Hydrogen Learning Demonstration Project: Fuel Cell Efficiency and Initial Durability

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Fuel Cell Seminar, 2006

Session: #1C : Transportation II
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Outline

- Project Objectives and Overview
- Industry Partners; H2 vehicles and stations
- Process and Methodology for Making Results Public
- Key Fall 2006 Results
  - Vehicles
    - Net fuel cell system efficiency
    - Fuel economy and range
    - Fuel cell durability
  - H2 Refueling Infrastructure
    - Total H2 produced or dispensed
    - Safety Events
    - Refueling Rates
    - H2 station fuel purity and impurities
- Summary and Future Results

Project Objectives and Targets

- Objectives
  - Validate H_2 FC Vehicles and Infrastructure in Parallel
  - Identify Current Status of Technology and its Evolution
  - Assess Progress Toward Technology Readiness
  - Provide Feedback to H_2 Research and Development

Hydrogen refueling station, Chino, CA Photo: NREL

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

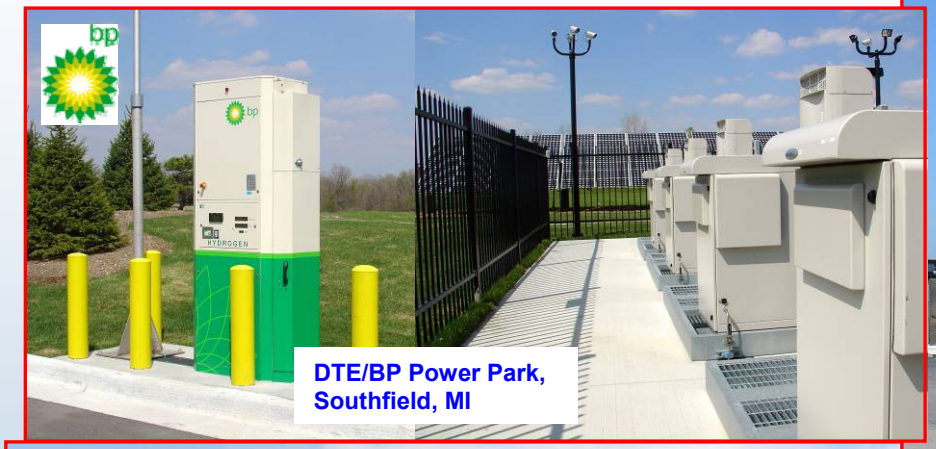
* To verify progress toward 2015 targets
** Subsequent projects to validate 2015 targets

Teams are Fielding Four Main Types of Vehicles

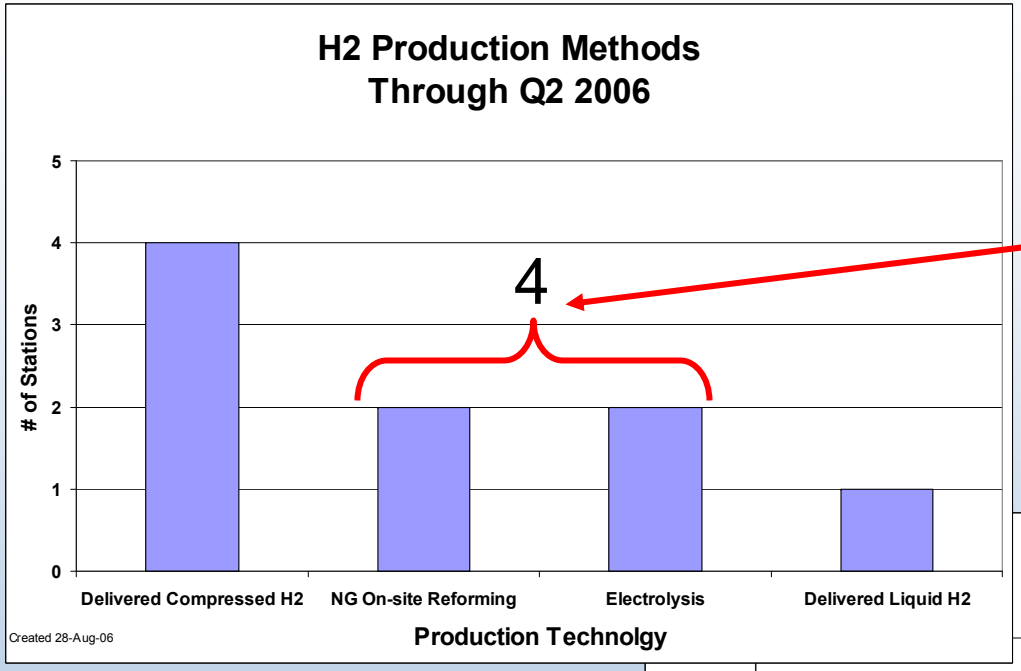
Validation also includes FCV Sprinter vans

Majority of 63 vehicles deployed to-date use 5,000 psi compressed H2 tanks

Representative Hydrogen Refueling Infrastructure Supporting Vehicles

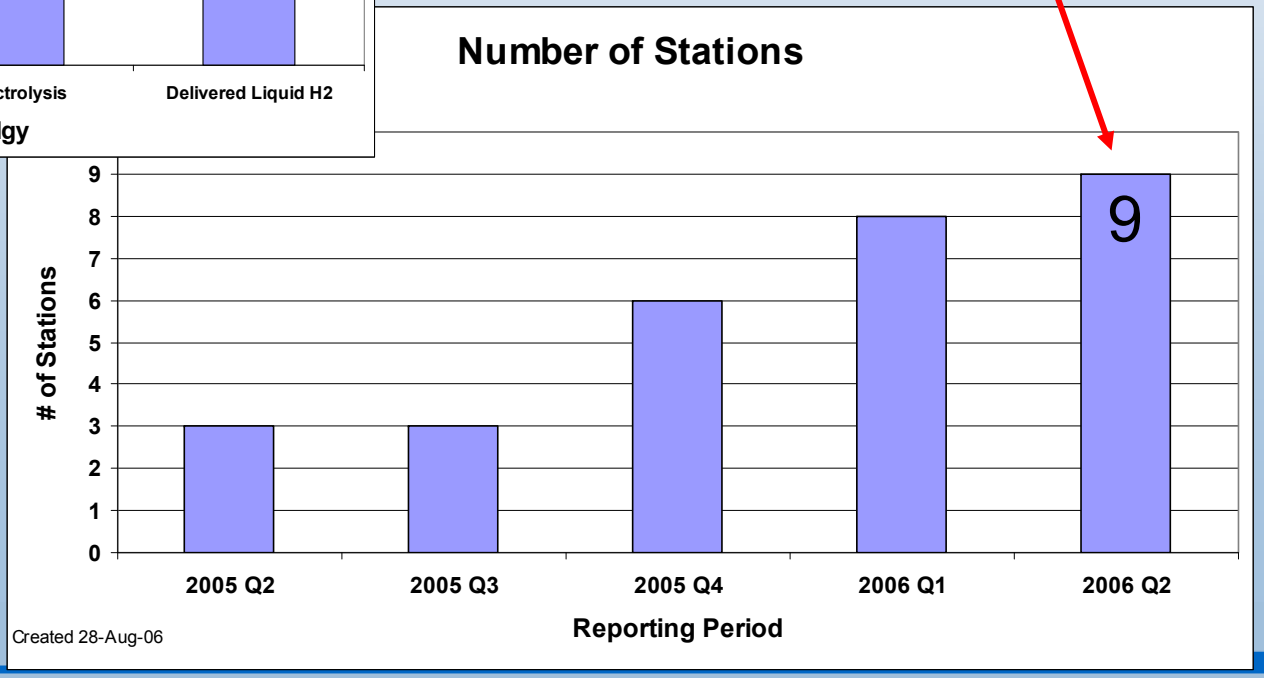


Number and Type of Learning Demo Hydrogen Refueling Stations Online

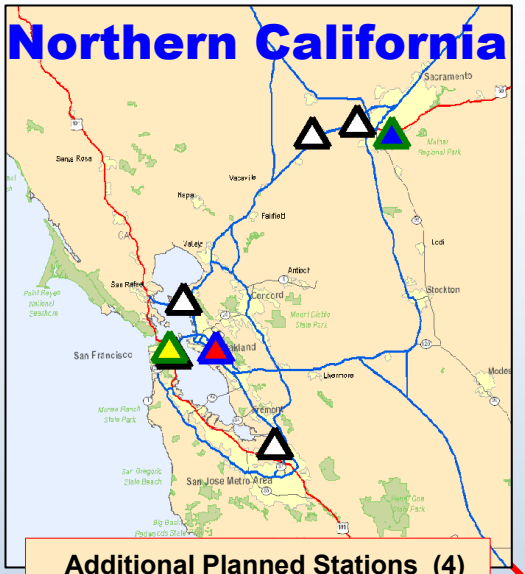


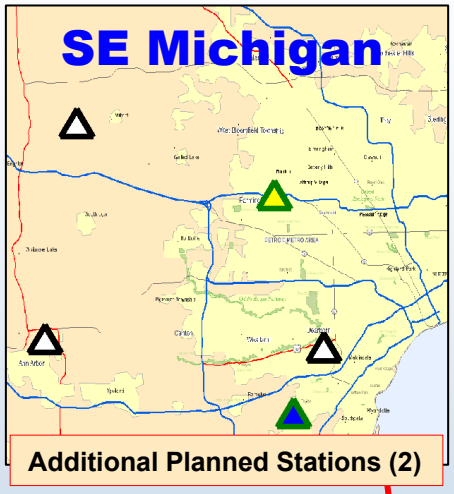
~1/2 of stations are producing H2 on-site

~1/2 of 20 planned refueling stations are online



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





Legend

- Chevron & Hyundai/Kia
- DaimlerChrysler & BP
- Ford & BP
- General Motors & Shell
- Other

Providing Data Analysis and Results for Both the Public and for the Industry Project Teams

Raw Data, Reports

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

Hydrogen Secure Data Center (HSDC)

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

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

Composite Data Products

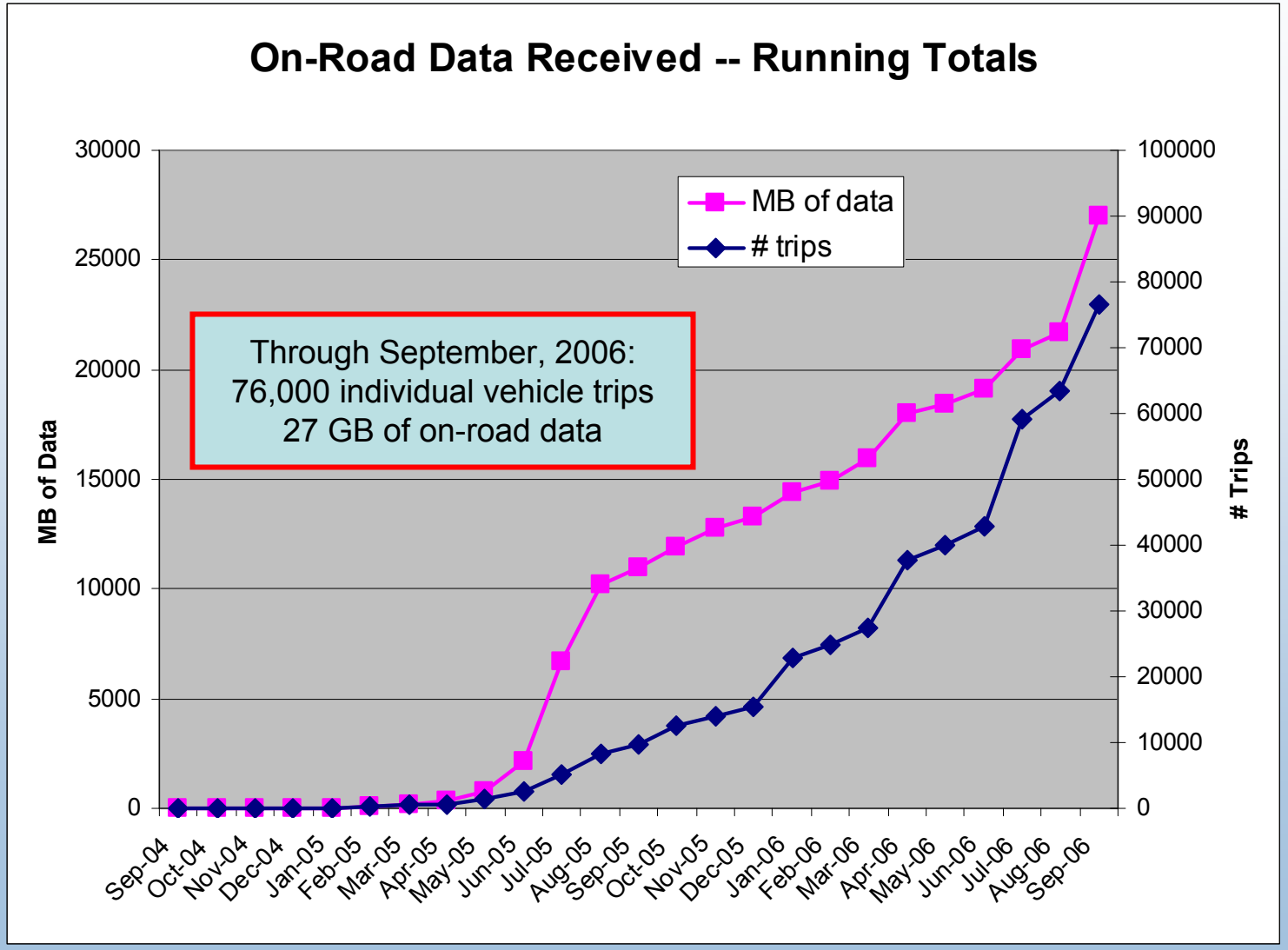
- Pre-agreed upon aggregate data results for public
- No confidential information

Detailed Data Products

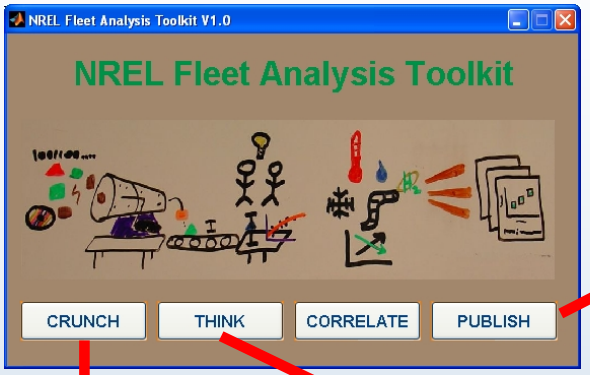
- Only shared with company which originated the data

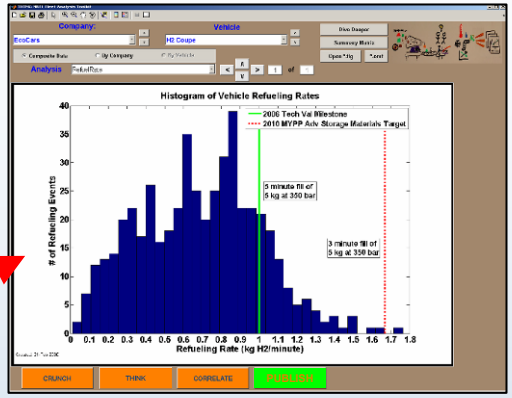
Five Quarters of Data Analyzed To-Date

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

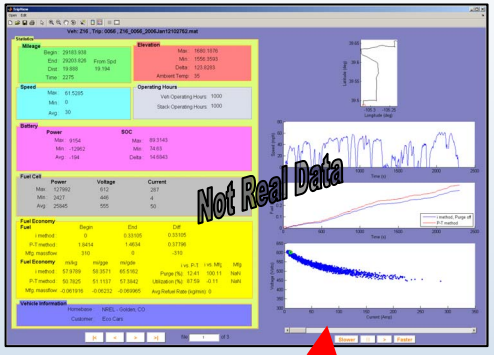


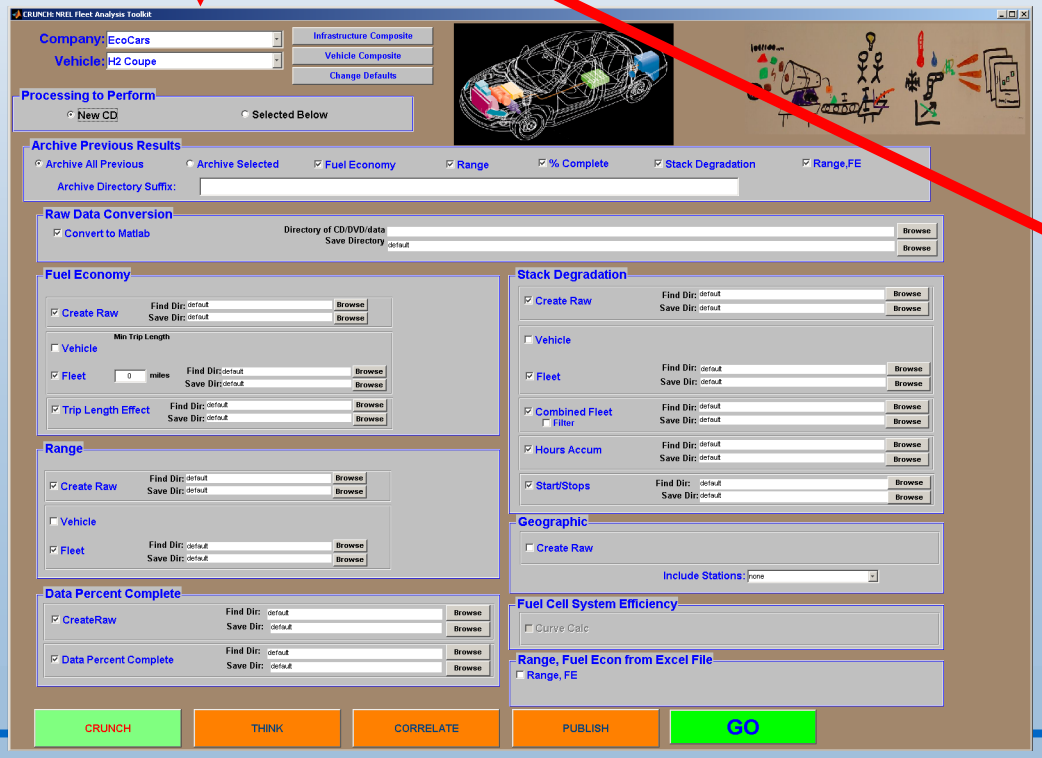
Analysis Calculations and Results are from NREL-Developed GUI – Fleet Analysis Toolkit (FAT)

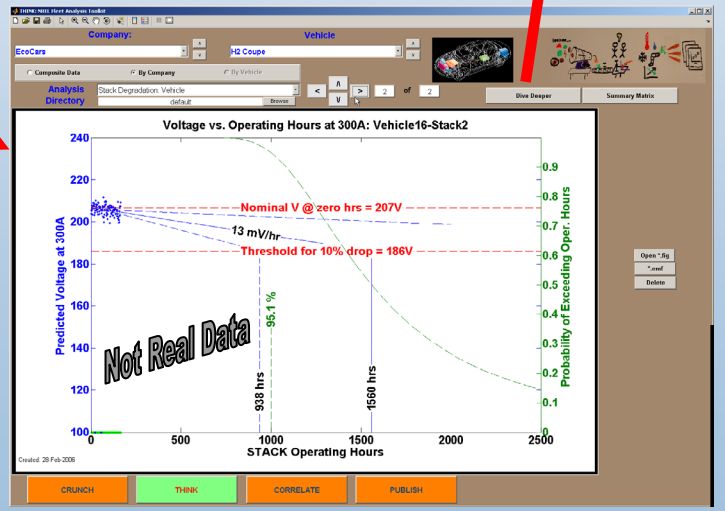




TripView





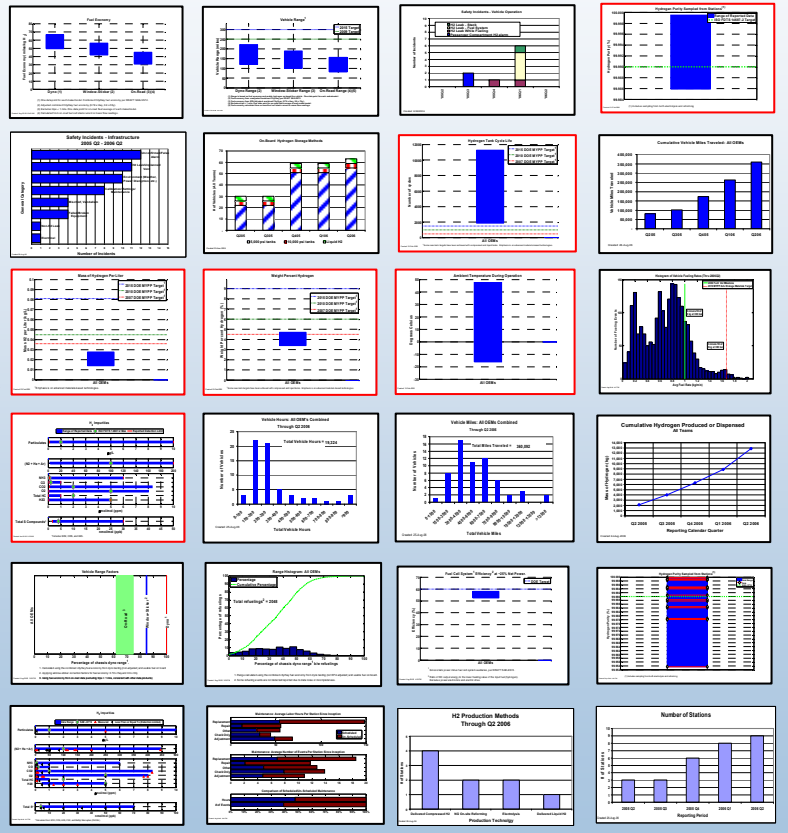


Quantity of Project Results Continues to Increase; Public Updates Every Six Months

25 Composite Data Products Have Now Been Published, Including Updating 10 of the 16 Published in Spring 2006

Spring 2006

Fall 2006



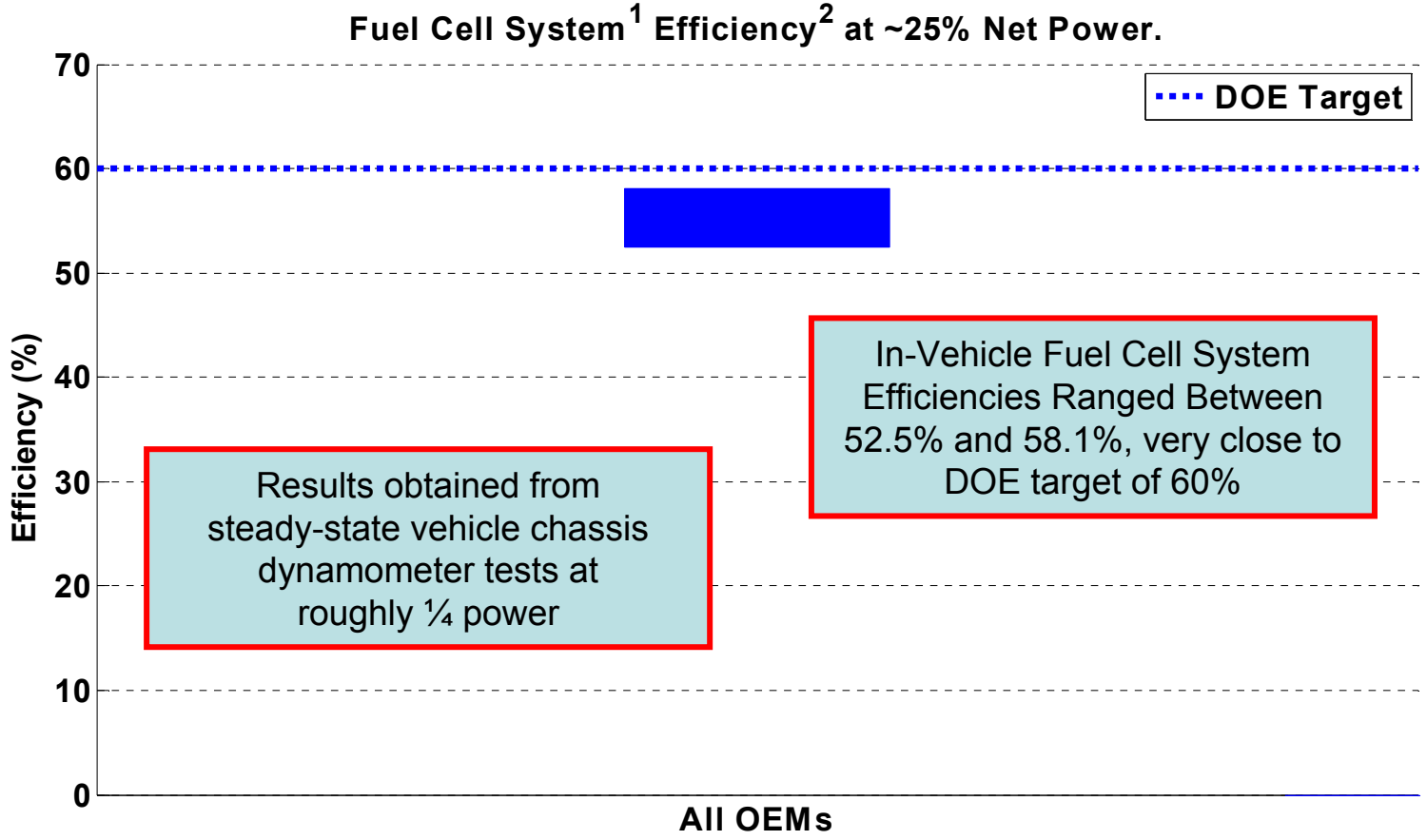
National Hydrogen Association Conference
March 13, 2006

EVS-22 Conference
October 26, 2006

Fuel Cell Seminar
November 15, 2006

RESULTS

Controlled System Tests Verify High Fuel Cell System Conversion Efficiency



[1] Gross stack power minus fuel cell system auxiliaries, per DRAFT SAEJ2615.

[2] Ratio of DC output energy to the lower heating value of the input fuel (hydrogen). Excludes power electronics and electric drive.

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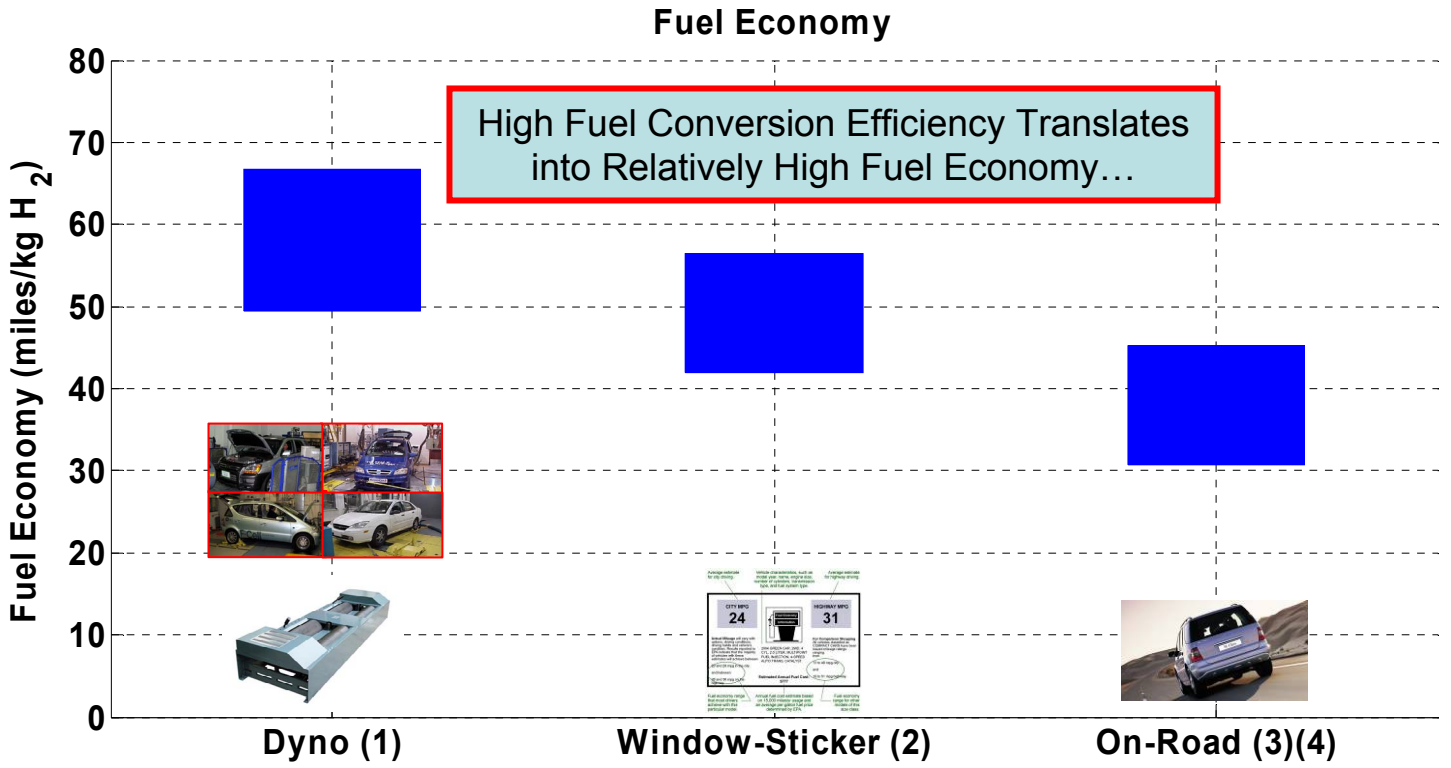
Dynamometer and On-Road Fuel Economy from Learning Demonstration Vehicles



(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 x Hwy, 0.9 x 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.

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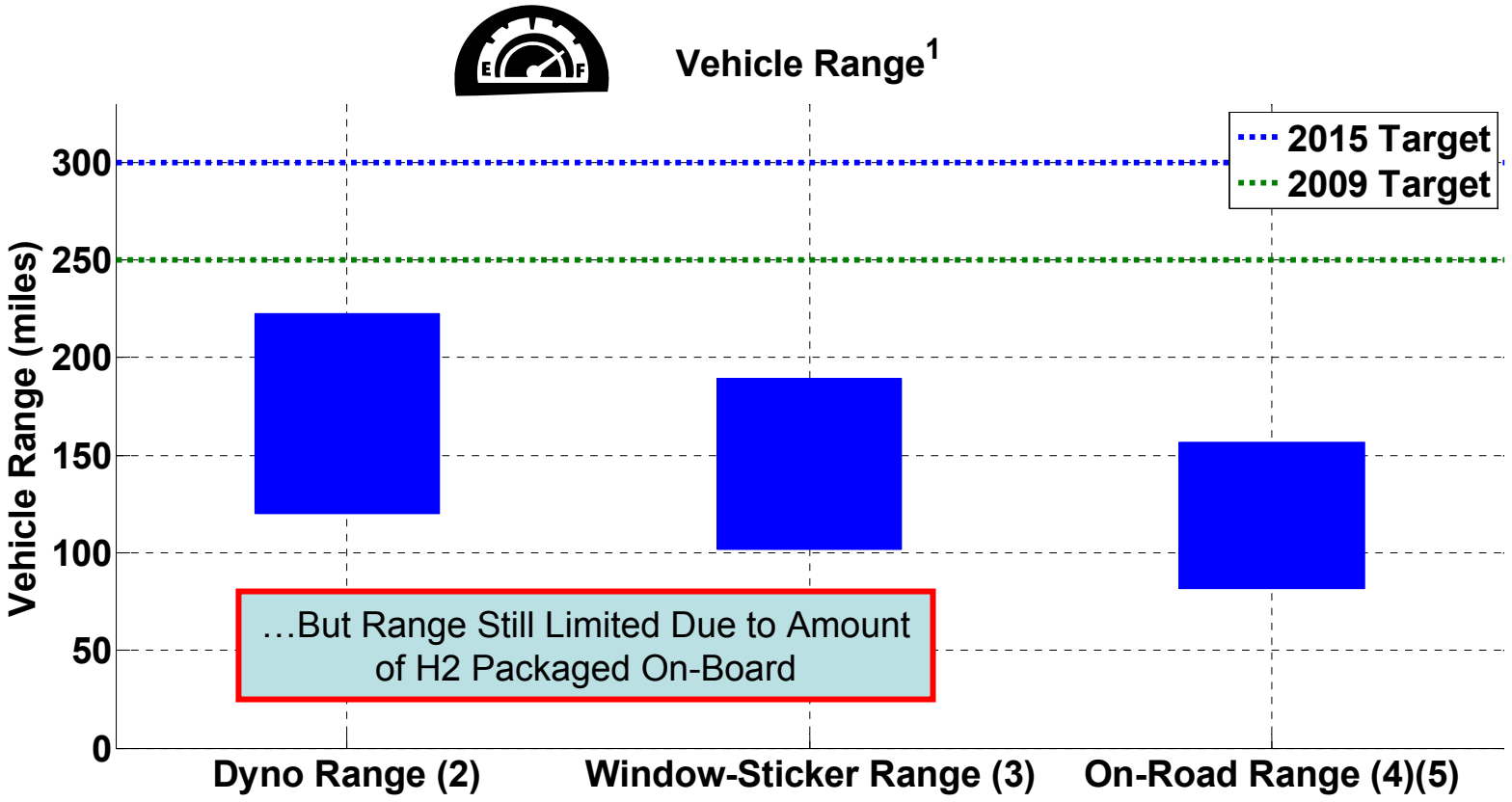
Vehicle Range Based on Fuel Economy and Usable H_2 Fuel Stored On-Board



(1) Range is based on fuel economy and usable hydrogen on-board the vehicle. One data point for each make/model.
(2) Fuel economy from unadjusted combined City/Hwy per DRAFT SAEJ2572.
(3) Fuel economy from EPA Adjusted combined City/Hwy (0.78 x Hwy, 0.9 x City).
(4) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(5) Fuel economy calculated from on-road fuel cell stack current or mass flow readings.

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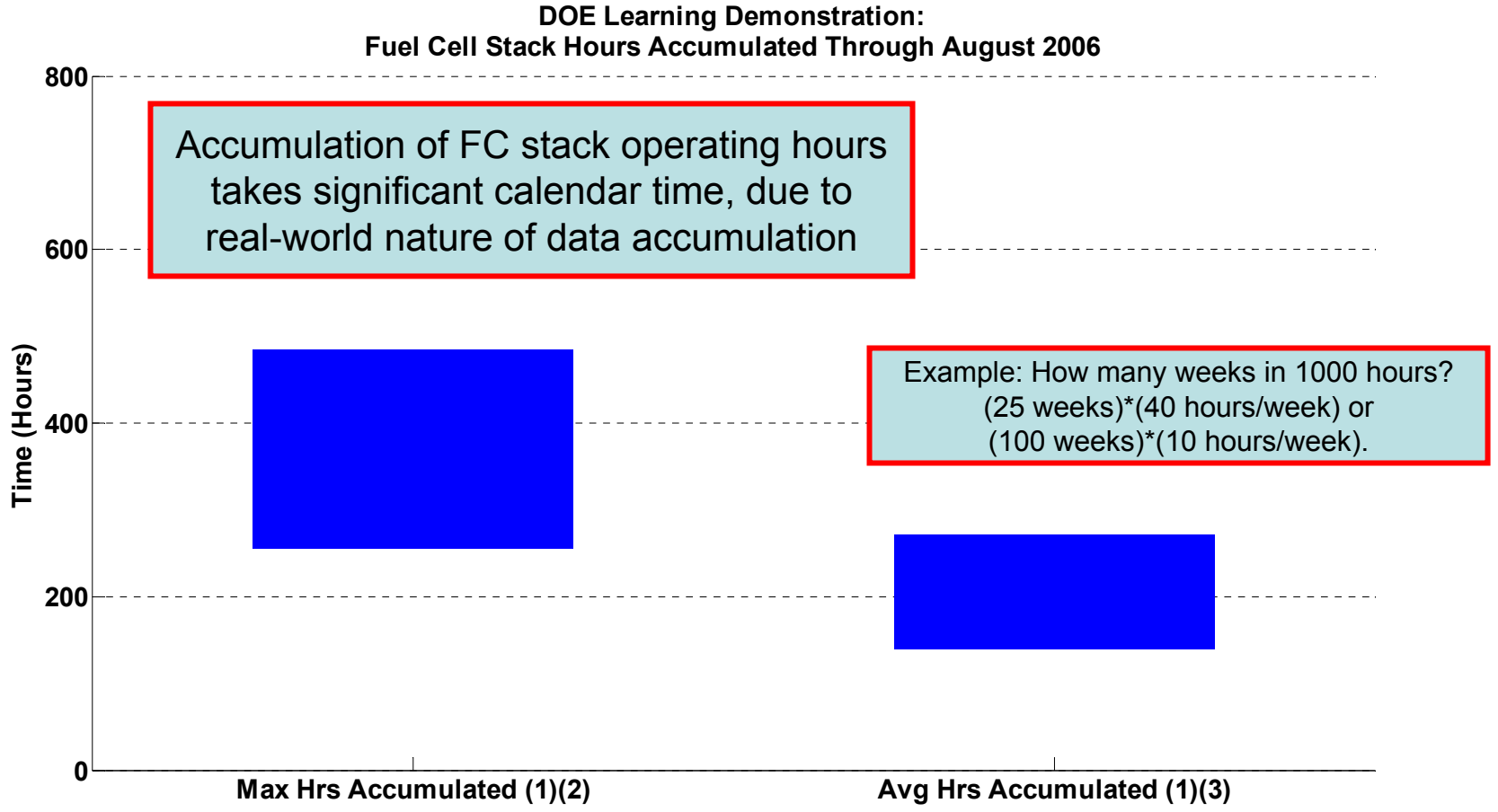
Learning Demo Fuel Cell Stack Hours Accumulated Through August 2006



(1) Range bars created using one data point for each OEM.
(2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
(3) Range (highest and lowest) of the average operating hours accumulated to-date of all stacks in each OEM's fleet.

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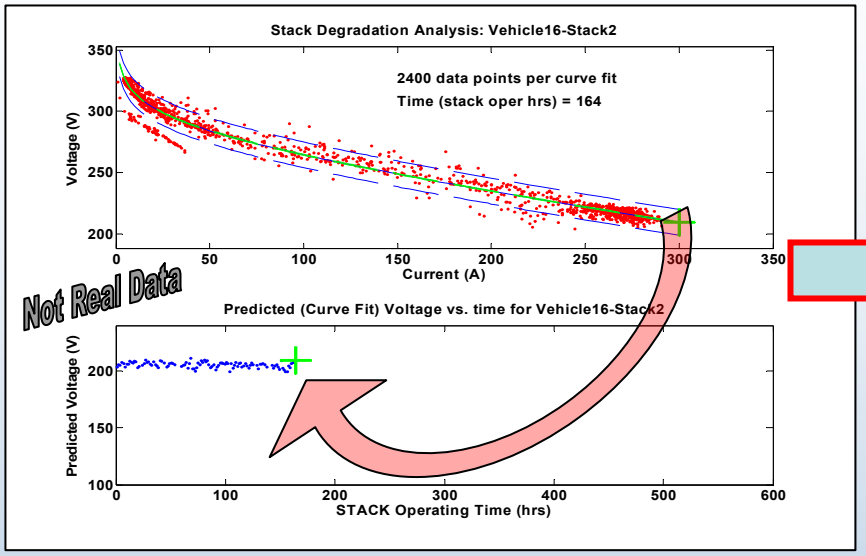
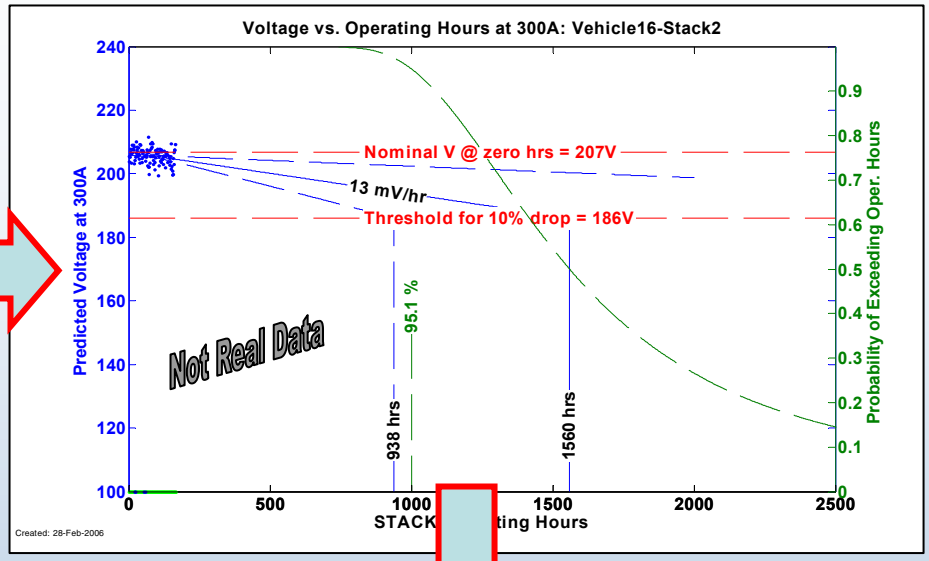
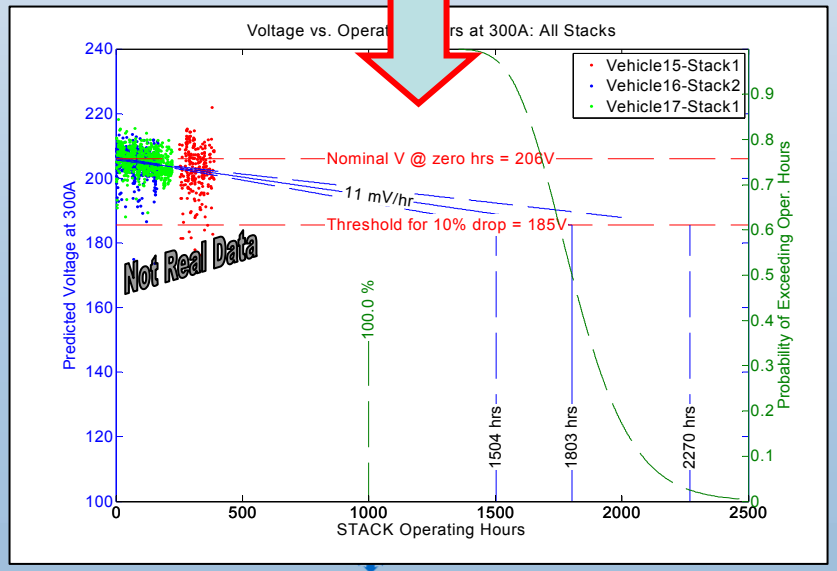
Limited Data Necessitated Projecting the Time to 10% Fuel Cell Stack Voltage Degradation



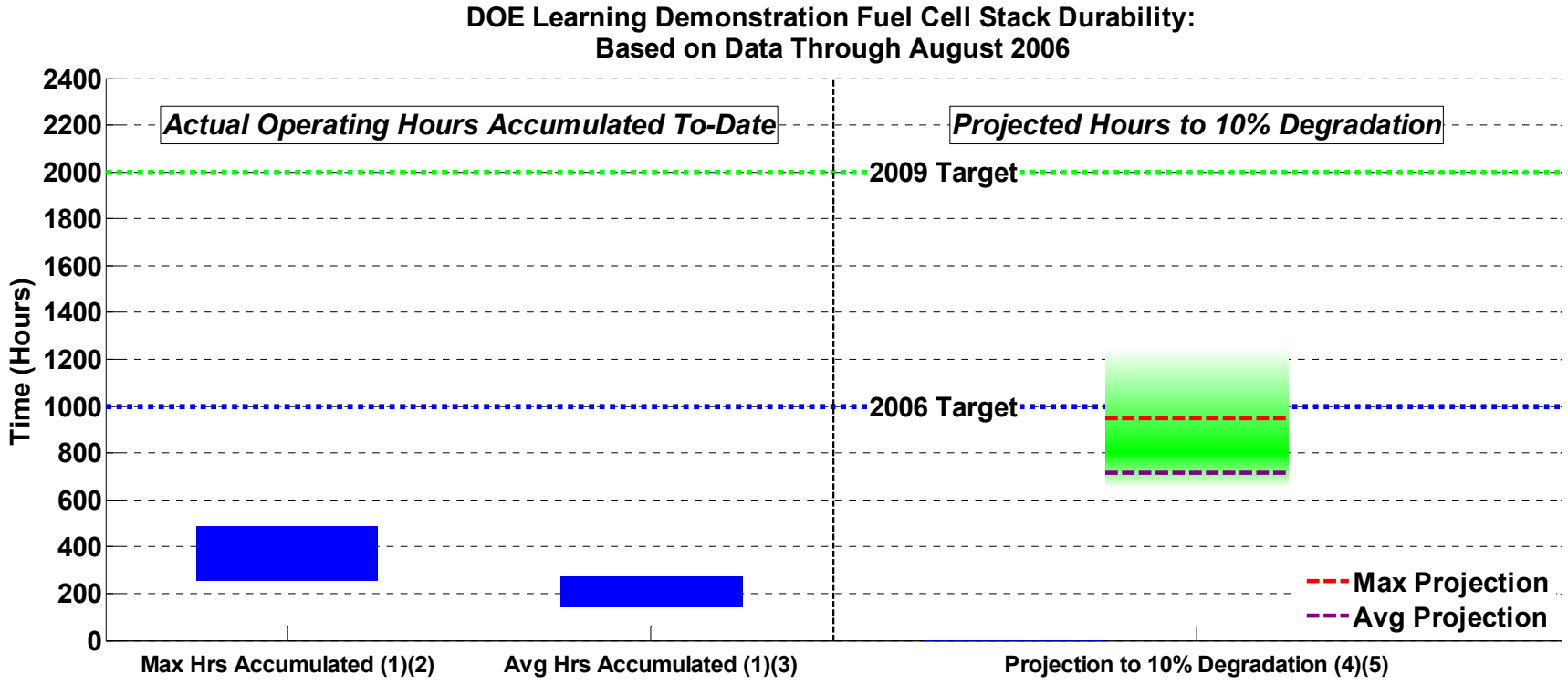


Note: 10% is an R&D metric for FC stack degradation. It does not necessarily indicate an end-of-life condition. OEMs may use other values or indicators.

Technique Makes Performance Projection Based on All Available FC Data; Includes Reporting Confidence in Results



Hours Accumulated To-Date and Projected Hours to 10% Stack Voltage Degradation



(1) Range bars created using one data point for each OEM.
(2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
(3) Range (highest and lowest) of the average operating hours accumulated to-date of all stacks in each OEM's fleet.
(4) Projection using on-road data -- degradation calculated at high stack current. This criterion is used for assessing progress against DOE targets, may differ from OEM's end-of-life criterion, and does not address "catastrophic" failure modes, such as membrane failure.
(5) Using one nominal projection per OEM: "Max Projection" = highest nominal projection, "Avg Projection" = average nominal projection. The shaded green bar represents an engineering judgment of the uncertainty due to data and methodology limitations. Projections will change as additional data are accumulated.

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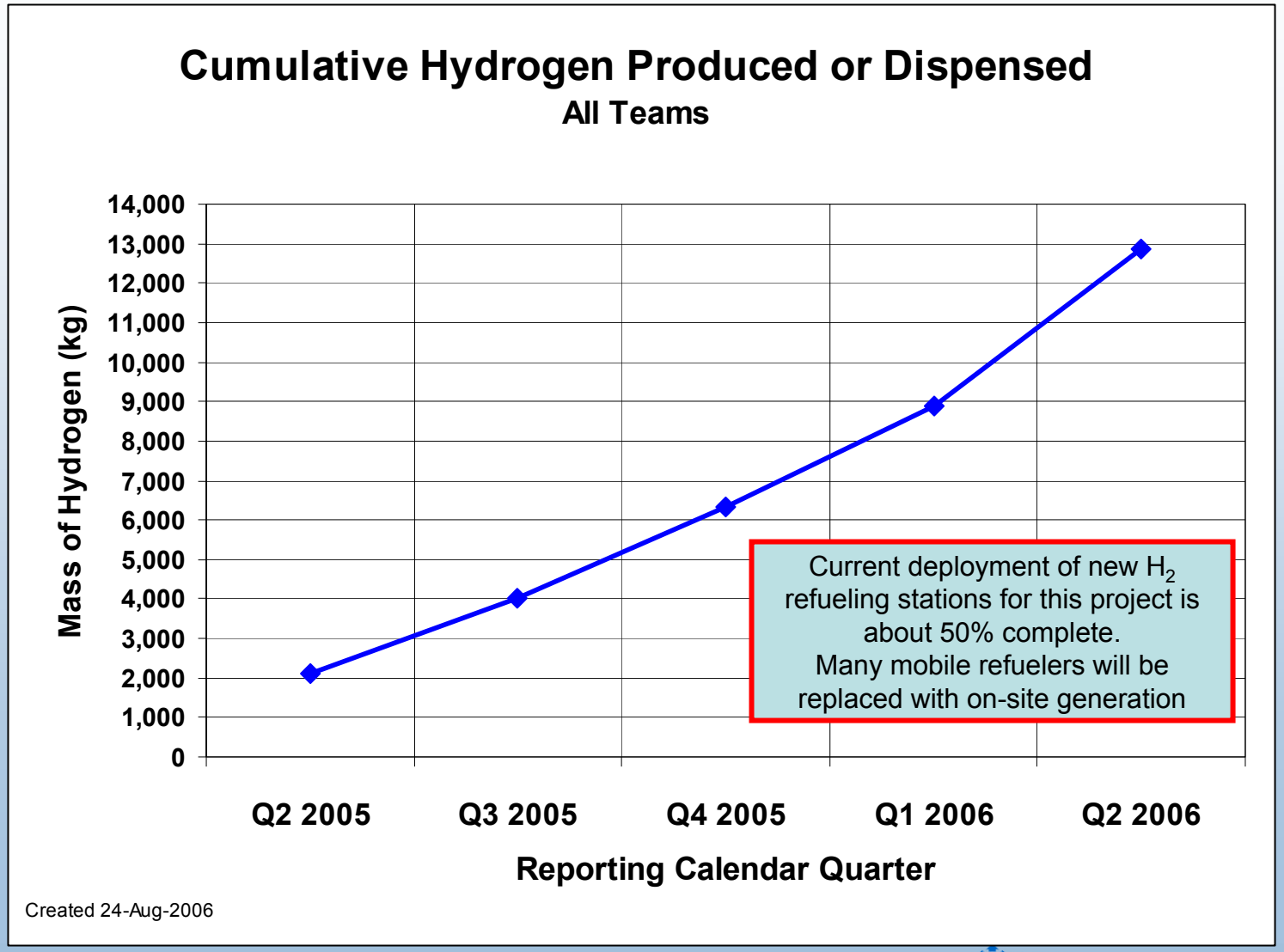
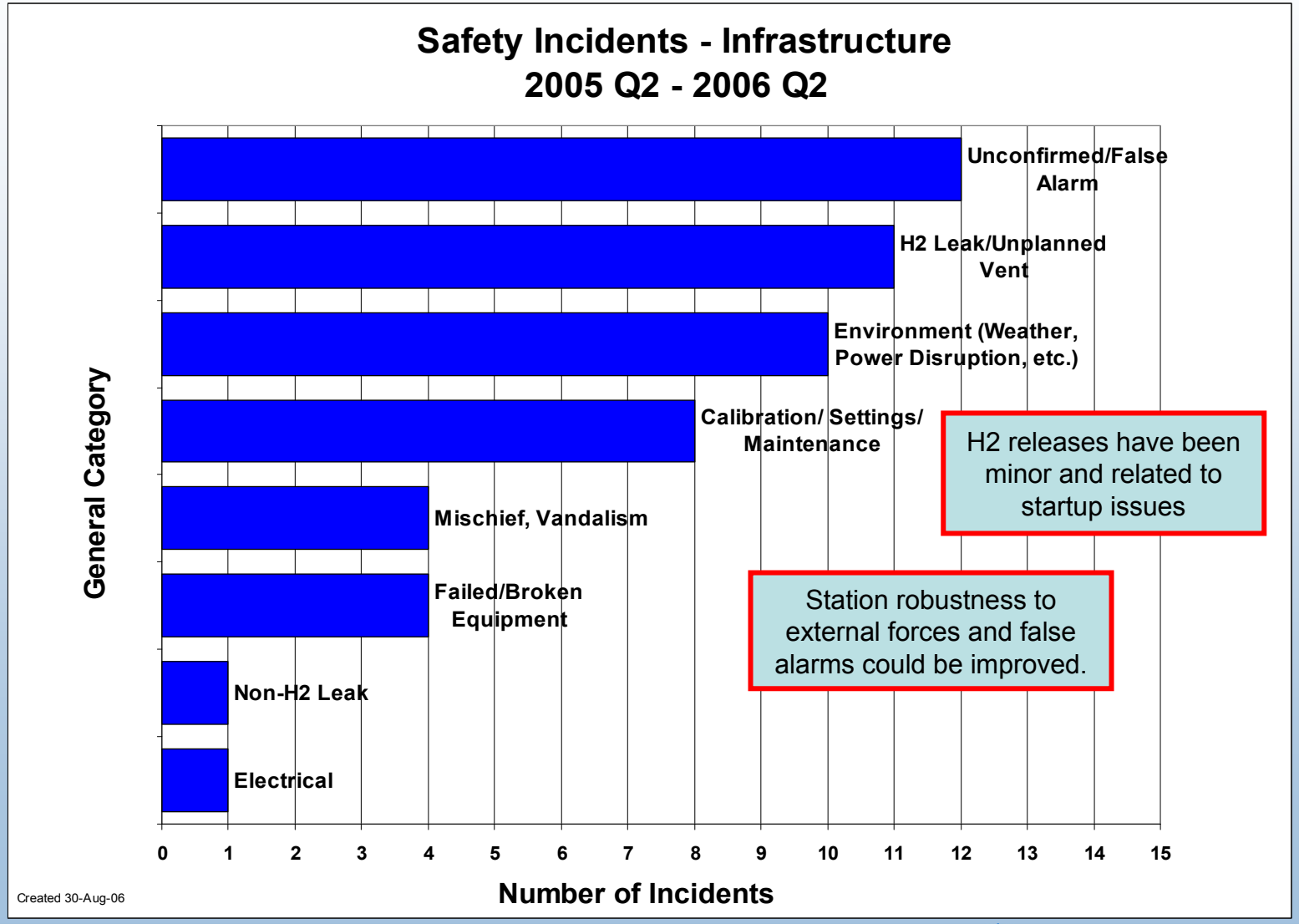
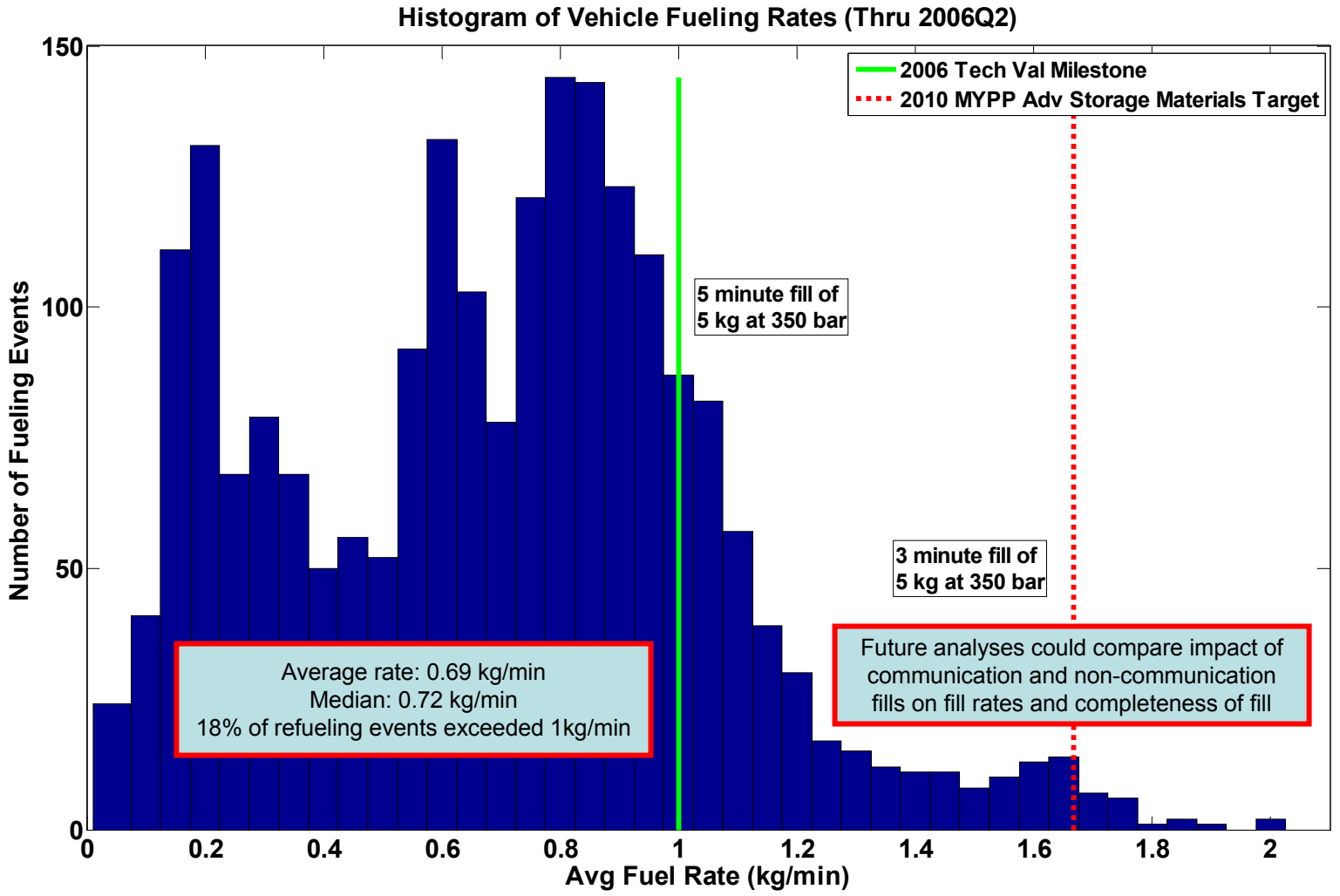
Cumulative Mass of H_2 Produced or Dispensed



Safety Incidents – Infrastructure



Actual Vehicle Refueling Rates from >2000 Events: Measured by Stations or by Vehicles



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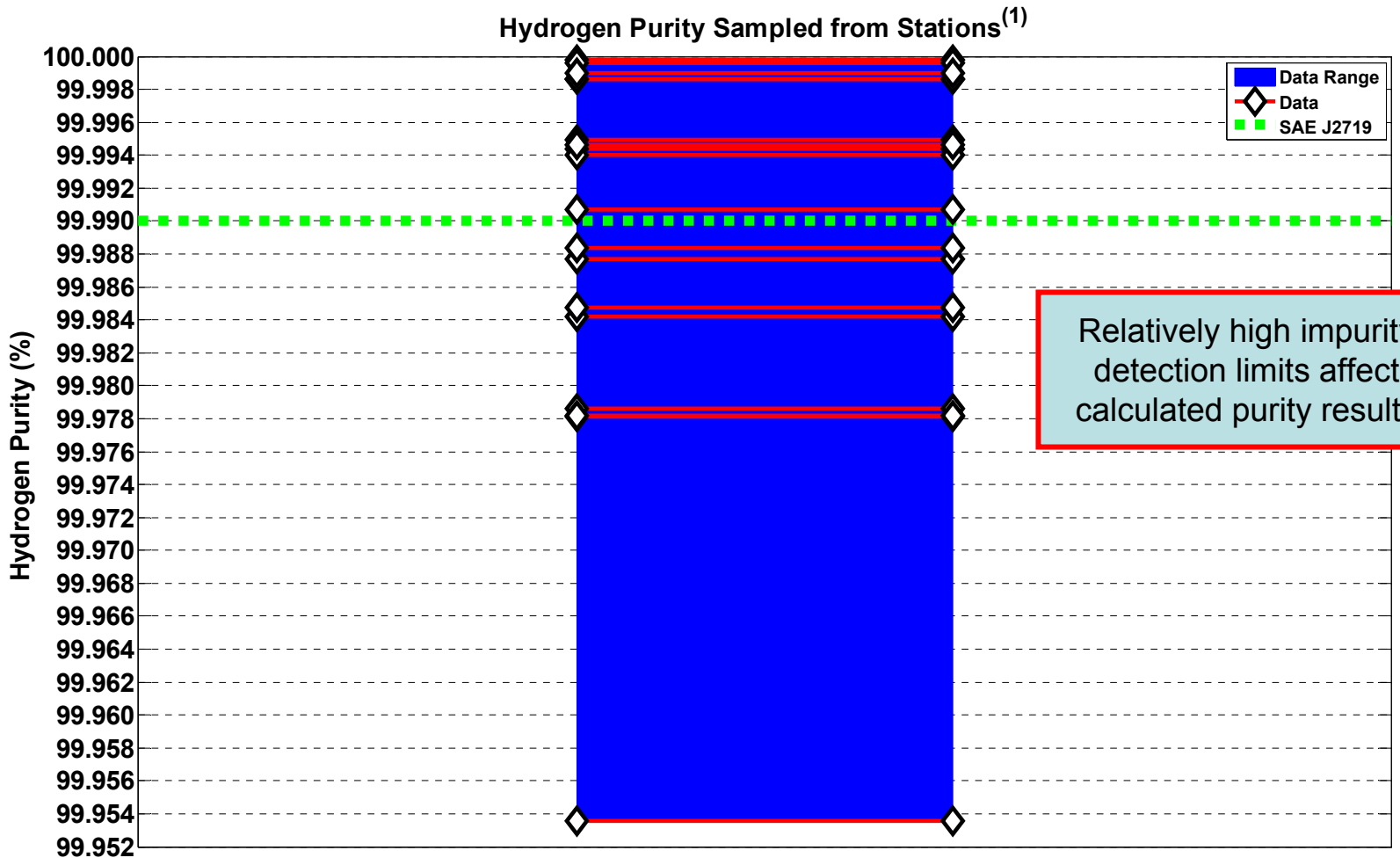
Hydrogen Purity Sampled from Stations Close to Target Majority of the Time



(1) Includes sampling from both electrolysis and reforming

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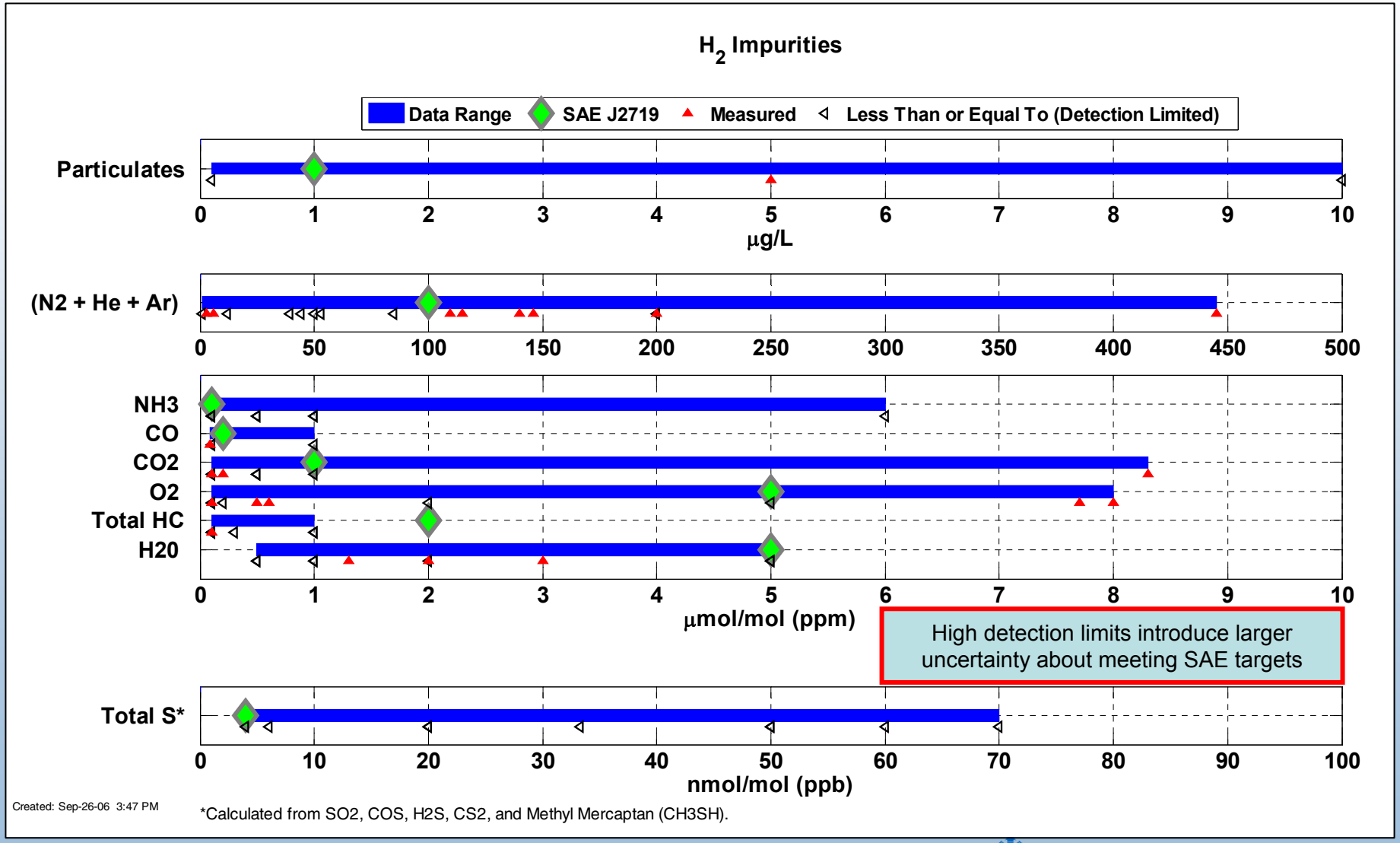
Hydrogen Impurities Sampled from All Stations – Includes On-Site Reformation, Electrolysis, and Delivered H_2



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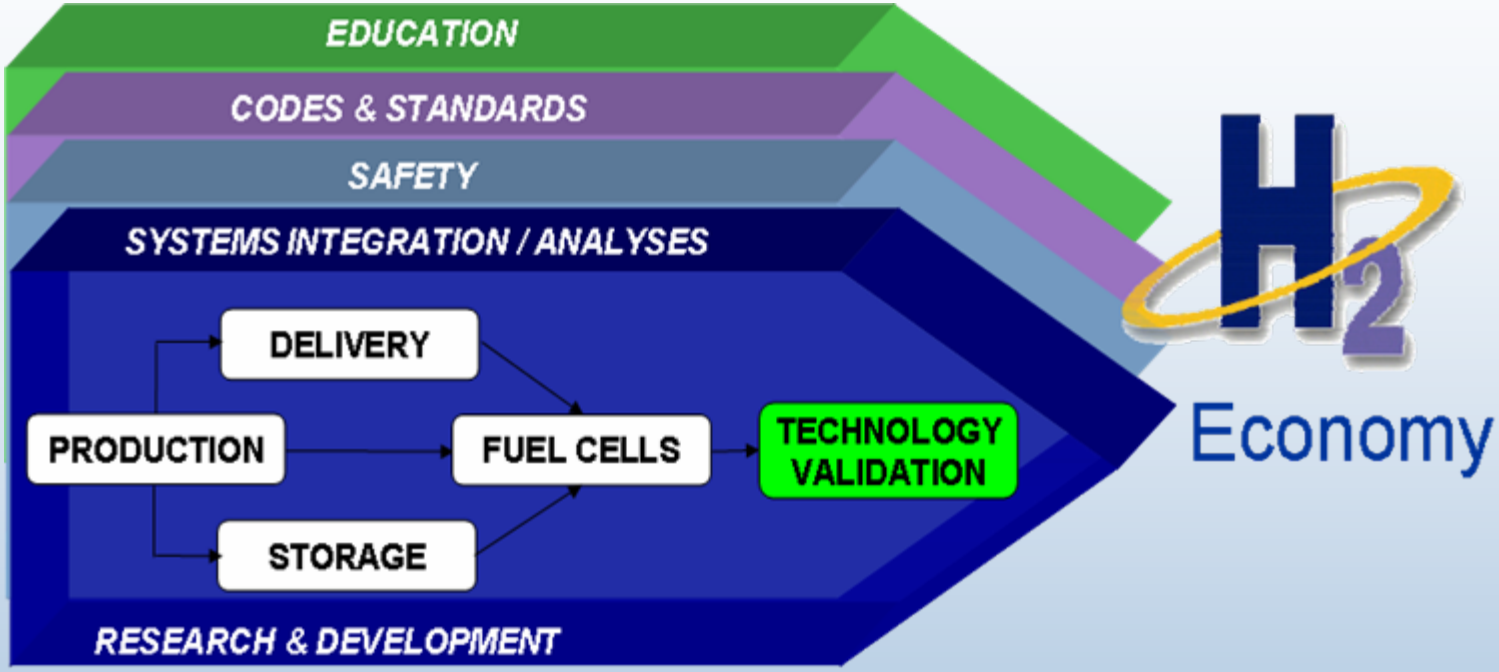
*Calculated from SO2, COS, H2S, CS2, and Methyl Mercaptan (CH3SH).

Summary

- First 5-quarters of project completed
  - 63 vehicles now in fleet operation
  - 9 stations in operation to support project vehicles
  - No major safety problems encountered
  - Total of 25 composite data products published to-date
- Project has identified current technical status relative to program targets
  - Will track improvements from 2nd generation stacks/vehicles introduced mid-way through project
- Future public results will include:
  - 6-month updates to existing composite data products
  - Fuel cell cold start-up times
  - H_2 production cost and efficiency
  - Other composite data products created based on insights learned

Questions and Discussion



Contact: Keith Wipke, National Renewable Energy Lab
303.275.4451 keith_wipke@nrel.gov

All public Learning Demo papers and presentations are available online at http://www.nrel.gov/hydrogen/proj_tech_validation.html