

National Fuel Cell Vehicle Learning Demonstration: Status and Results



**California Air
Resources Board
2009 ZEV Symposium**

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This presentation does not contain any proprietary, confidential, or otherwise restricted information

Outline

- Project Objectives and Partners
- Overall Project Status
- Vehicle Analysis Results
- Infrastructure Analysis Results
- Summary

Fuel Cell Vehicle Learning Demonstration Project Objectives and Targets

- Objectives

- Validate H₂ FC Vehicles and Infrastructure in Parallel
- Identify Current Status and Evolution of the Technology
- Objectively Assess Progress Toward Technology Readiness
- Provide Feedback to H₂ Research and Development

Key Project 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 <small>Under review</small>	\$2-3/gge



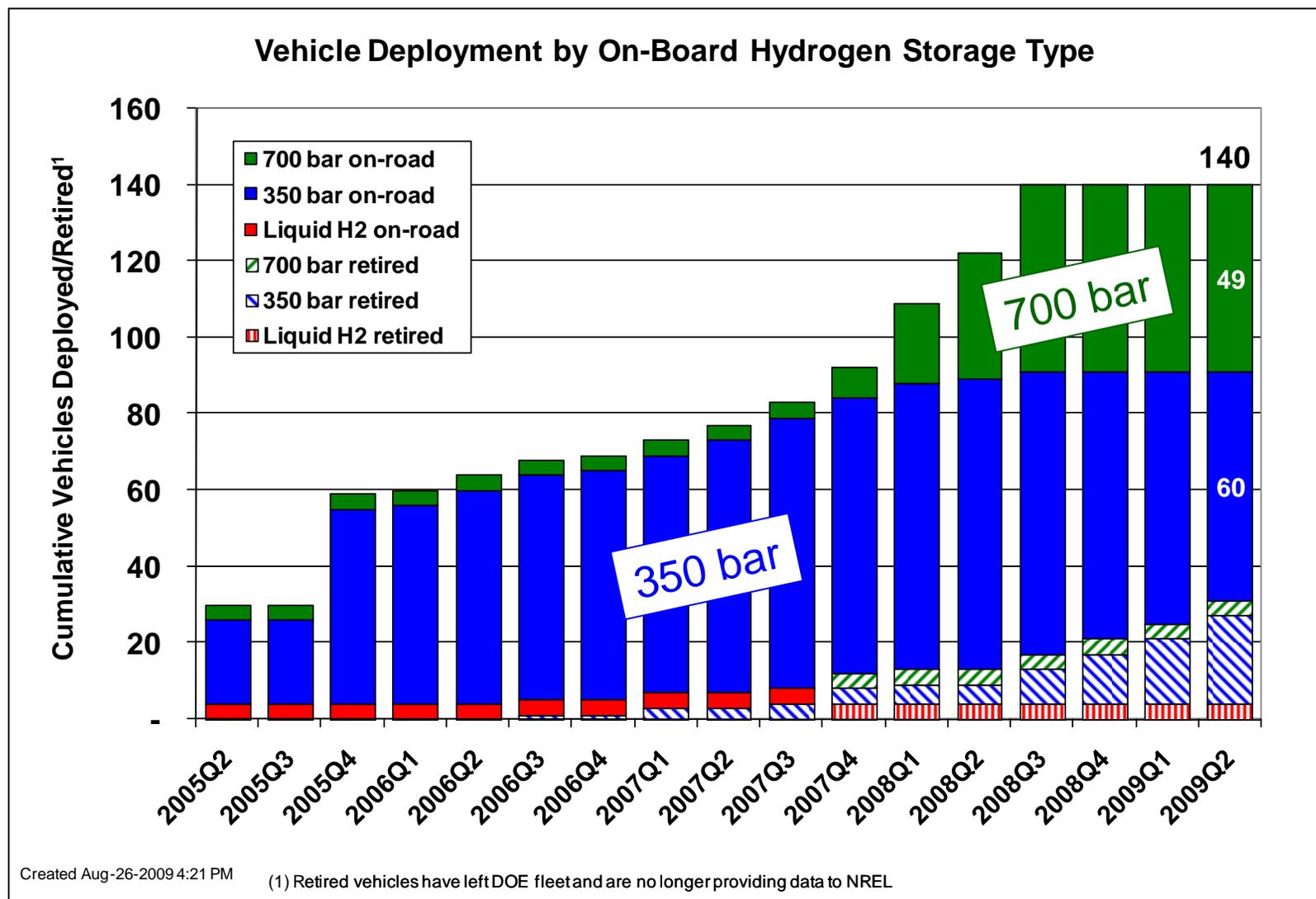
Solar Electrolysis Station, Sacramento, CA

Photo: NREL

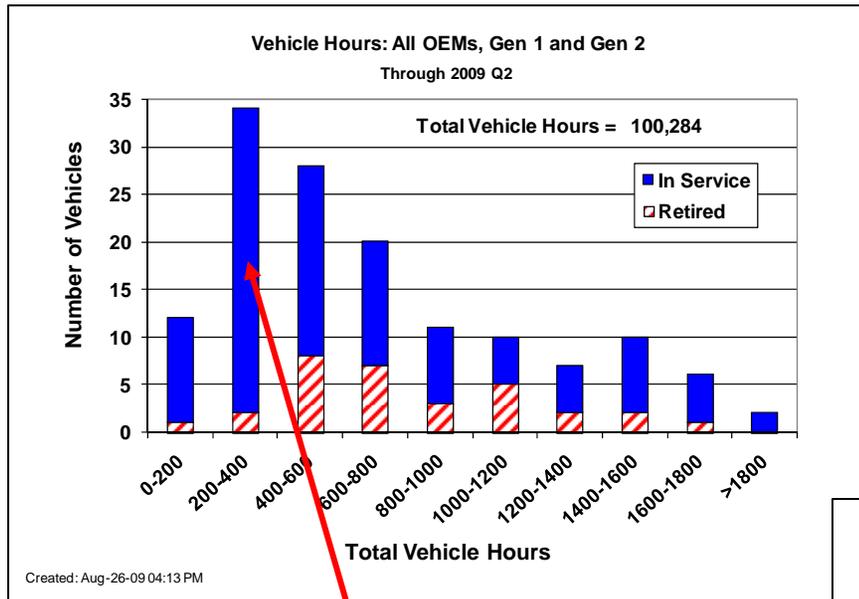
Industry Partners: Four Automaker/Energy-Supplier Teams



Vehicle Deployment Complete at 140 FCVs, Some Early Vehicles Retired

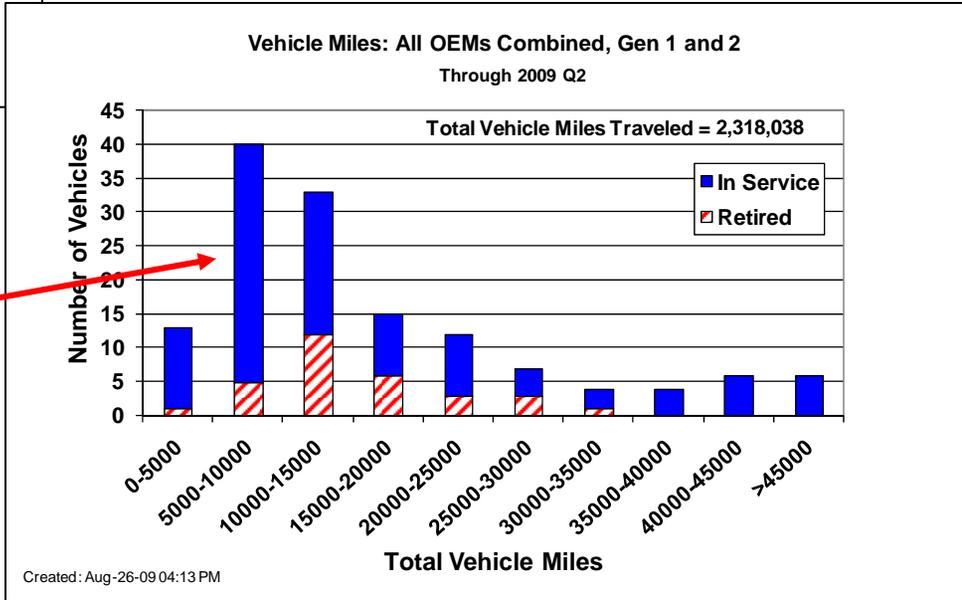


DOE Learning Demo Fleet Has Surpassed 100,000 Vehicle Hours and 2.3 Million Miles



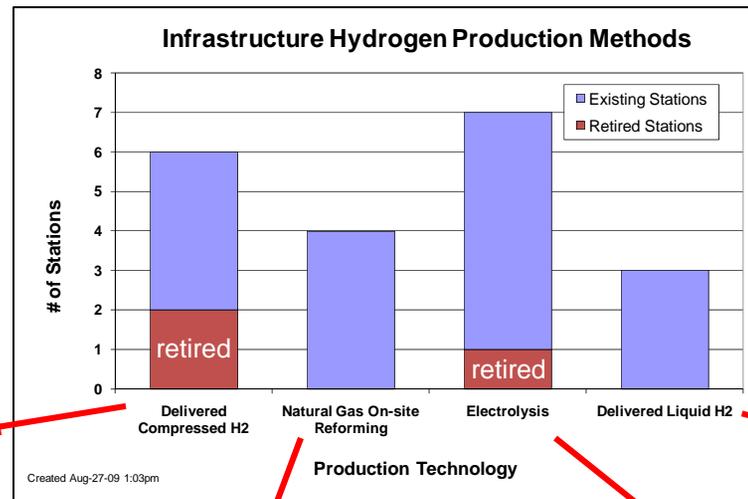
Some Gen 1 vehicles have now been retired (red bars)

Gen 2 vehicles make up most of 2nd bulge at low hours/miles

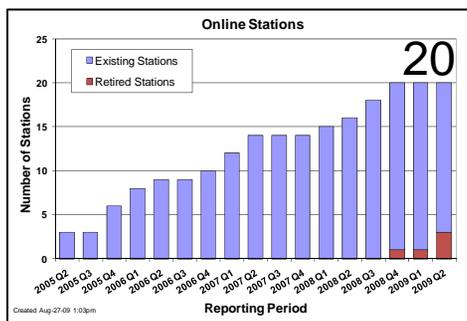


Project Exploring 4 Types of Hydrogen Refueling Infrastructure: Delivered and Produced On-Site

Mobile Refueler
Sacramento, CA



Delivered Liquid, 700 bar
Irvine, CA



Steam Methane Reforming
Oakland, CA

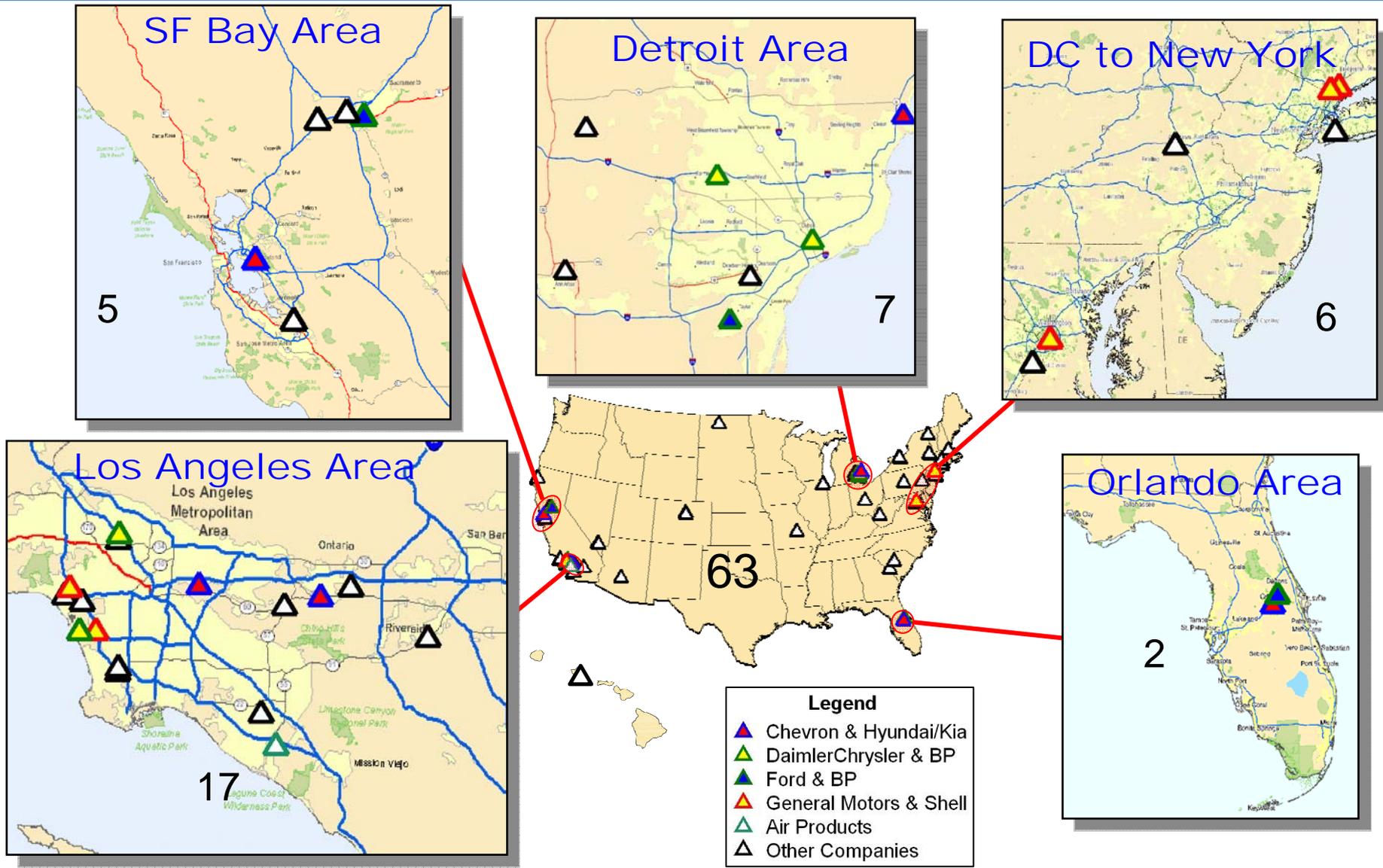


Water Electrolysis
Santa Monica, CA

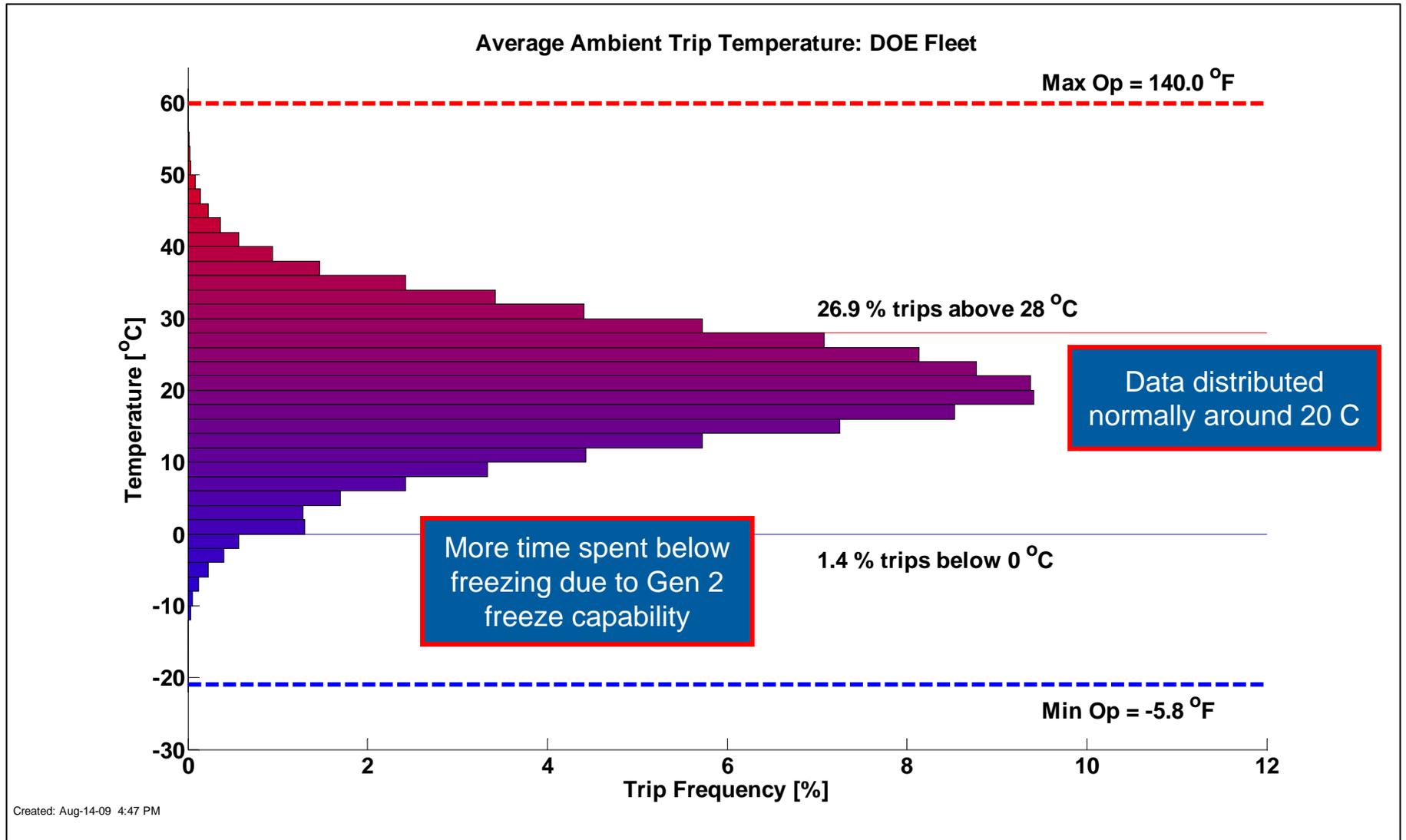


Total of 115,000 kg H₂
produced or dispensed

Refueling Stations Test Performance in Various Climates; Learning Demo Stations Comprise ~1/3 of all U.S. Stations



Average Ambient Temperature of Learning Demo Vehicles Spans Most Climates



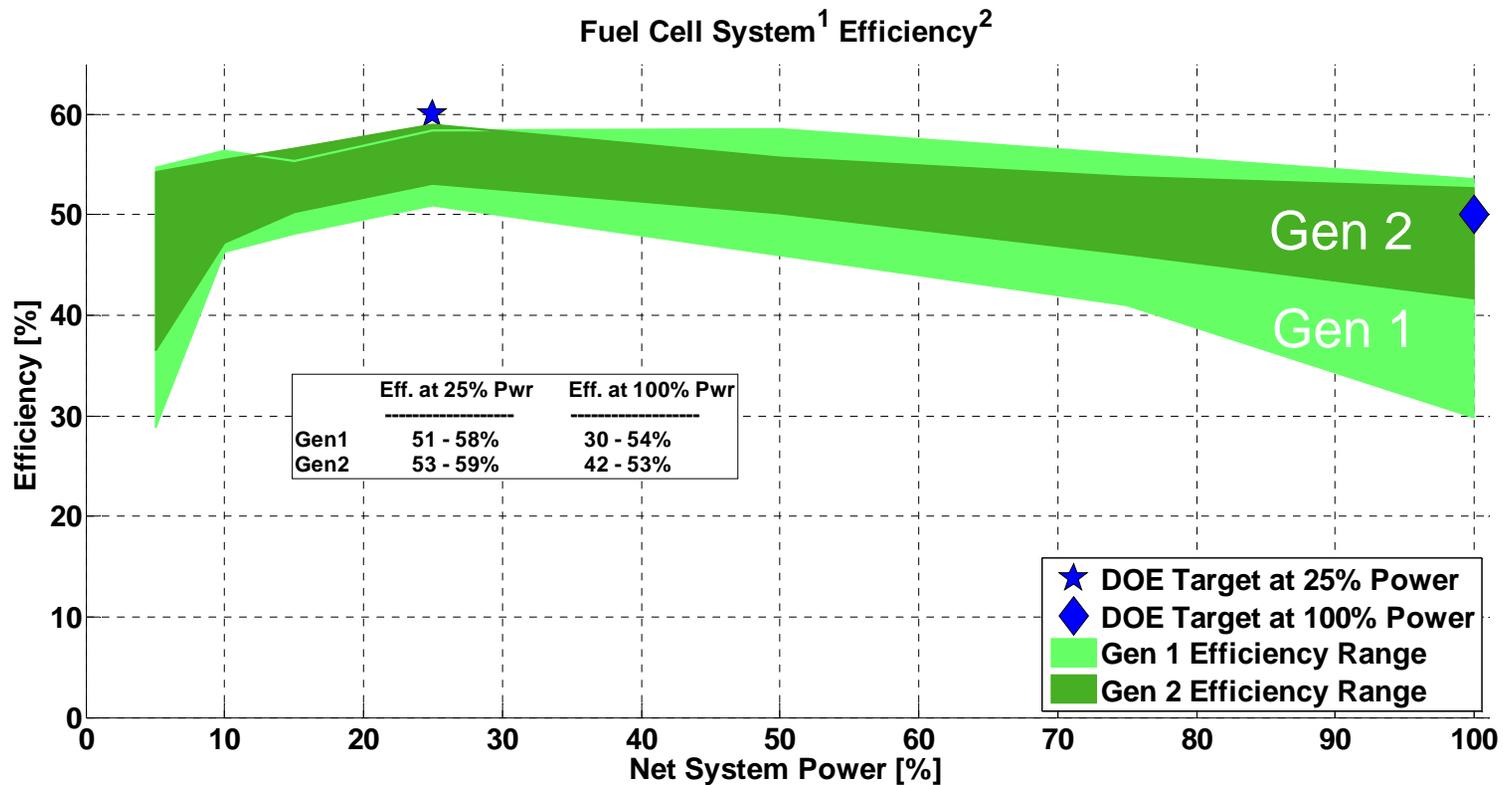
72 Public Composite Data Products Have Been Published; New Results and Updates Every 6 Months

Last Briefing to
CARB Was 3 Years
Ago with 24 Results



A small subset of the
72 latest results follow

While Improving Durability and Freeze Capability, FC System Efficiency Stays High



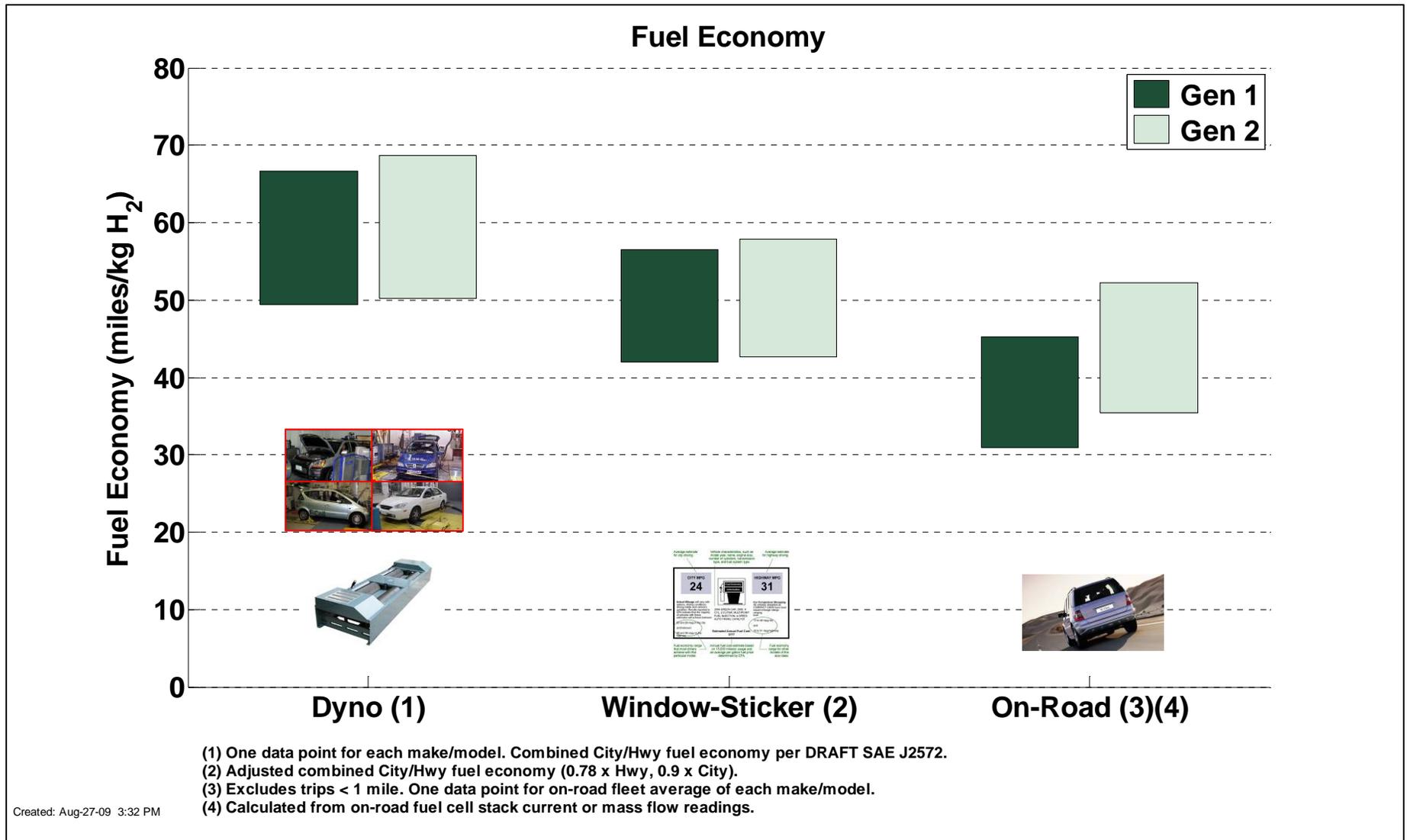
¹ Gross stack power minus fuel cell system auxiliaries, per DRAFT SAE J2615. Excludes power electronics and electric drive.

² Ratio of DC output energy to the lower heating value of the input fuel (hydrogen).

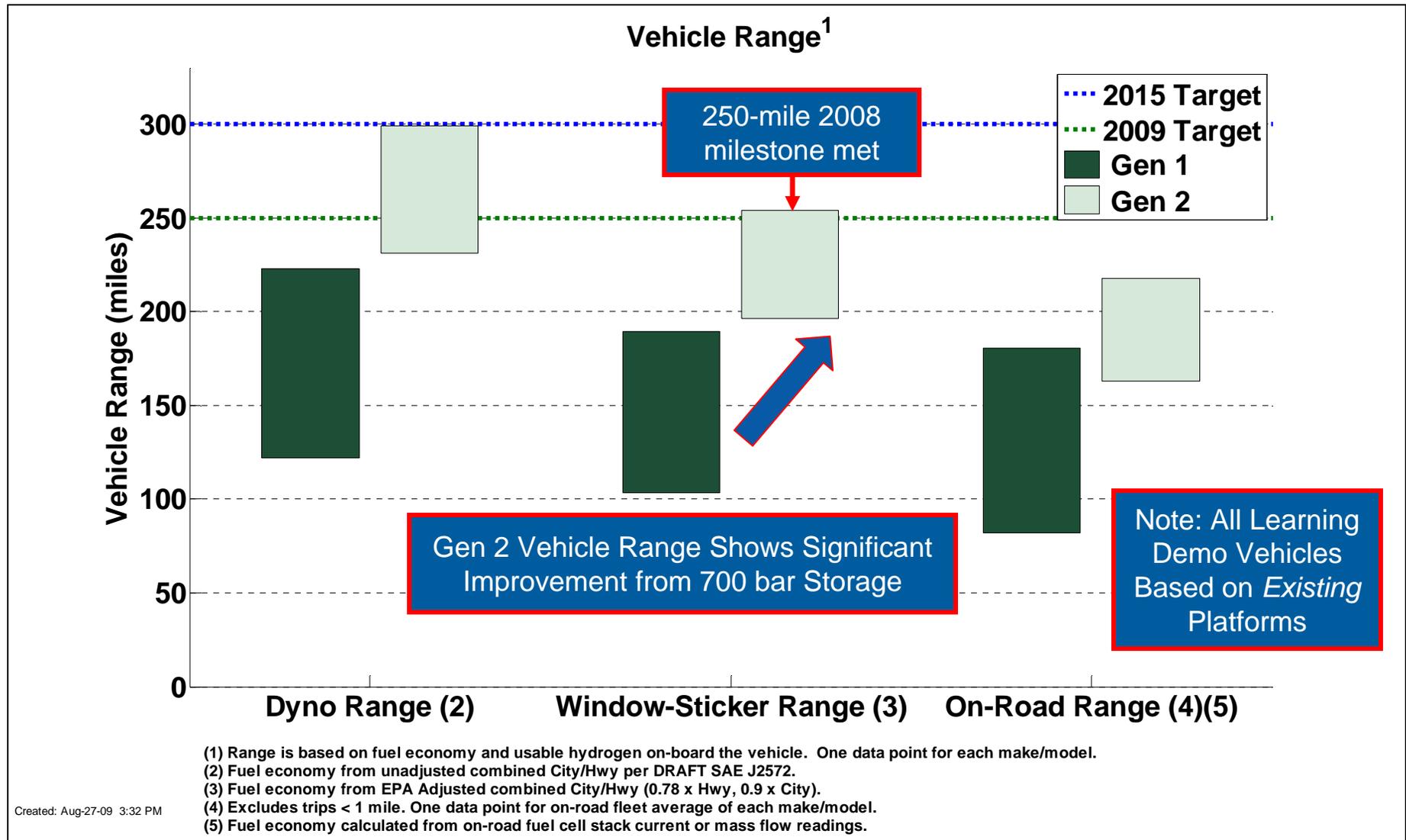
³ Individual test data linearly interpolated at 5,10,15,25,50,75, and 100% of max net power. Values at high power linearly extrapolated due to steady state dynamometer cooling limitations.

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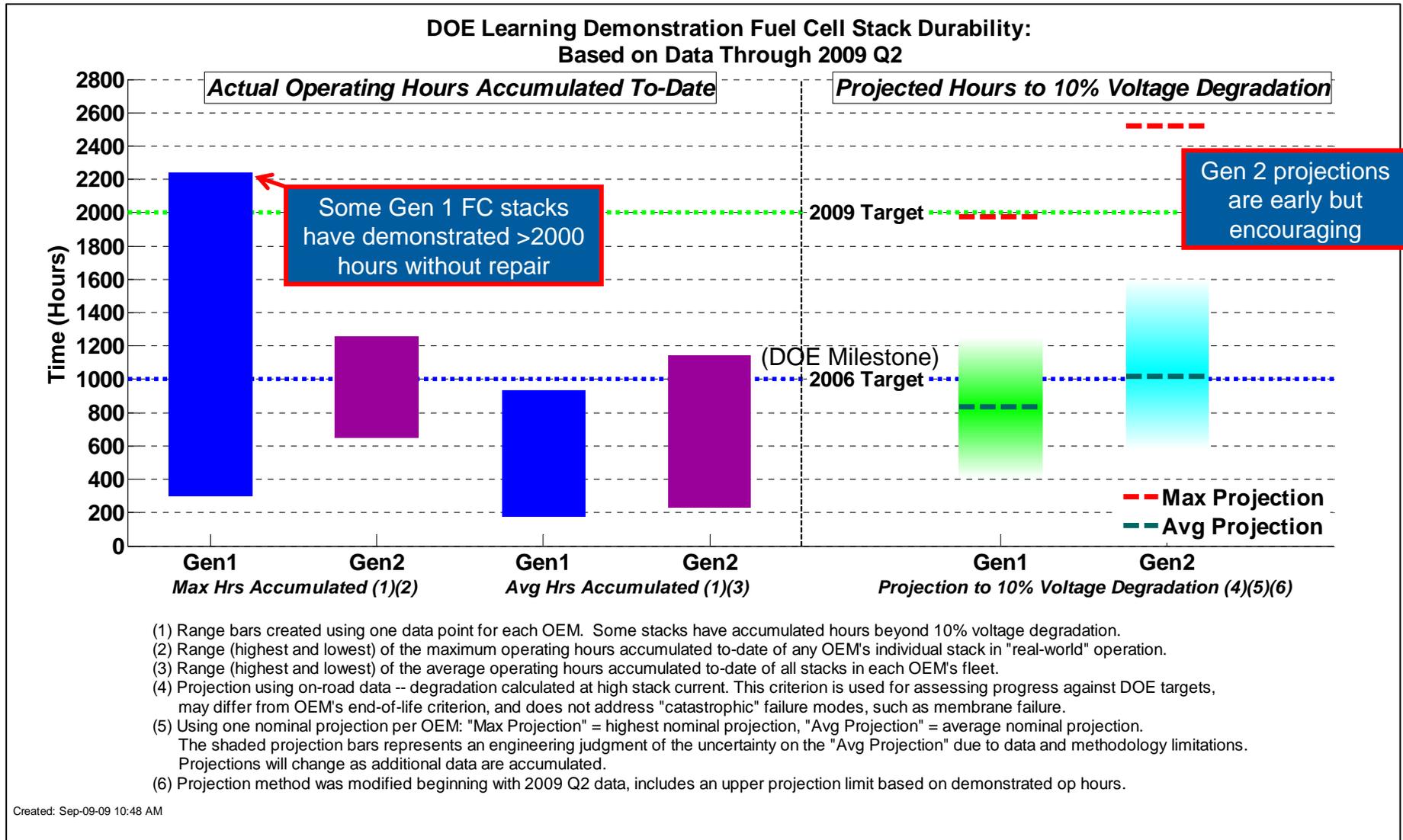
Ranges of Fuel Economy from Dynamometer and On-Road Data Slightly Improved for Gen 2



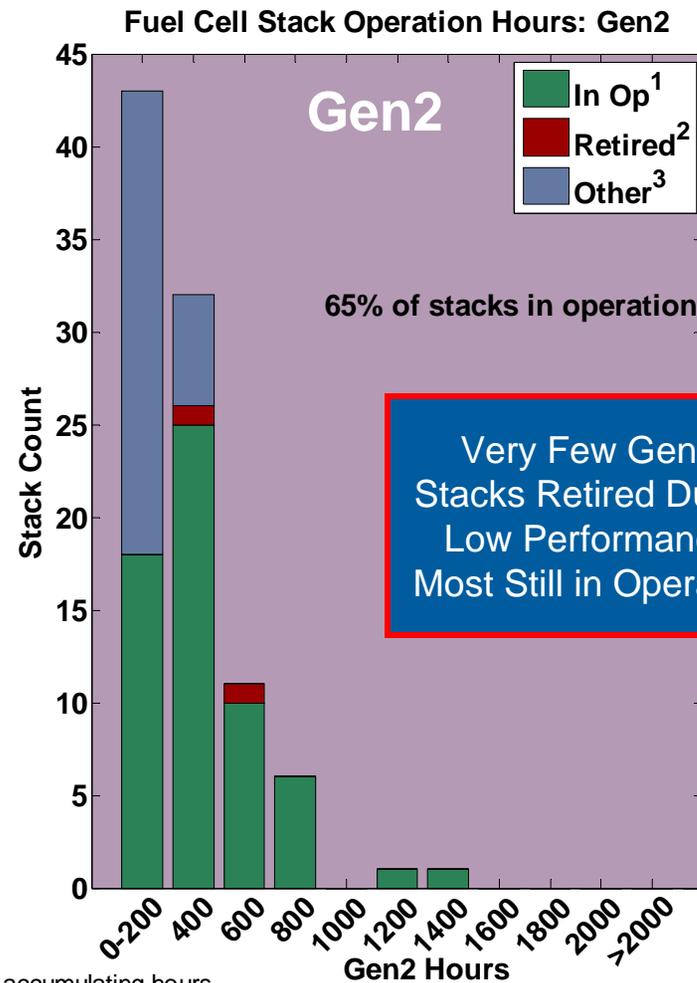
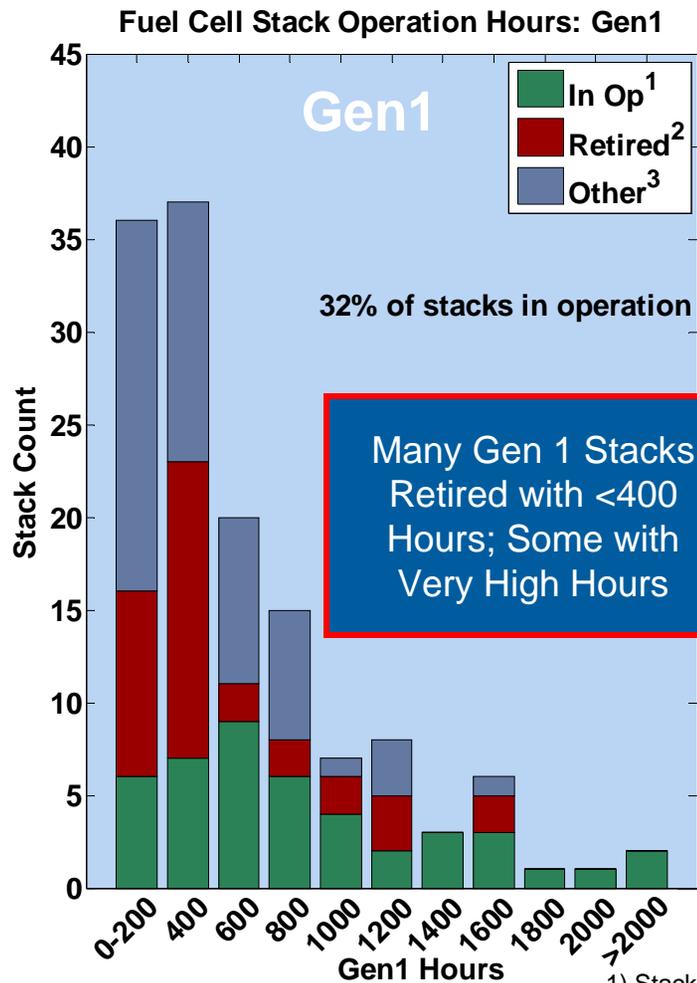
Driving Range for Gen 1 and Gen 2 Vehicles: Based on Fuel Economy and Usable H₂



Gen 1 and Gen 2 Stack Operating Hours and Projected Time to 10% Voltage Drop



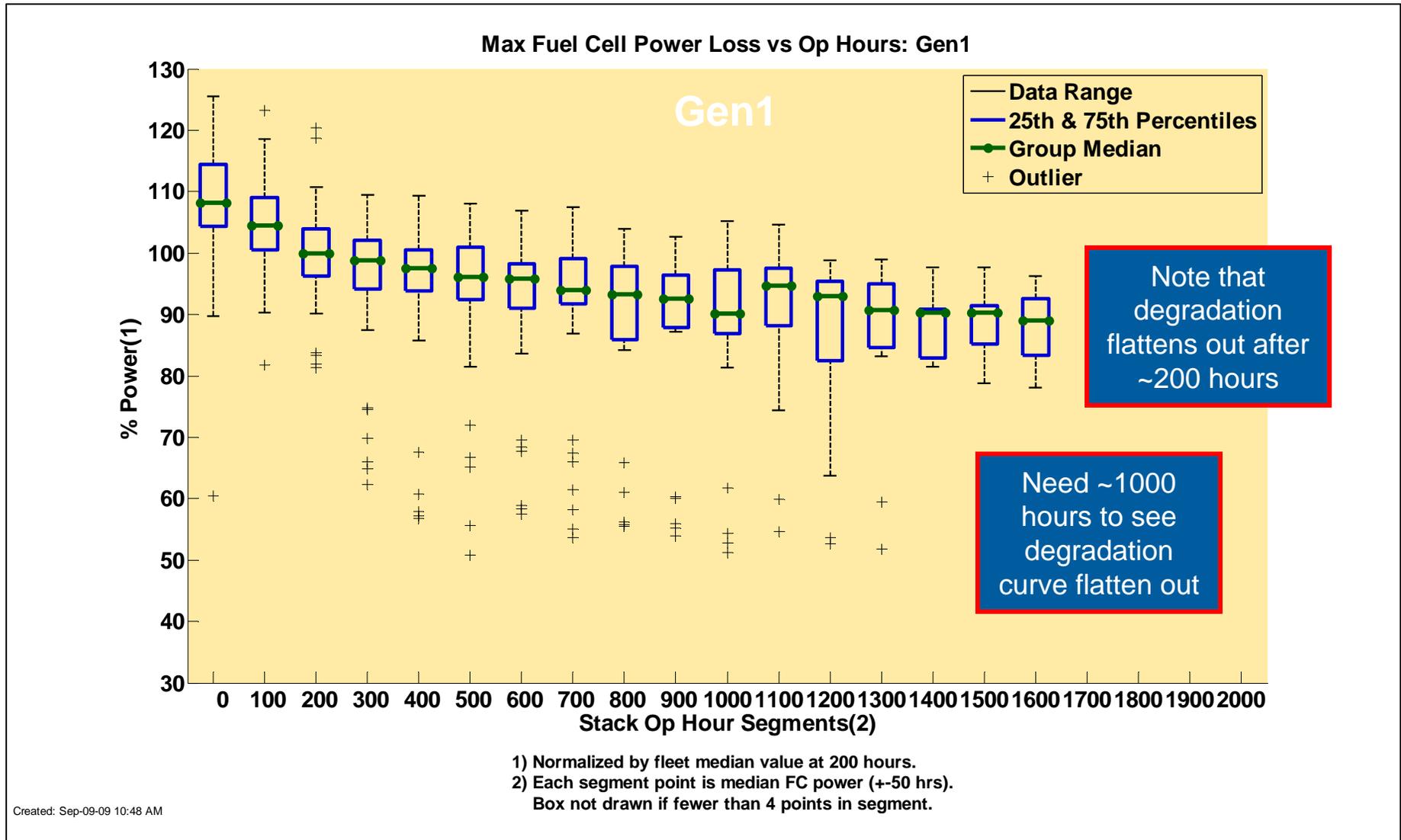
Fuel Cell Stack Operation Hours; Early in Gen 2 Life, But Results Encouraging



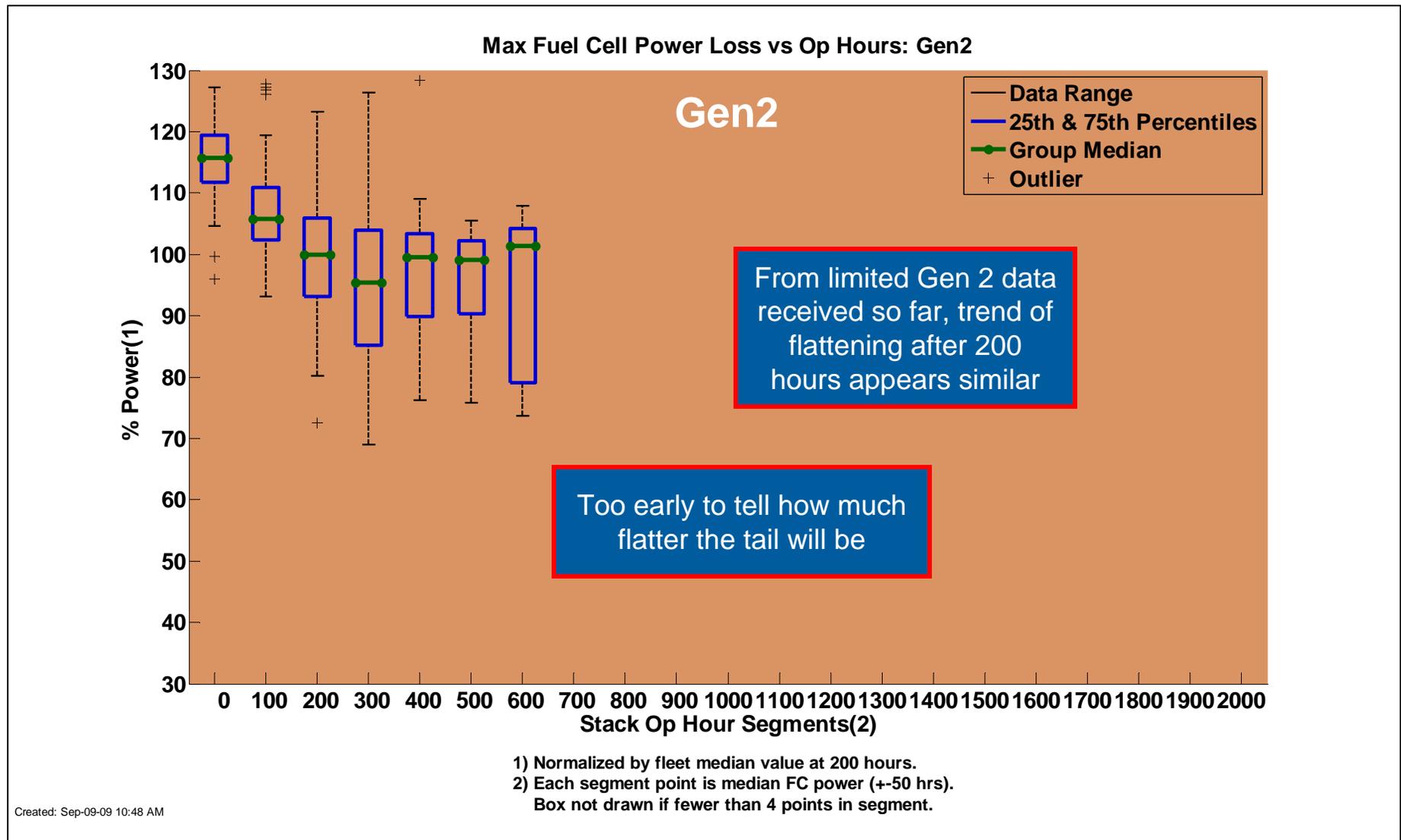
- 1) Stack currently accumulating hours
- 2) Stack removed for low performance
- 3) Stack not currently accumulating hours, but not removed because of low performance

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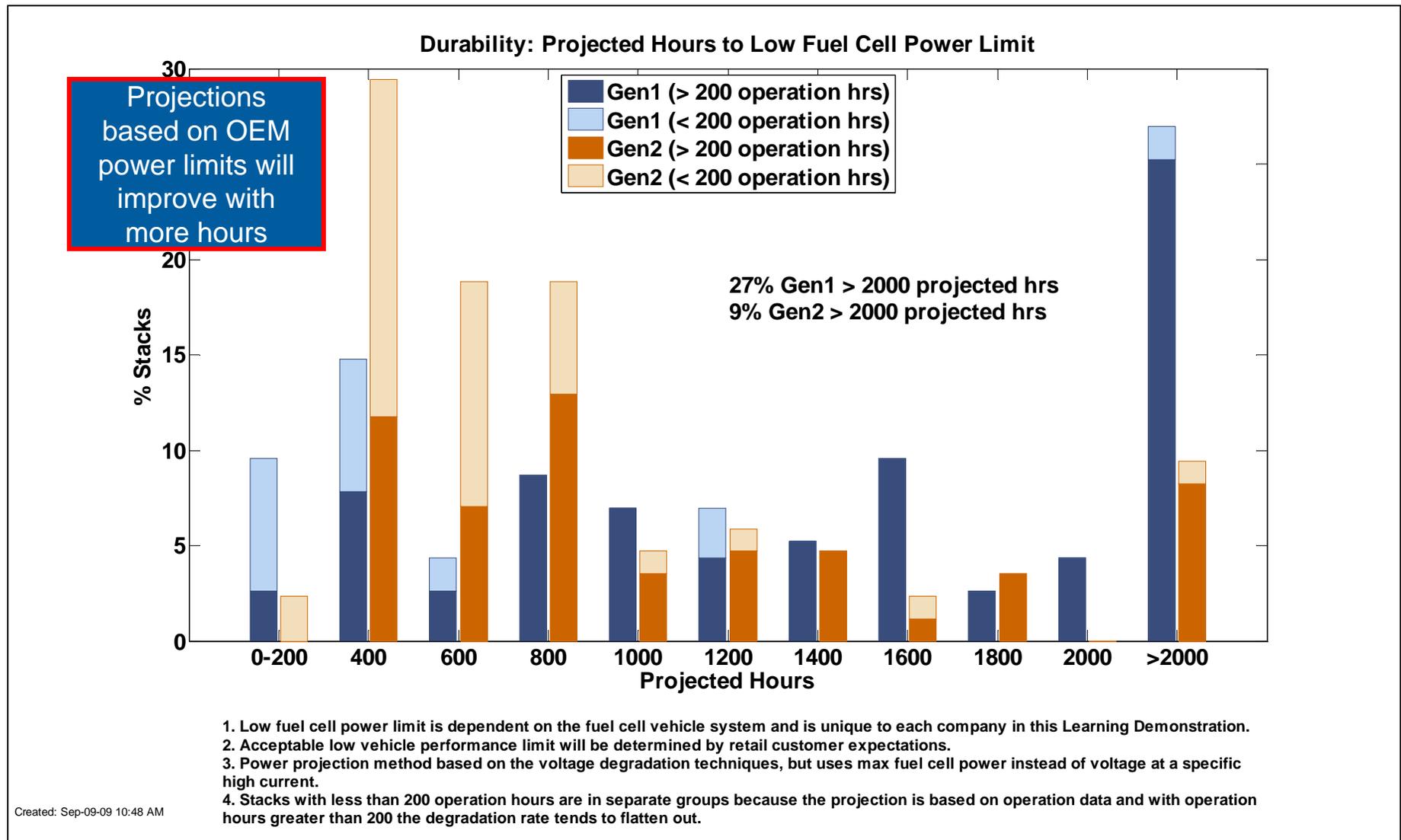
Max Fuel Cell Power Degradation – Gen 1



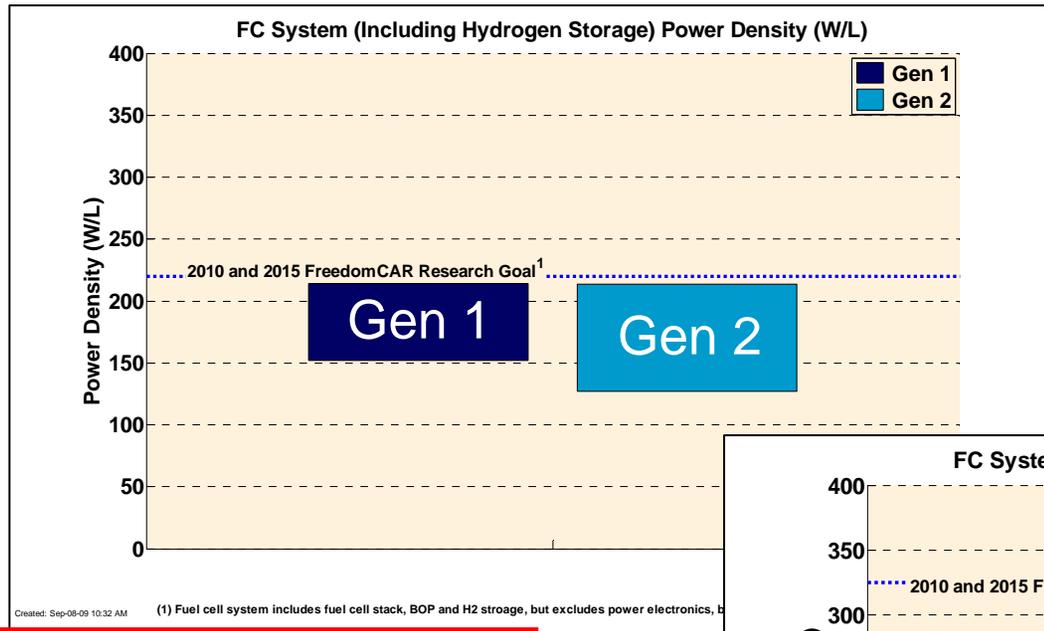
Max Fuel Cell Power Degradation – Gen 2



Projected Hours to OEM Low Power Operation Limit

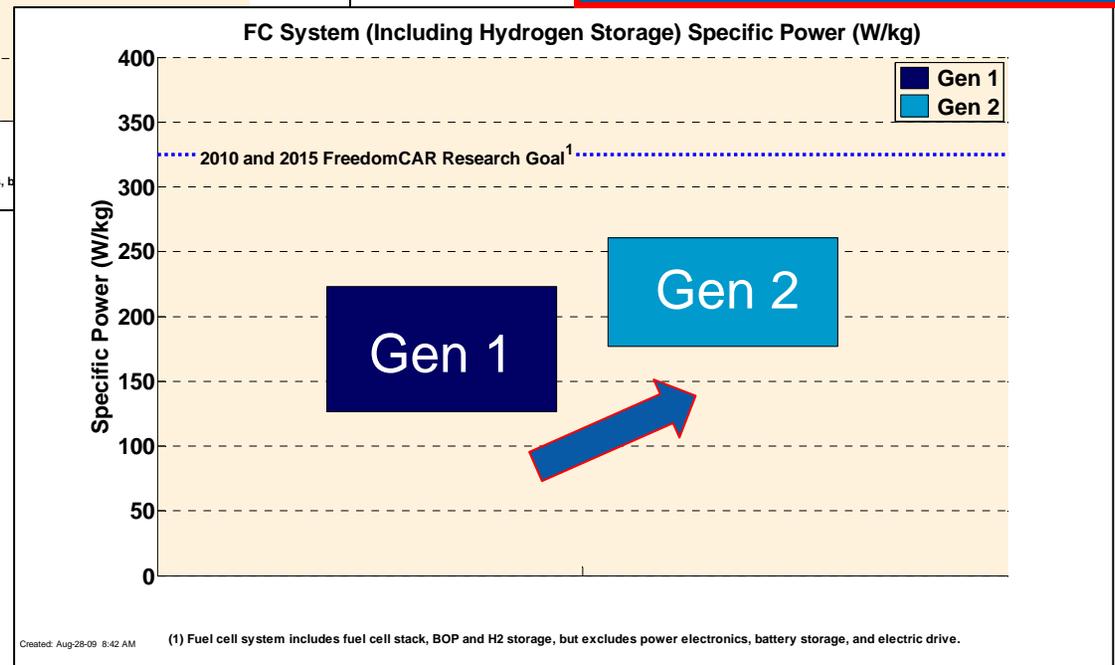


Fuel Cell System (including H2 storage) Close to 2010 and 2015 W/L and W/kg Targets

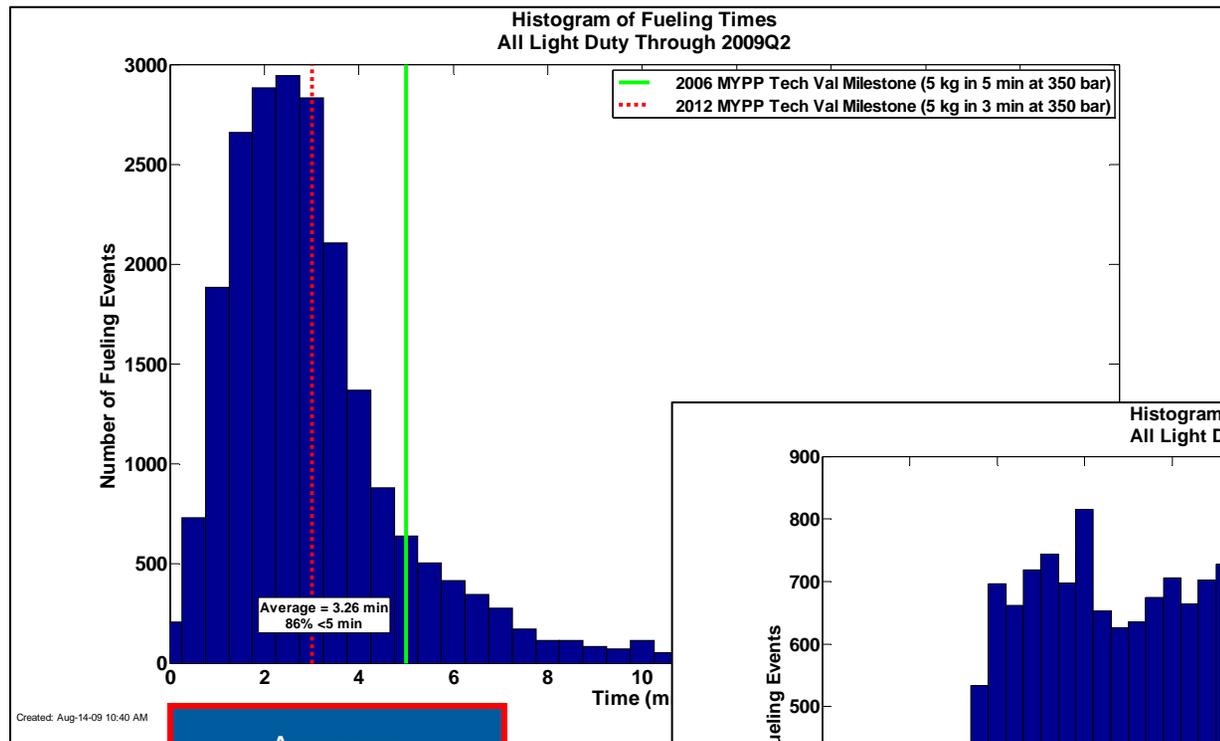


Significant Improvements
Seen in Specific Power
(...systems getting lighter)

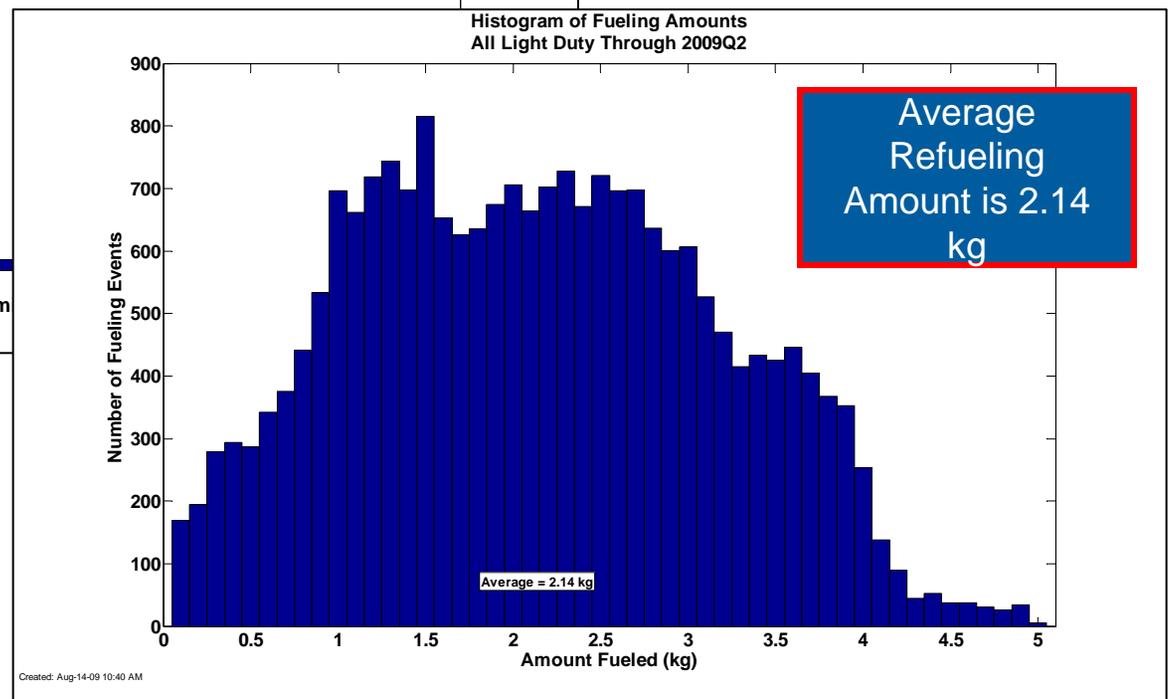
Power Density Held Similar
Between Gen 1 and Gen 2
(...same size or larger)



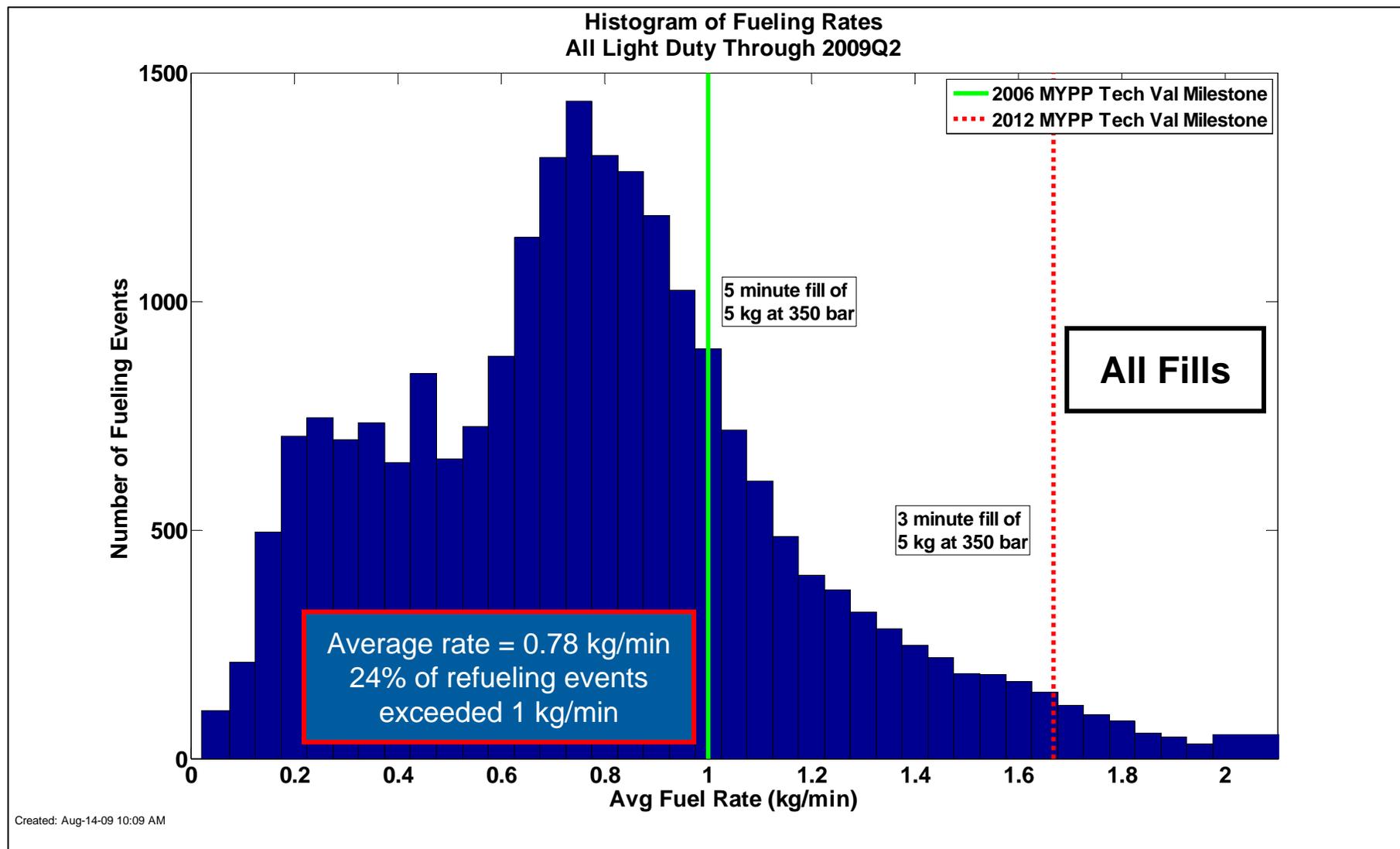
Refueling Times are Short; Amounts are Reflective of Demonstration-Sized Systems



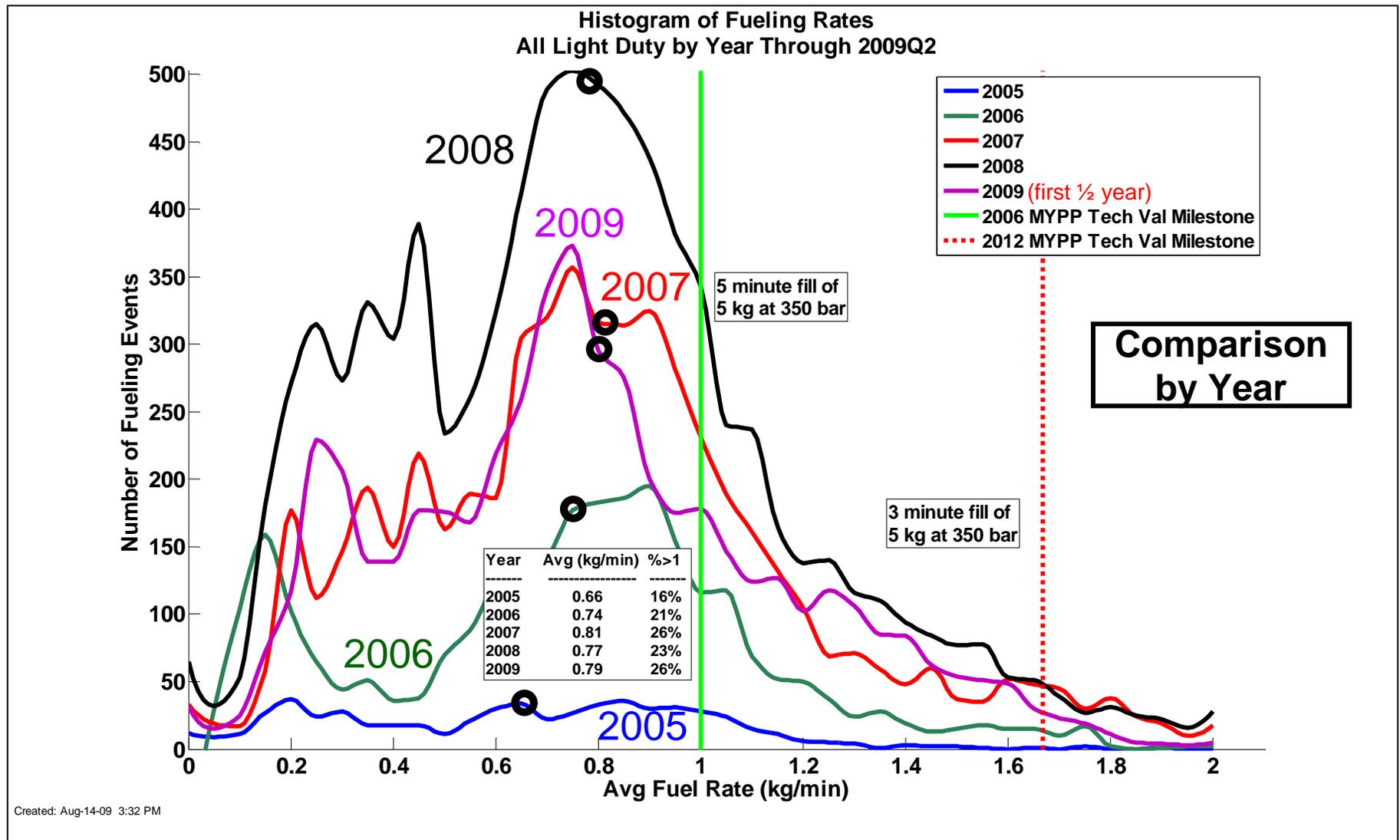
Average Refueling Time is 3.26 minutes



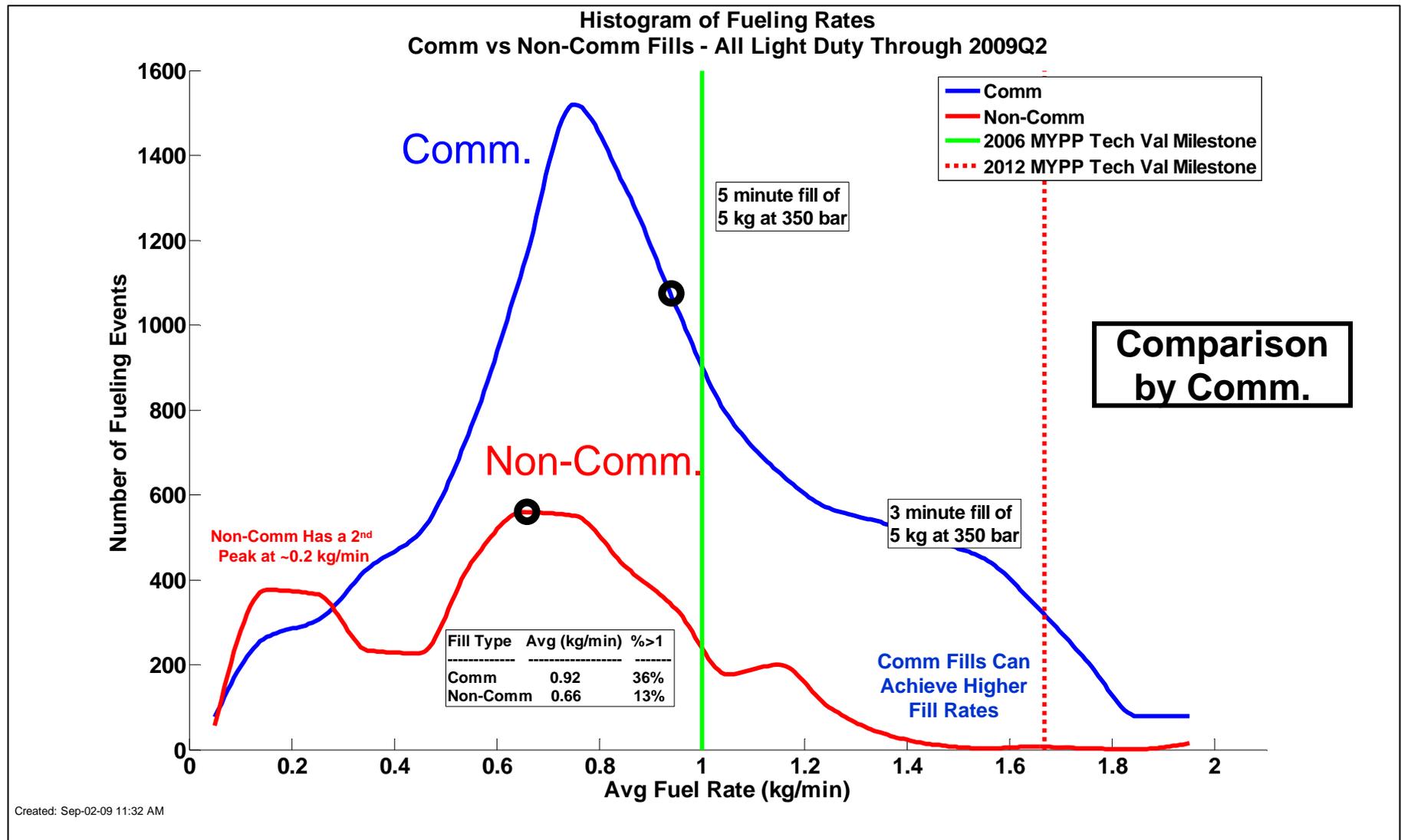
Actual Vehicle Refueling Rates from 21,000 Events: Measured by Stations or by Vehicles



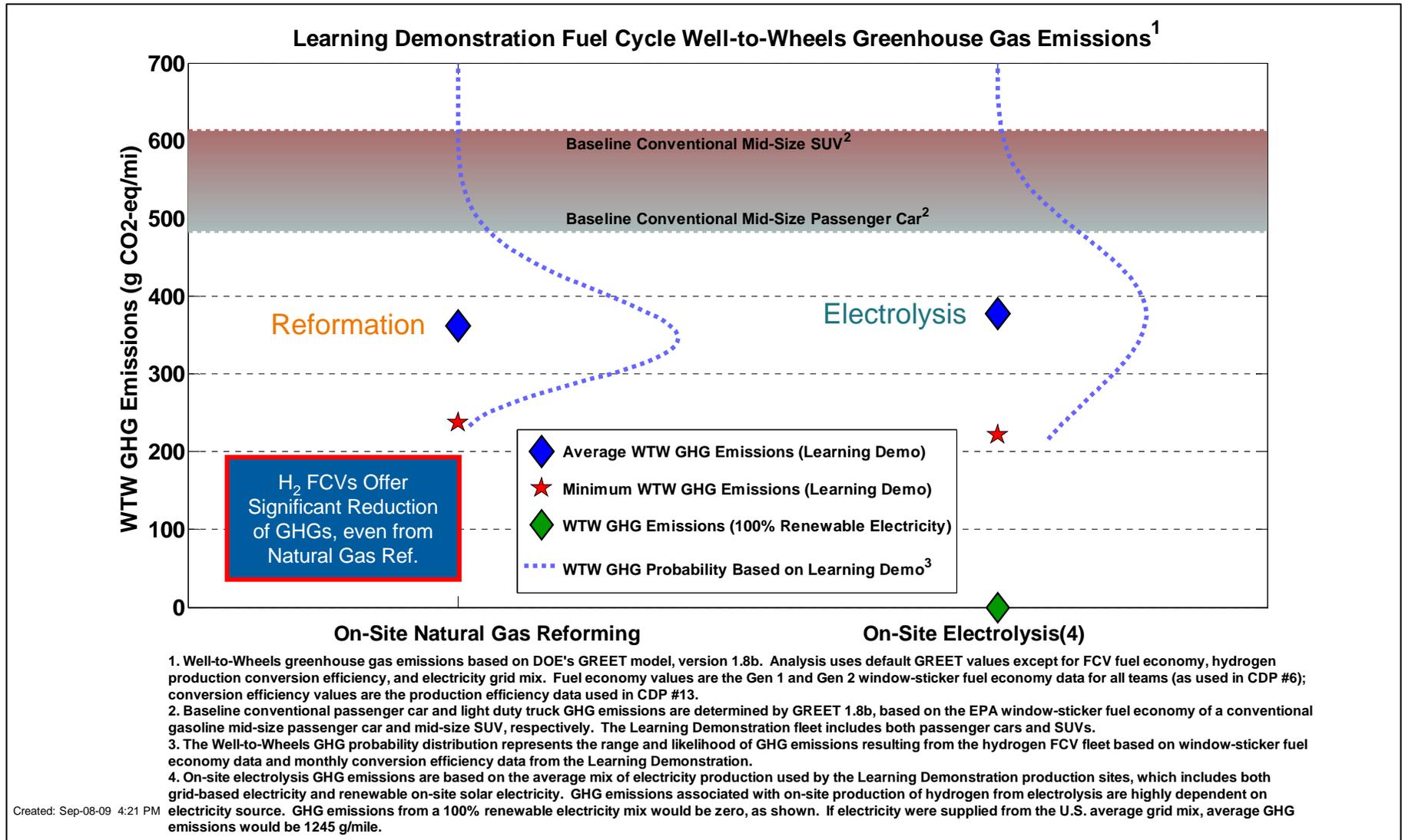
Refueling Rates by Year: ~1/4 Now Exceed 1 kg/min, 2009 to be Highest # of Fills



Communication H₂ Fills Achieving 39% Higher Average Fill Rate than Non-Communication



Learning Demonstration Vehicle Greenhouse Gas Emissions Using Actual Production Efficiencies and Fuel Economies



Summary

- Learning Demo evaluation is ~80% complete
 - 140 vehicles and 20 stations deployed
 - 2.3 million miles traveled, 115,000 kg H₂ produced or dispensed
 - 346,000 individual vehicle trips analyzed
 - Project to continue through 2010
- Emphasis from project has been on providing maximum value from the data collected during project
 - 72 results have been published
 - Updates every 6 months
 - Current results are always available on our web page
- Vehicle/Station Status
 - 2nd generation vehicles have now been on road for >1 year
 - Station deployment nearing completion; some early stations retired
- Similar Evaluations Now Underway at NREL for FC Forklifts & Backup Power

Questions and Discussion



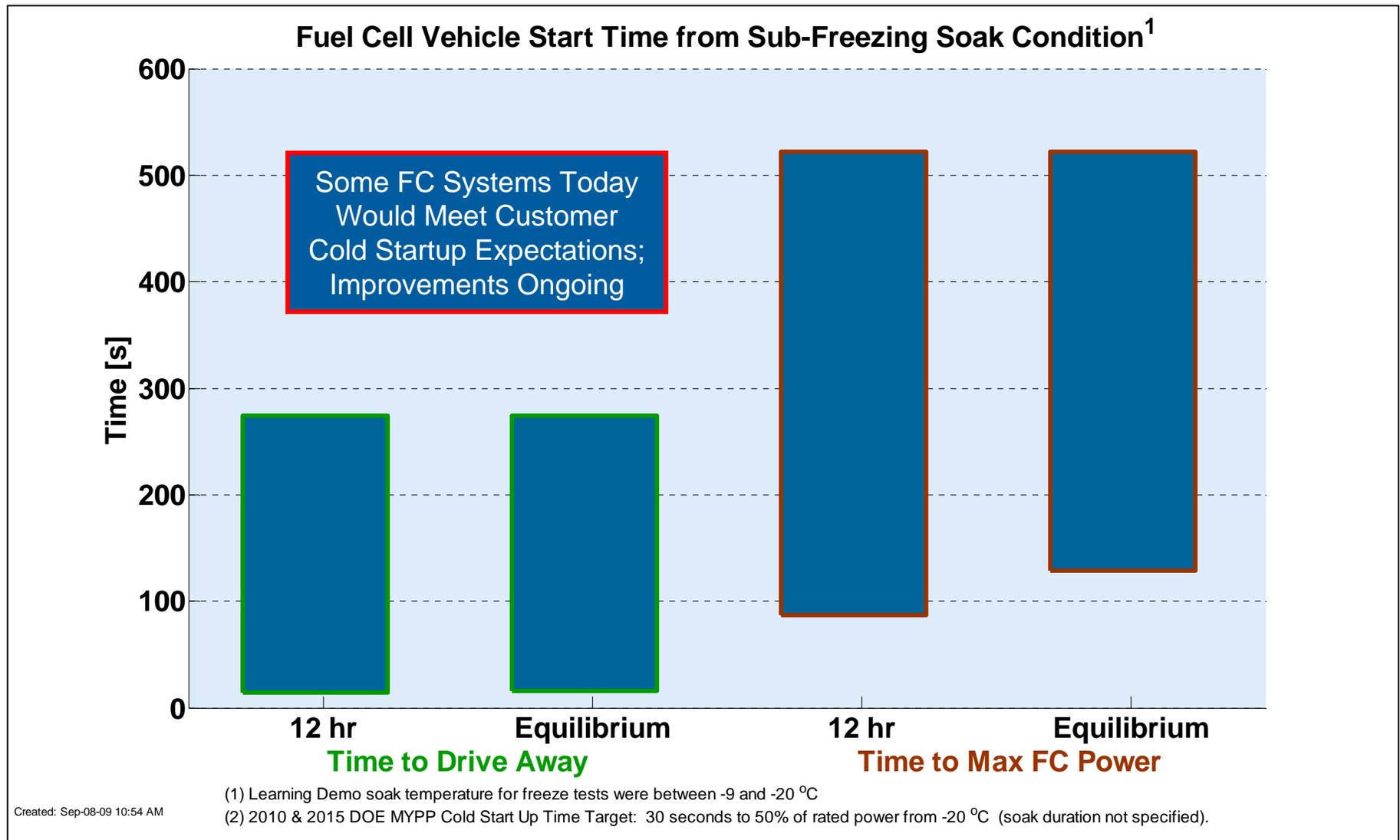
The NREL
Learning Demo
Analysis Team in
Colorado

Primary Contact: Keith Wipke, National Renewable Energy Lab
303.275.4451 keith.wipke@nrel.gov

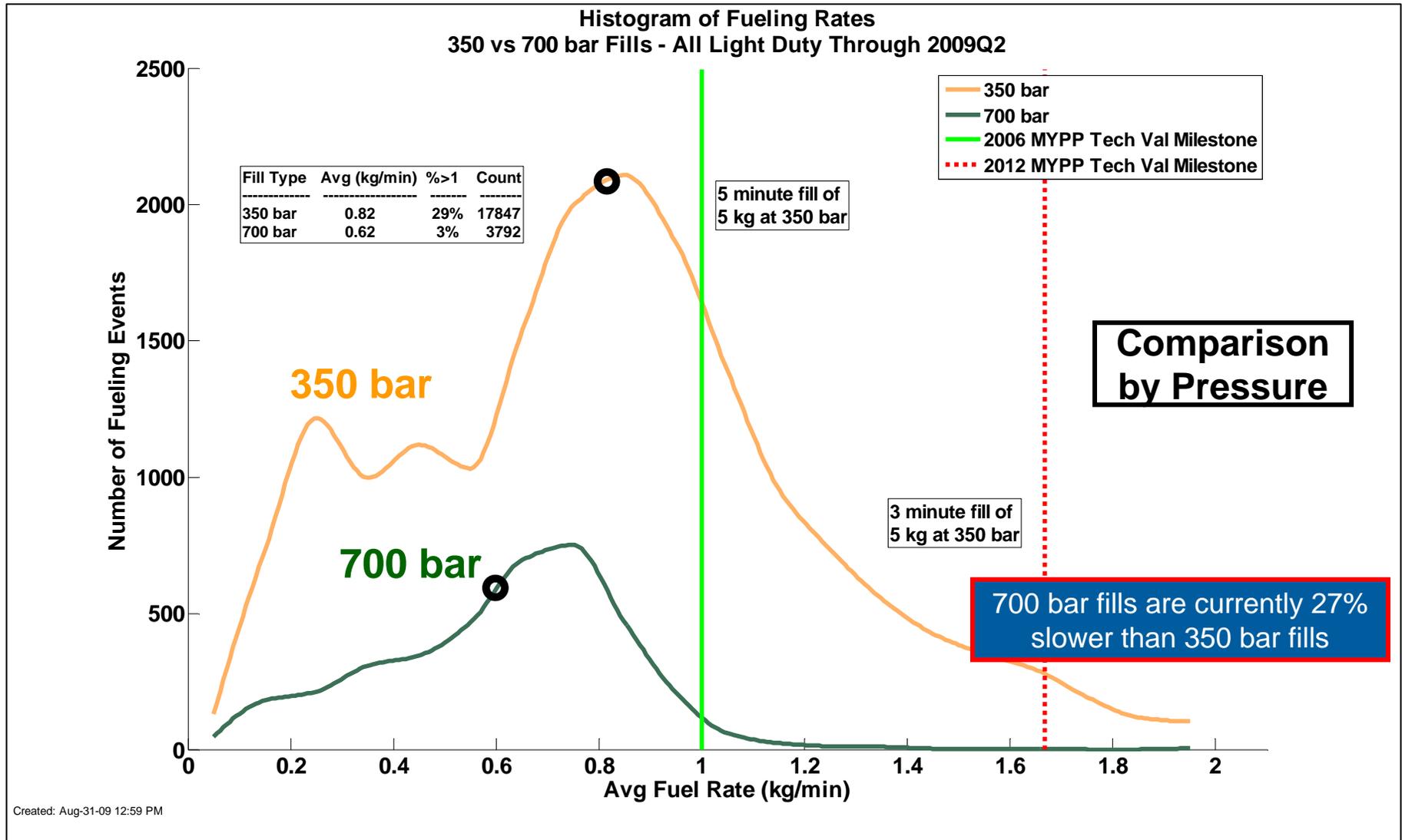
All public Learning Demo and FC Bus Evaluation papers and presentations are available
online at http://www.nrel.gov/hydrogen/proj_tech_validation.html

Additional Results for Reference

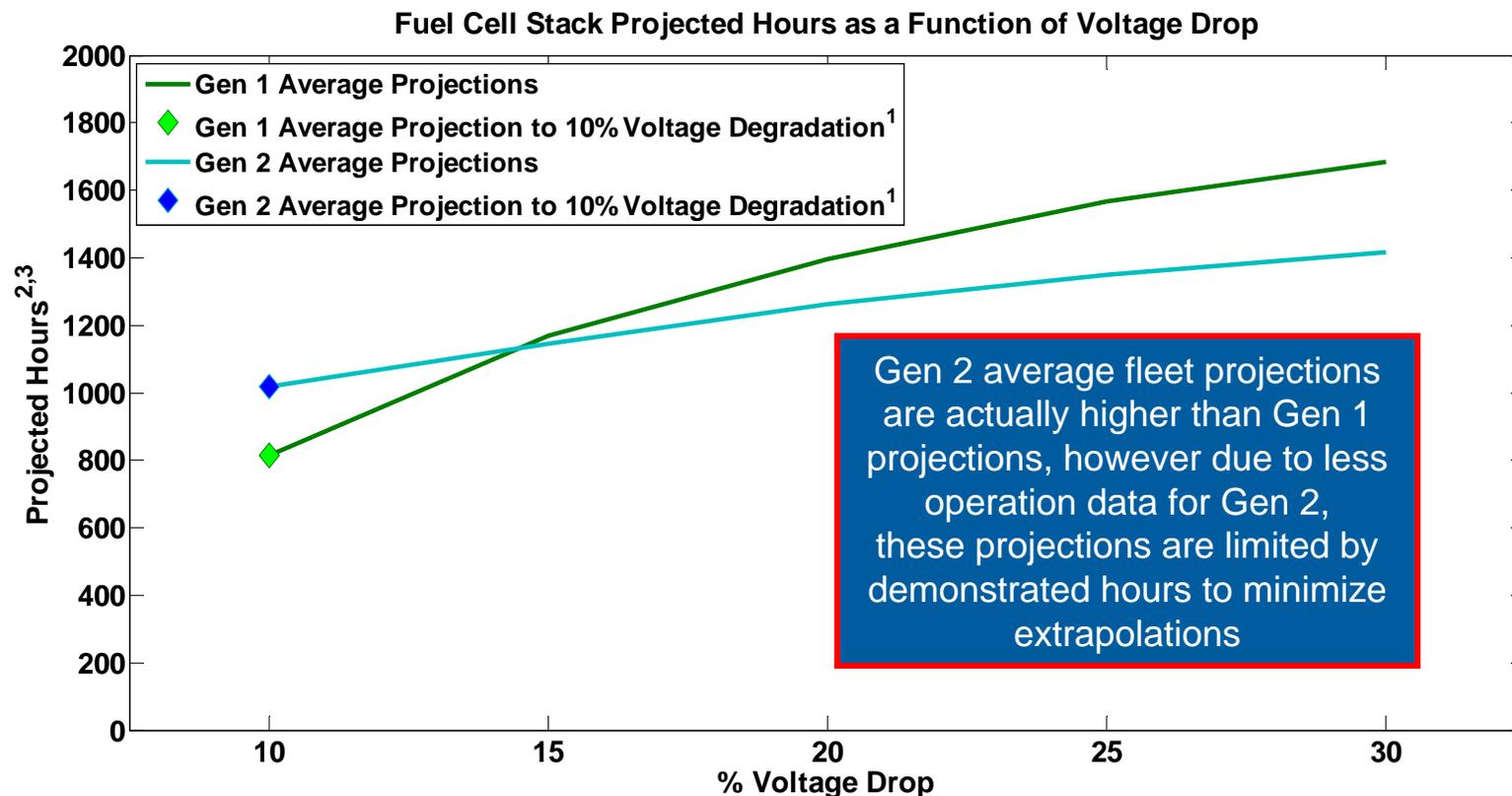
Fuel Cell Start Times from Sub-Freezing Soak Conditions



Comparison of Fueling Rates for 350 and 700 bar Pressure Fueling Events



10% Voltage Drop Is One Metric – Sensitivity of Projections to % Voltage Drop



- (1) 10% Voltage degradation is a DOE metric for assessing fuel cell performance.
- (2) Projections using on-road data -- degradation calculated at high stack current.
- (3) Curves generated using the Learning Demonstration average of each individual fleet average at various voltage degradation levels.
- (4) The projection curves display the sensitivity to percentage of voltage degradation, but the projections do not imply that all stacks will (or do) operate at these voltage degradation levels.
- (5) The voltage degradation levels are not an indication of an OEM's end-of-life criteria and do not address catastrophic stack failures such as membrane failure.
- (6) All OEM Gen 2 average fleet projections are higher than Gen1 projections, however due to less operation data for Gen 2, these projections are limited by demonstrated operation hours to minimize extrapolations.

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