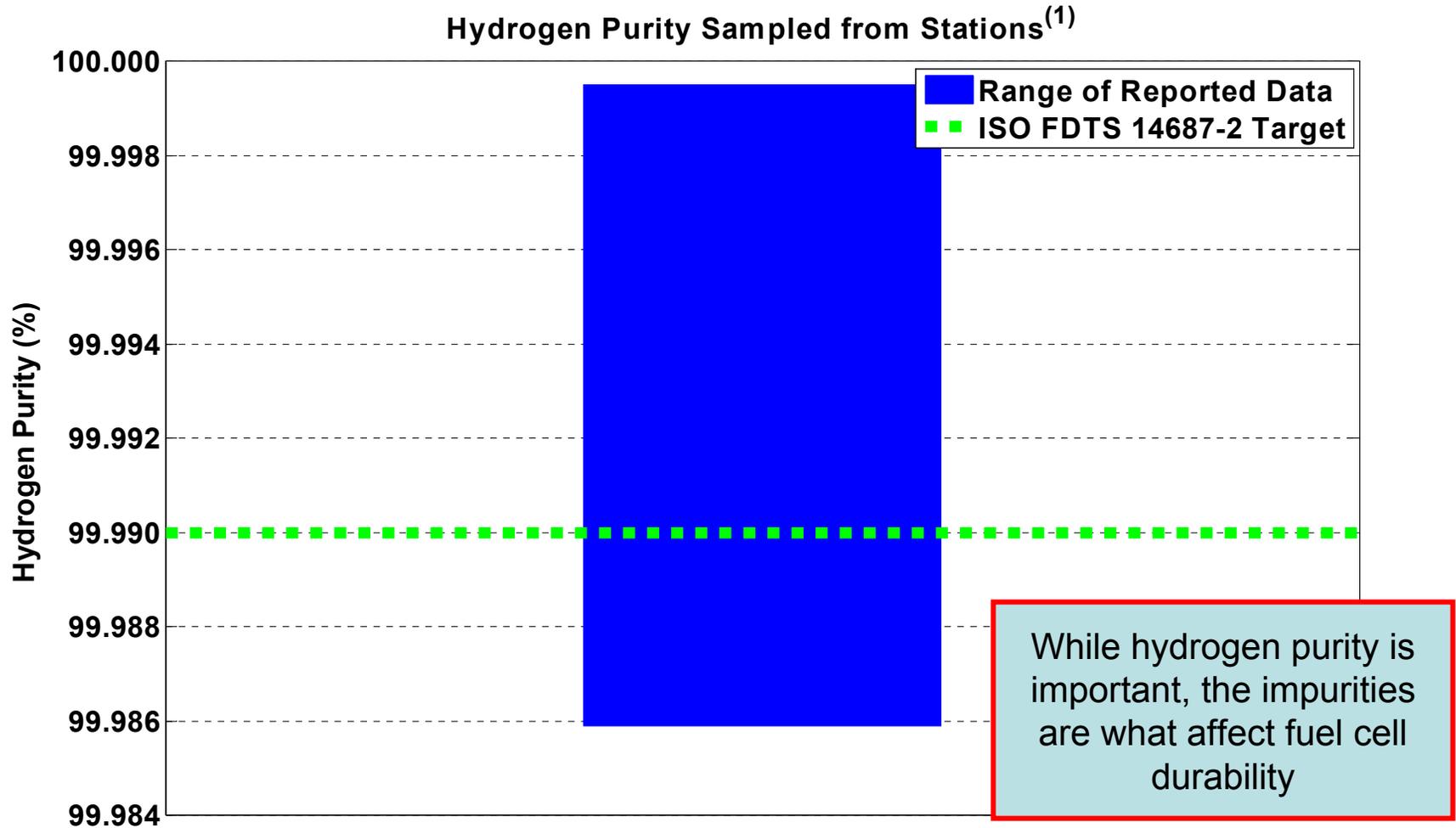


Created: 23-Feb-2006

<sup>1</sup>Emphasis is on advanced materials-based technologies.

Compressed and liquid H<sub>2</sub> tanks meet durability and short term weight %, but don't meet long-term weight % or volumetric capacity targets for vehicles

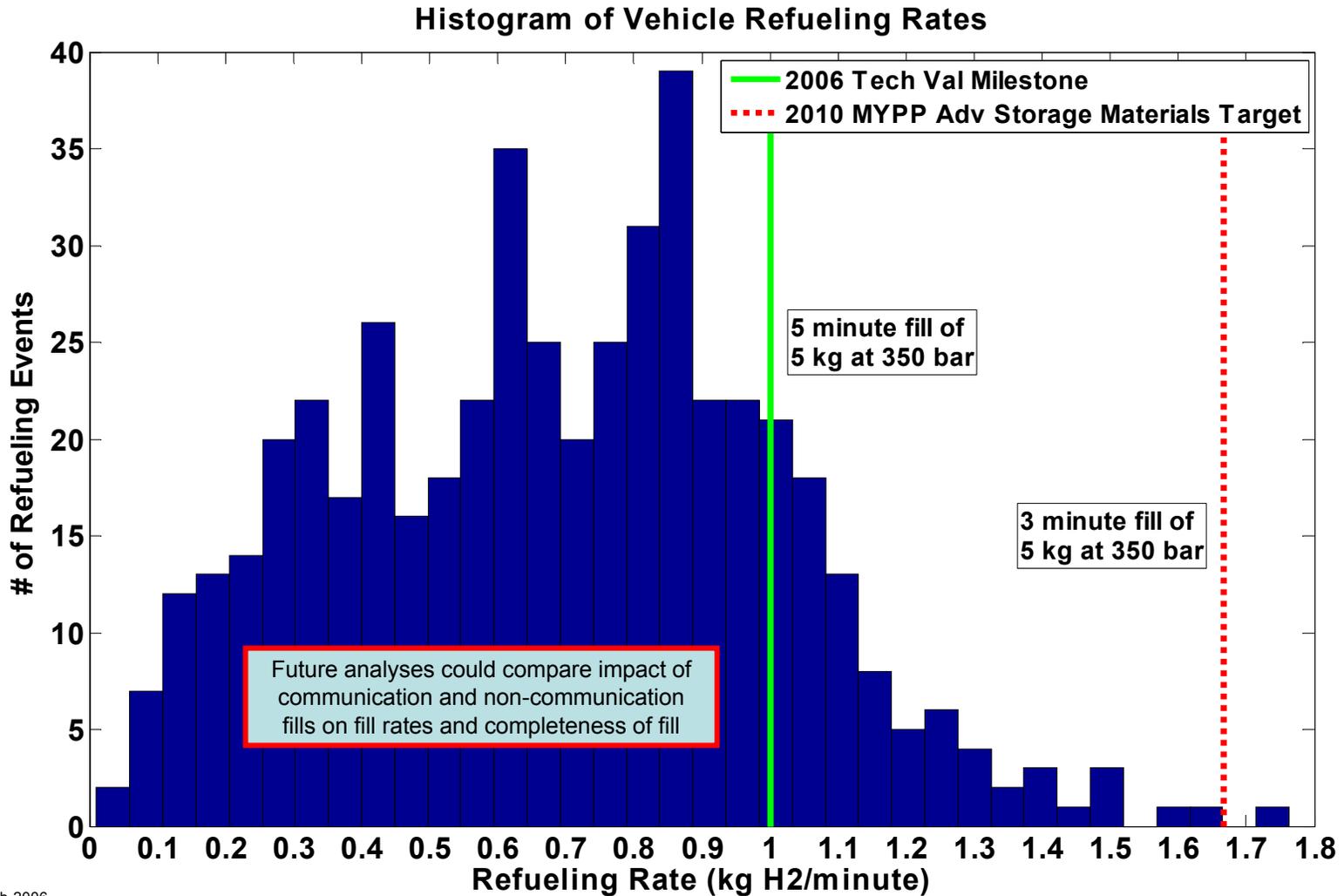
# Hydrogen Purity Sampled from Stations Meets Target Majority of the Time



(1) Includes sampling from both electrolysis and reforming

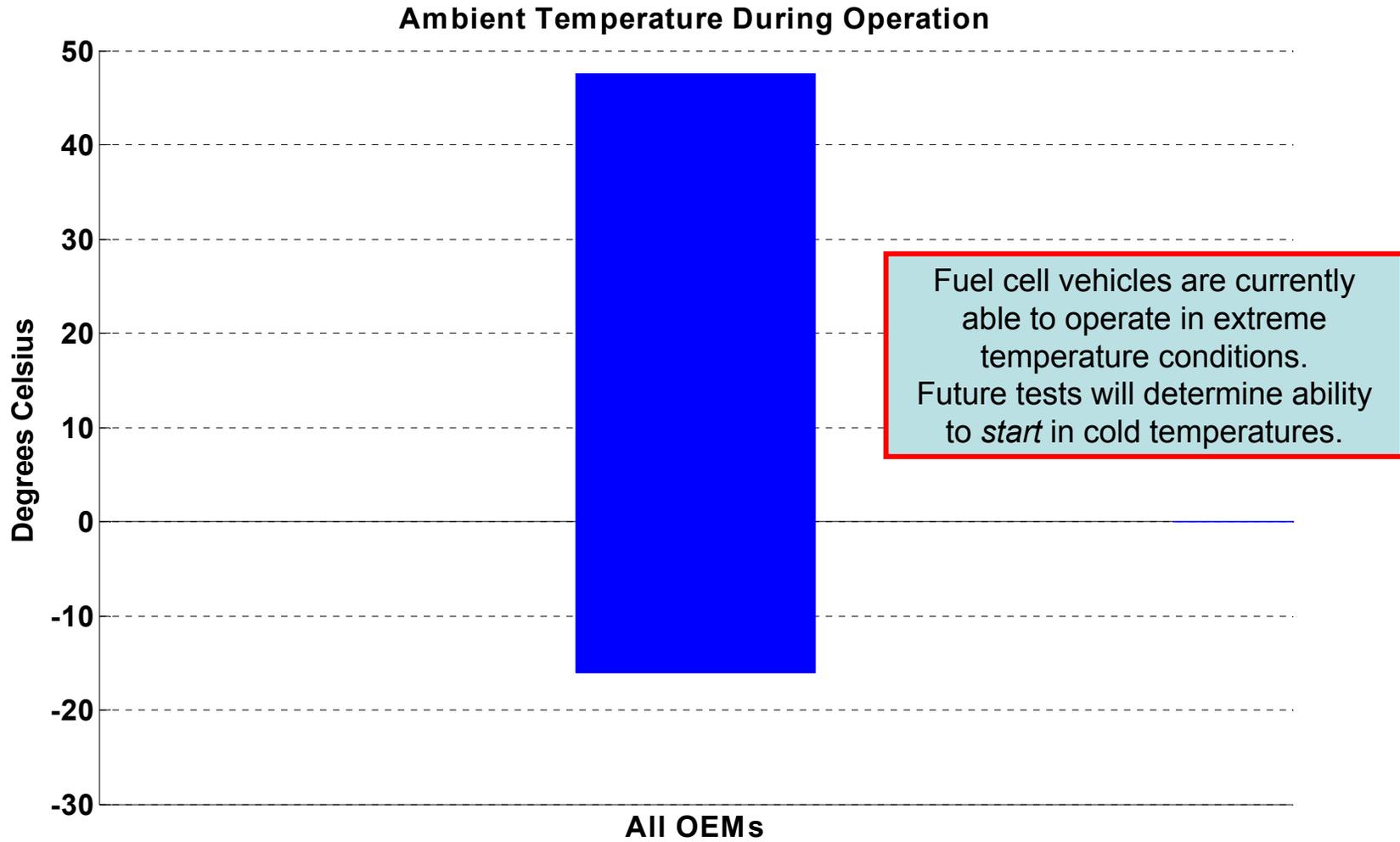
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# Actual Vehicle Refueling Rates: Measured by Stations or by Vehicles



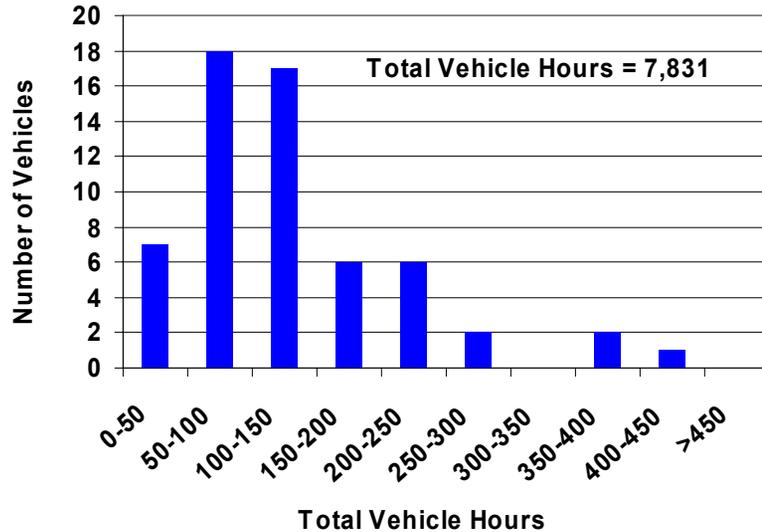
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# Range of Ambient Temperature During Vehicle Operation



# Vehicle Operating Hours and Miles Traveled Distribution

Vehicle Hours: All OEM's Combined through Q4 2005

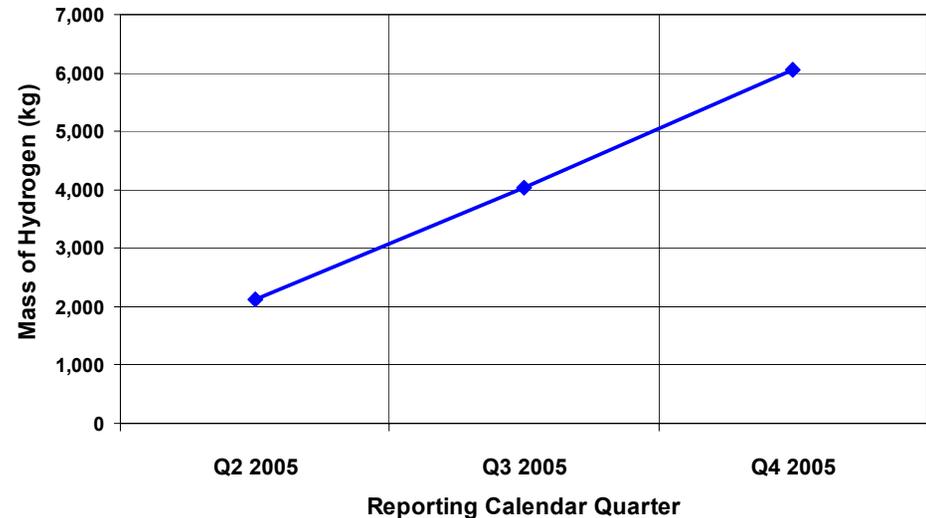


Created: 16-Feb-2006

Fleet is young, but vehicle usage is increasing and initial fleets are approaching full Gen 1 vehicle deployment

Large amount of hydrogen used includes both vehicle refueling and on-site electricity production

Cumulative Hydrogen Produced or Dispensed  
All Teams Combined

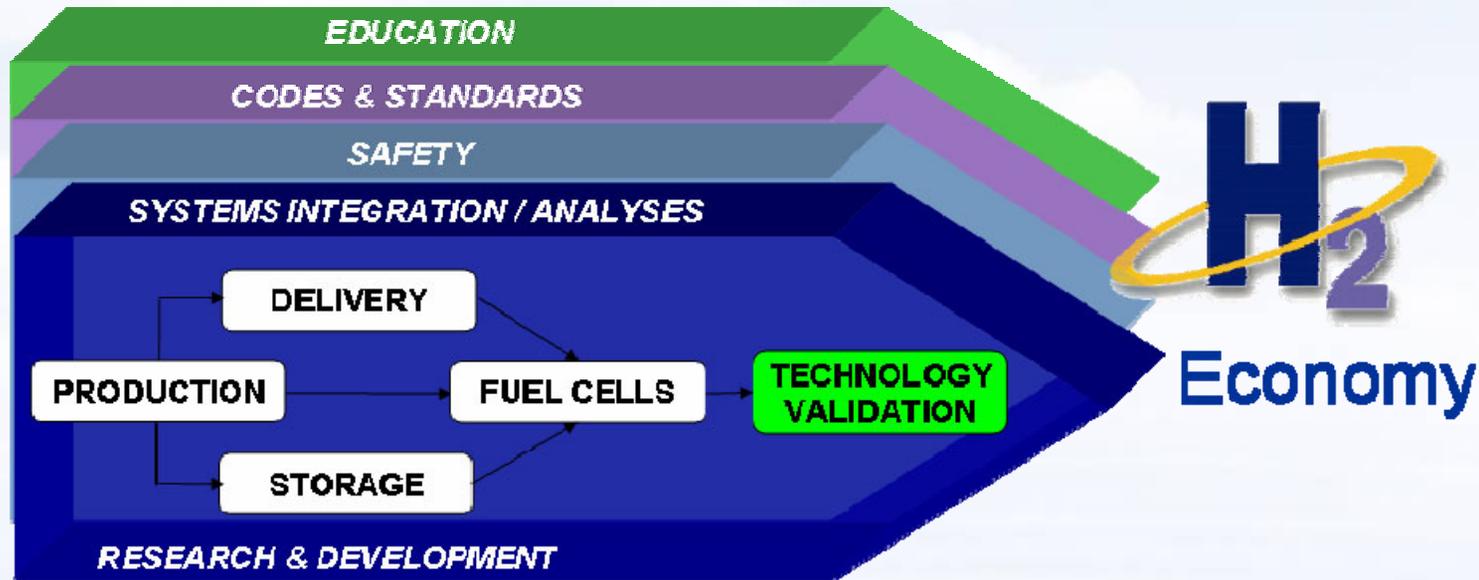


Created 21-Feb-2006

# Summary

- **First year of the 5-year project completed**
  - 59 vehicles now in fleet operation
  - Several new refueling stations opened
  - No major safety problems encountered
- **Project has identified current technical status relative to program targets**
  - Will track improvements from 2<sup>nd</sup> generation stacks/vehicles introduced mid-way through project
- **Future public results will include:**
  - FC durability, reliability, efficiency, and start-up times
  - H<sub>2</sub> production cost, efficiency, and maintenance

# Questions and Discussion



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[http://www.nrel.gov/hydrogen/proj\\_tech\\_validation.html](http://www.nrel.gov/hydrogen/proj_tech_validation.html)