

Conclusion of the National FCEV Learning Demonstration Project



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Outline

- Project Goals
- Vehicle and H₂ Station Deployment Status
- Highlights of Latest Vehicle and Infrastructure Analysis Results and Progress
- Learning Demo Next Steps and Project Wrap-up
- Summary



Fuel Cell Electric Vehicle Learning Demo

Project Objectives, Relevance, and Targets

- Objectives
 - Validate H₂ FC Vehicles and Infrastructure in Parallel
 - Identify Current Status and Evolution of the Technology
- Relevance
 - Objectively 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

Note: Project extended 2 years through 2011



Burbank, CA station. Photo: NREL

Involvement of Industry Teams Has Evolved



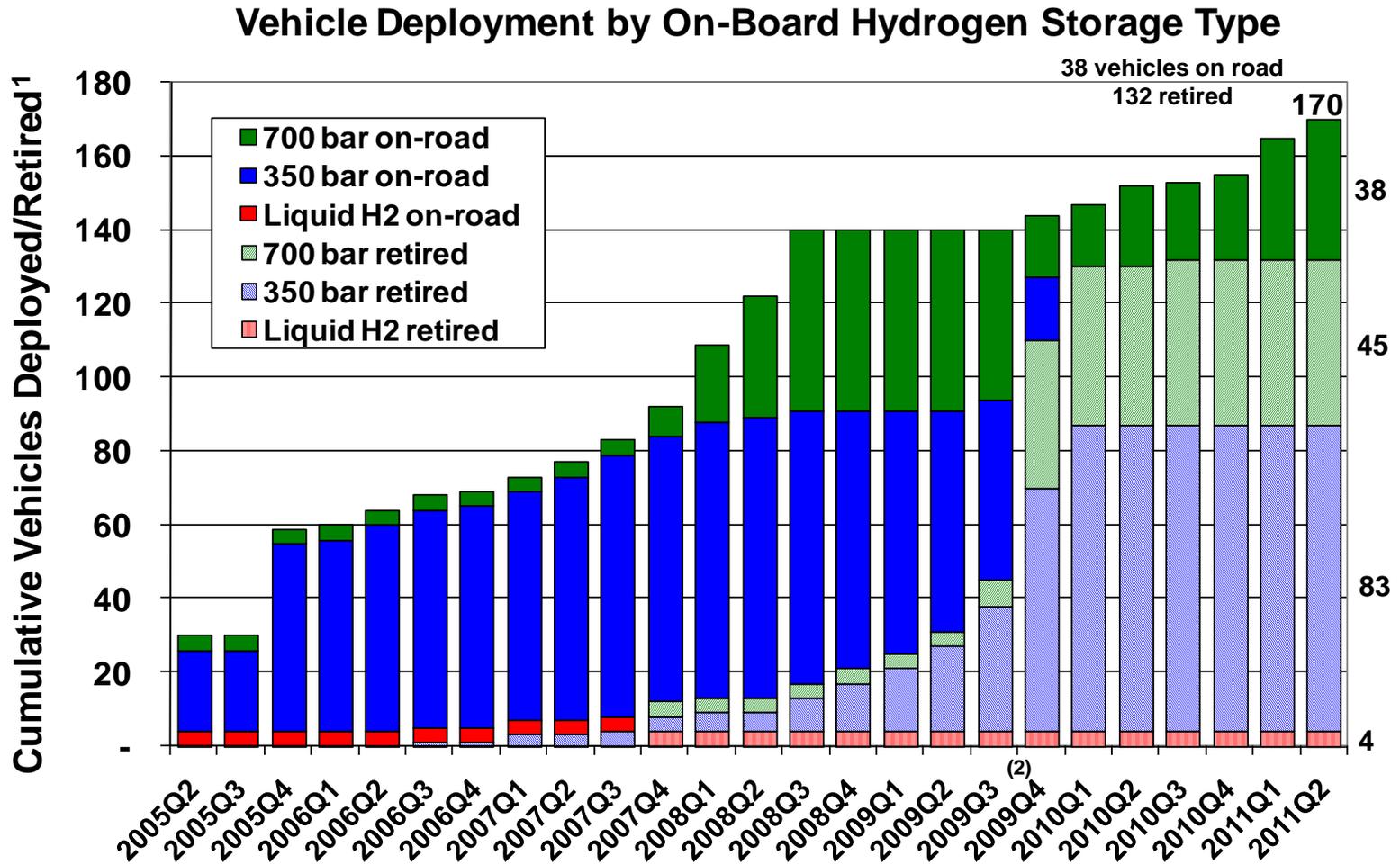
◆ Ford/BP and Chevron/Hyundai-Kia Concluded in 2009



Daimler, GM, and Air Products Continue to Demonstrate Vehicles/Stations within Project through CY2011



Current Vehicle Deployment Status

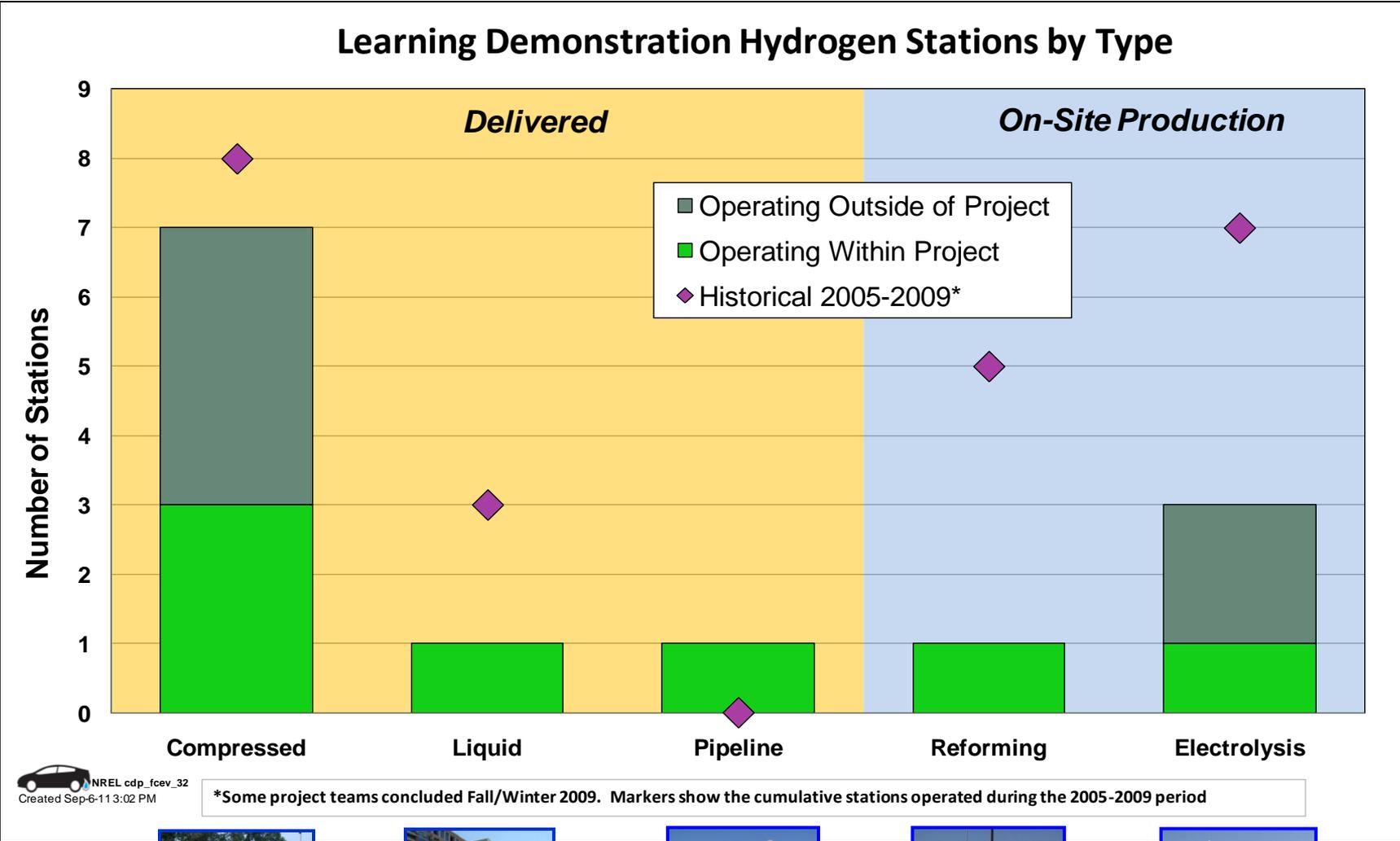


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(1) Retired vehicles have left DOE fleet and are no longer providing data to NREL
(2) Two project teams concluded in Fall/Winter 2009

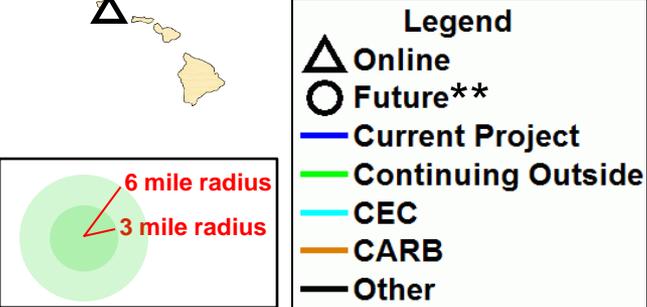
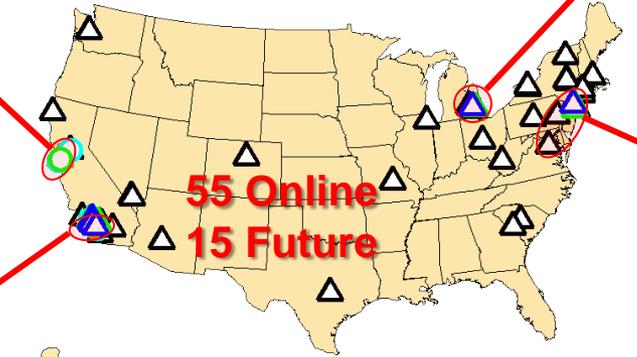
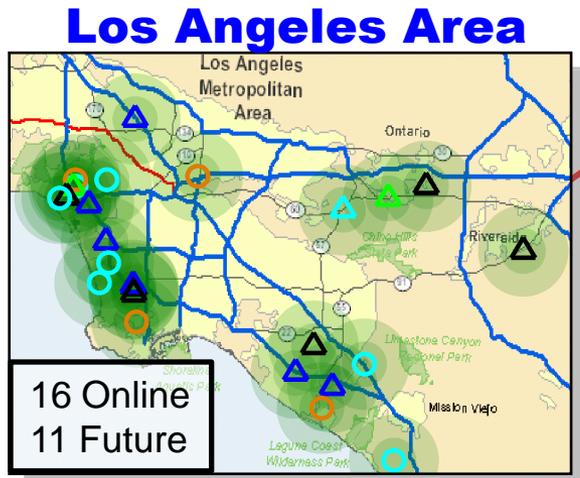
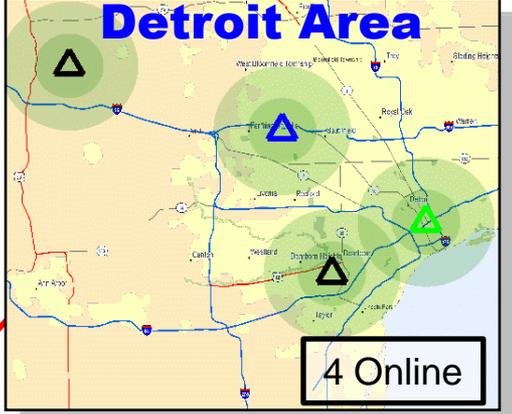
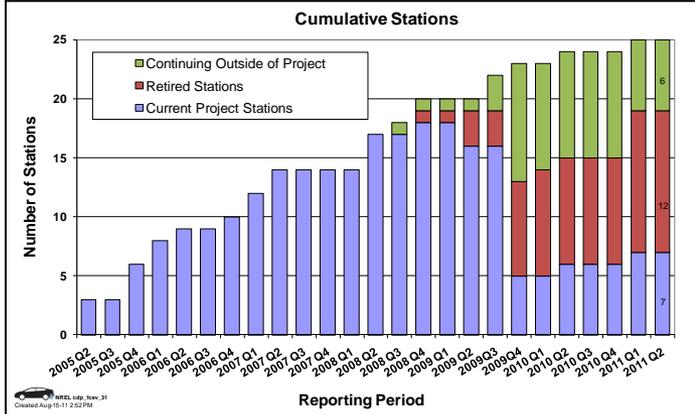
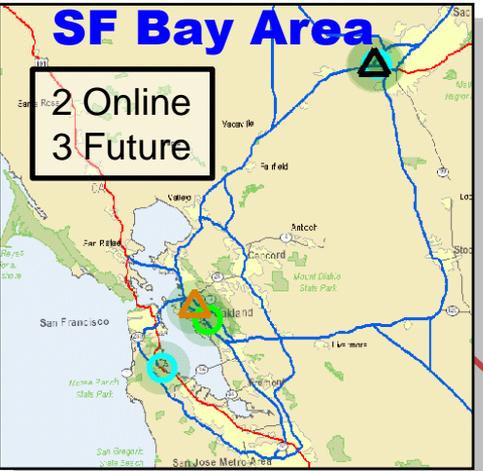
Data from a few more vehicles expected this quarter

Current Infrastructure Status: Stations that Continue to Operate are Mostly Delivered Compressed Hydrogen



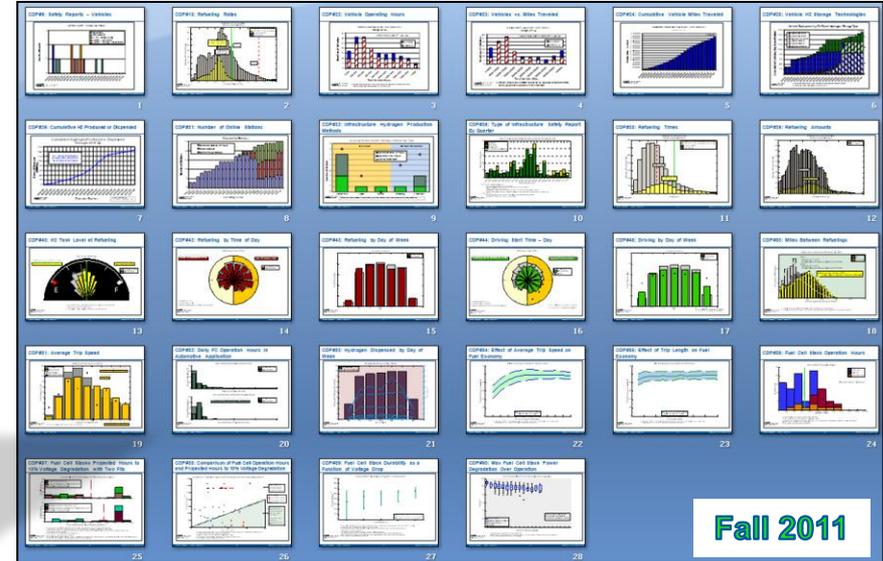
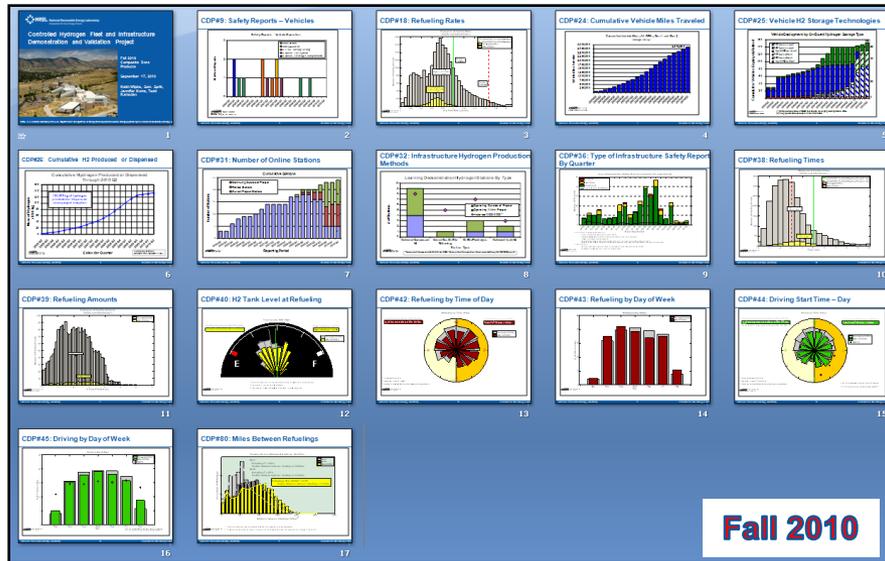
Status: Out of 25 Project Stations, 13 Are Still Operational* (~1/2 outside of DOE project)

* CDP station status is as of 6/30/11



** Funded by state of CA or others, outside of this project

What's New in the Fall 2011 CDP Results vs. the Fall 2010 Results?



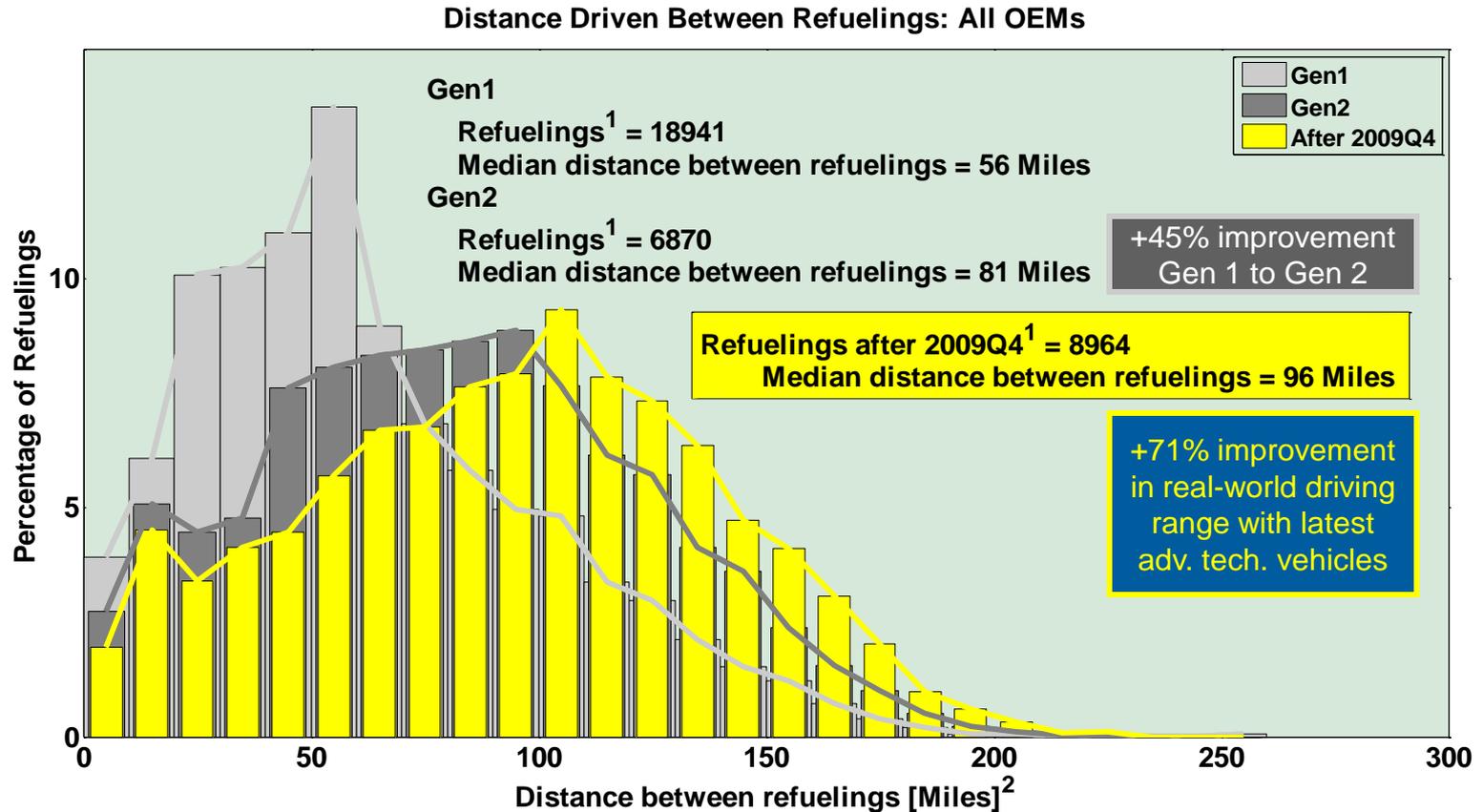
16 Fall 2010 Results

28 Fall 2011 Results

- No “new” CDPs, but we updated 16 previously published CDPs with data from Spring 2010
- Results on most recent durability, range, fuel economy, not yet possible to publish until more data accumulated
- Covers data from 2 Learning Demo OEMs + CHIP project
- Emphasized changes observed in last 6 months through use of gray (old) and colors (new)

- 12 new CDPs, and updates to the 16 previously published CDPs with data from last 12 months
- Results include station utilization, fuel economy, and durability
- Covers data from 2 Learning Demo OEMs + CHIP project
- Many of results are created using same analysis routines as for MHE, buses, and backup power

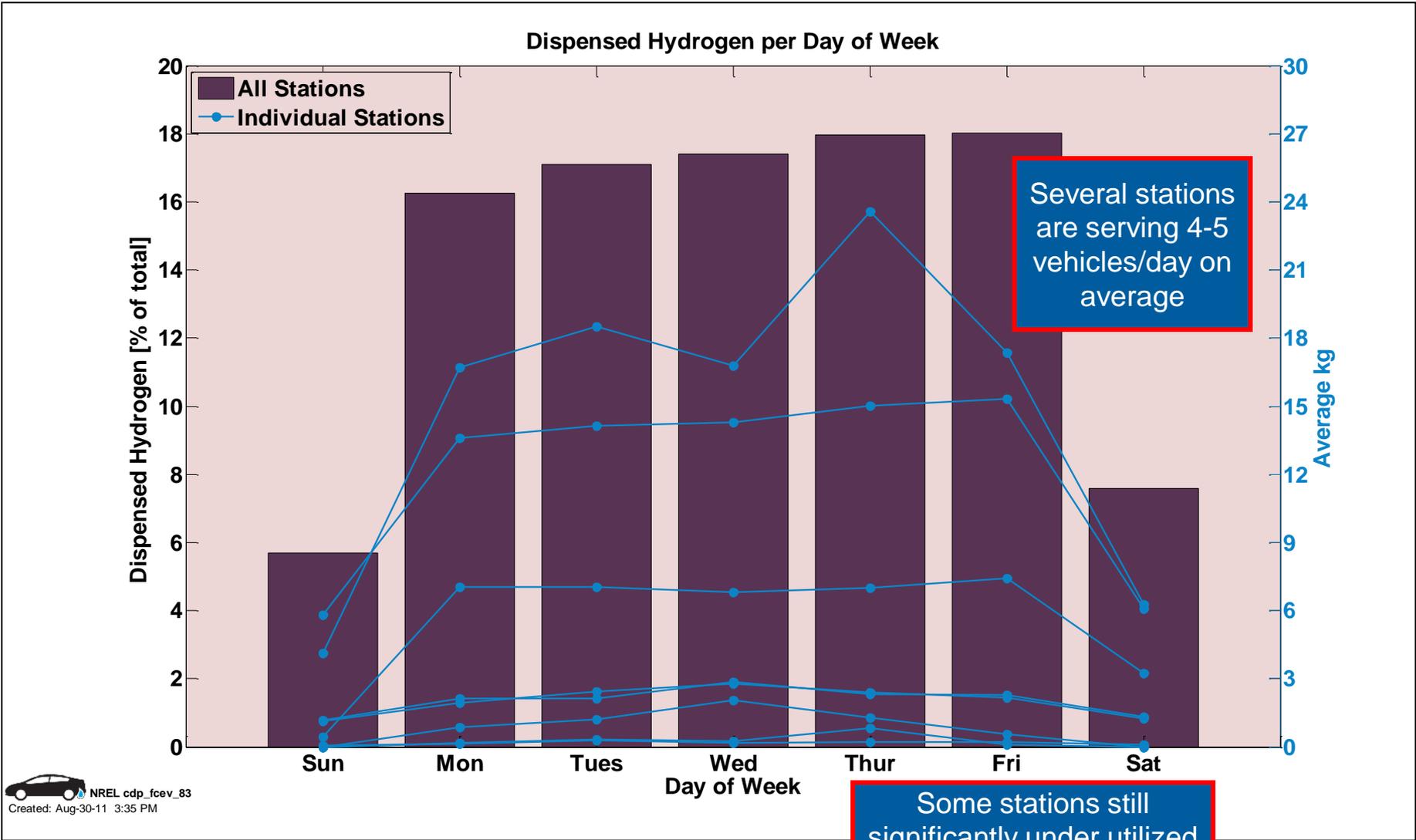
Results Show Significant Improvement in Real-World Driving Range Between 3 Sets of Vehicles



1. Some refueling events are not detected/reported due to data noise or incompleteness.
2. Distance driven between refuelings is indicative of driver behavior and does not represent the full range of the vehicle.

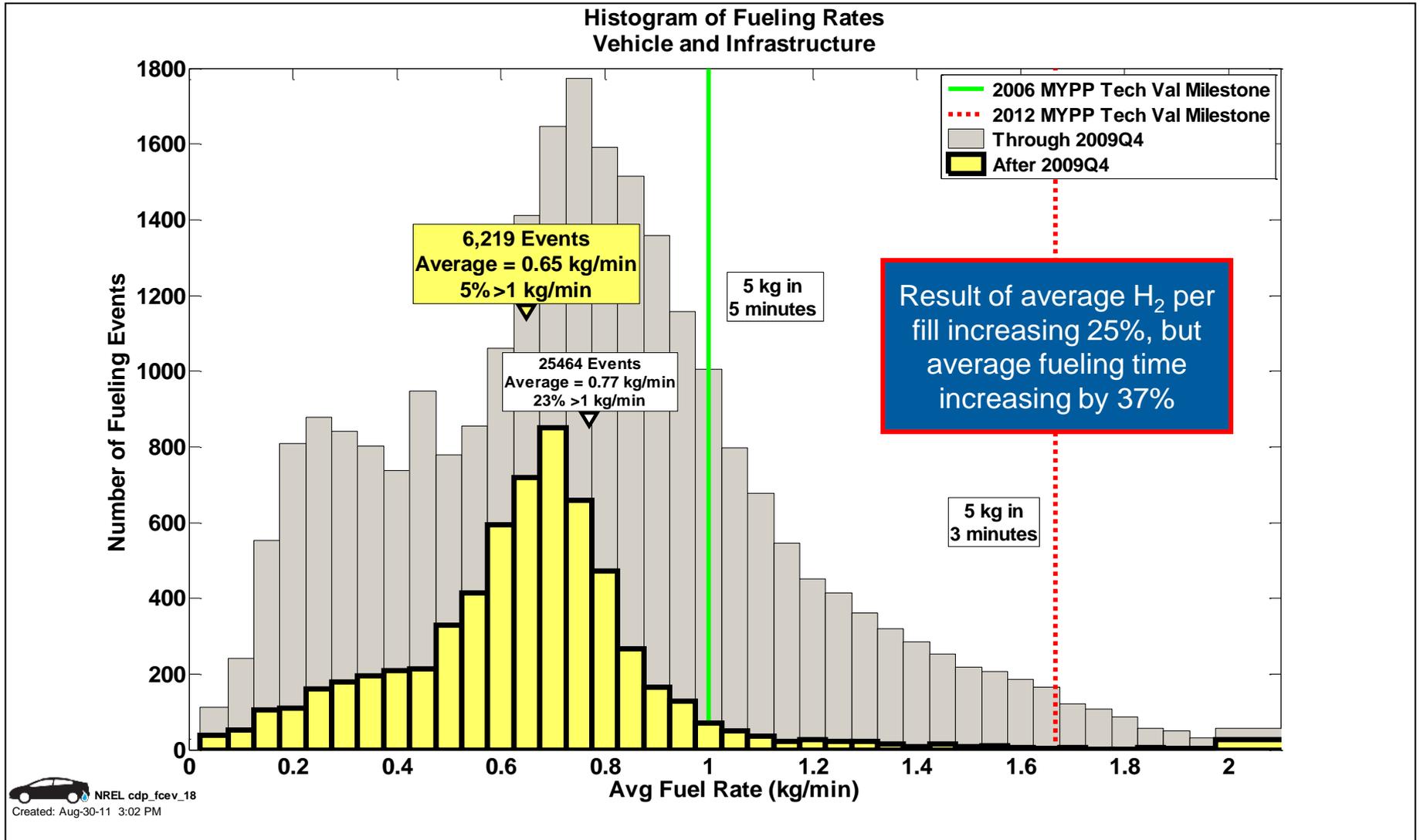
Note: Actual range possible >200 miles

Some CDPs Are Now Looking at the Transition from Demo to Early Market – Utilization is Important

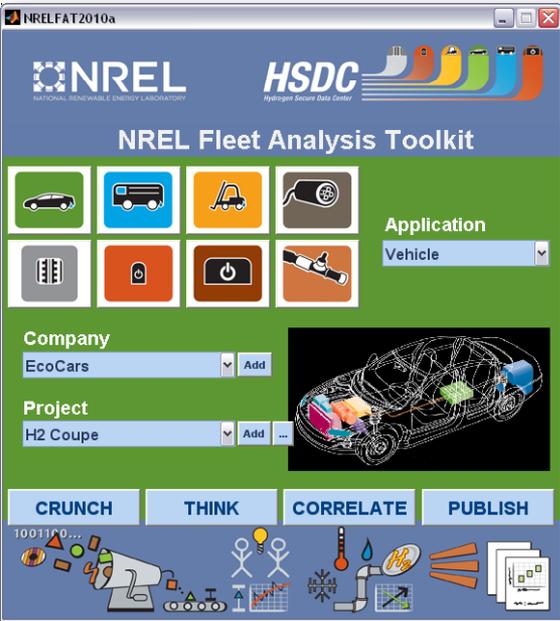
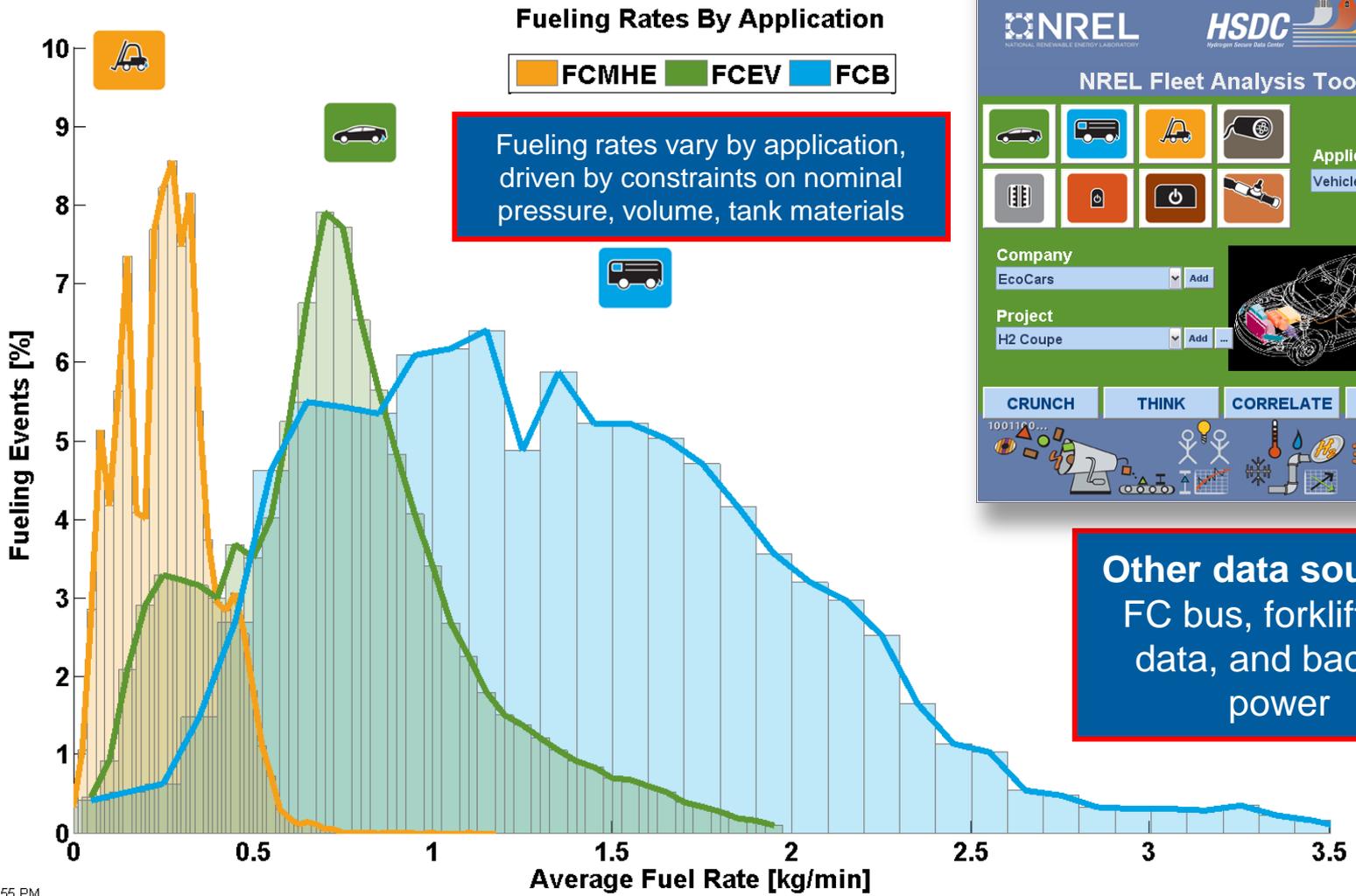


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Changes in Refueling Rate Trends: Average Refueling Rate Decreased 16%



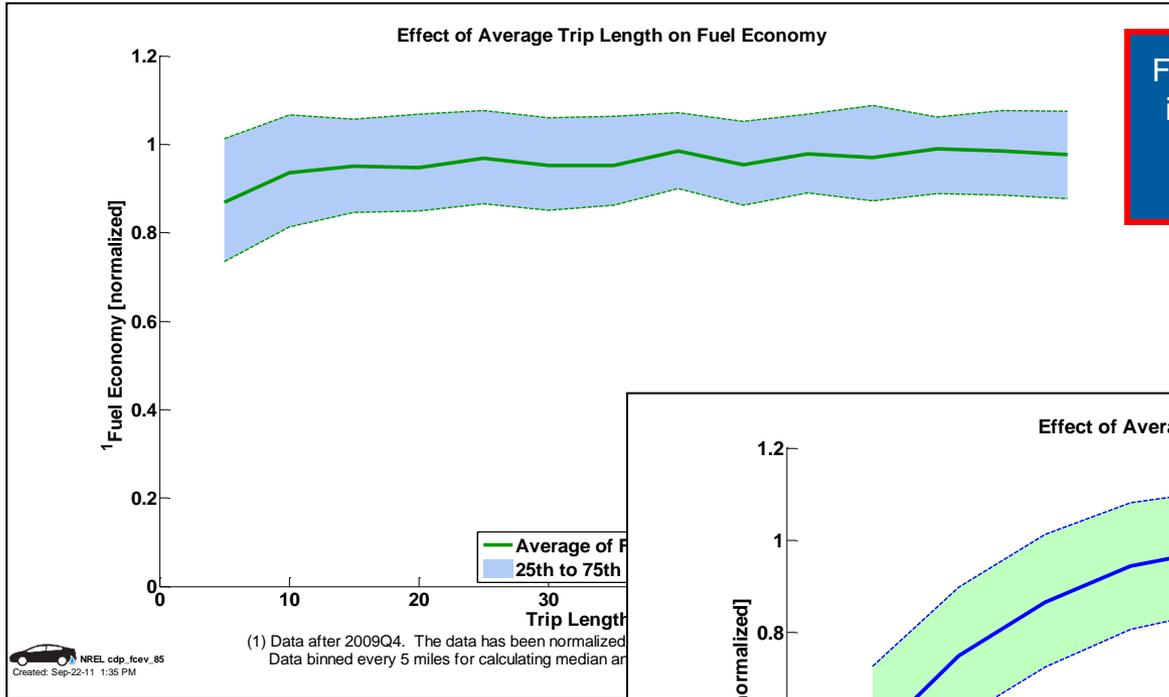
Leveraged Analysis at NREL Across Applications Being Applied to Compare Similarities/Differences



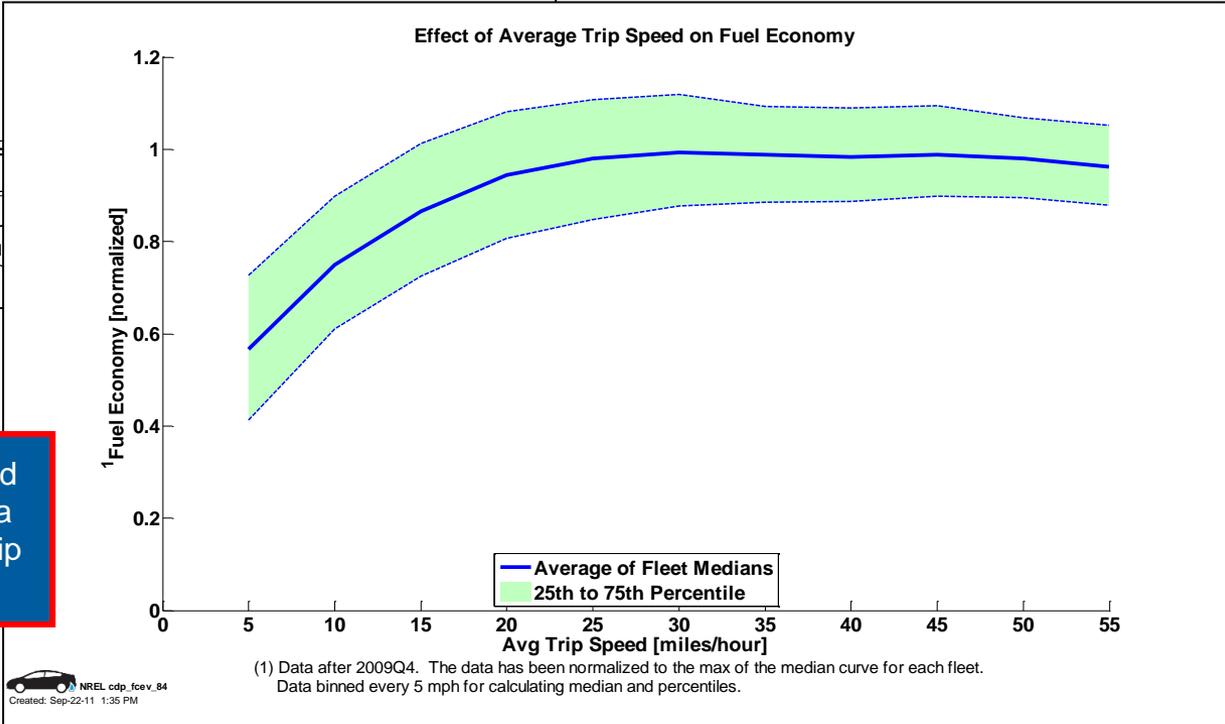
Other data sources:
FC bus, forklift, lab data, and backup power

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Factors Affecting Fuel Economy Were Quantified, Showing Large Spread in Data



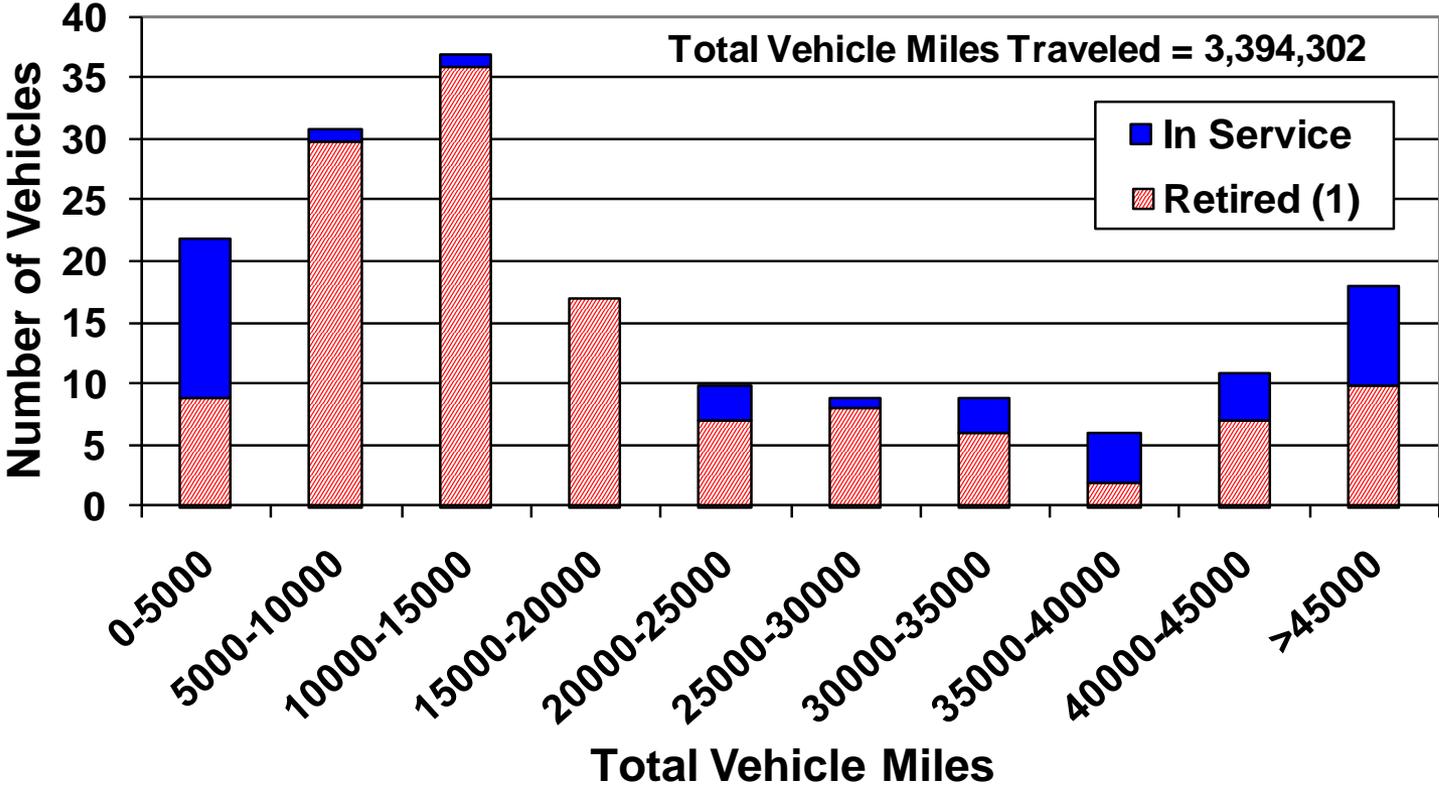
Fuel economy relatively insensitive to average trip length, except for very short trips



Factor of 2X observed for fuel economy as a function of average trip speed

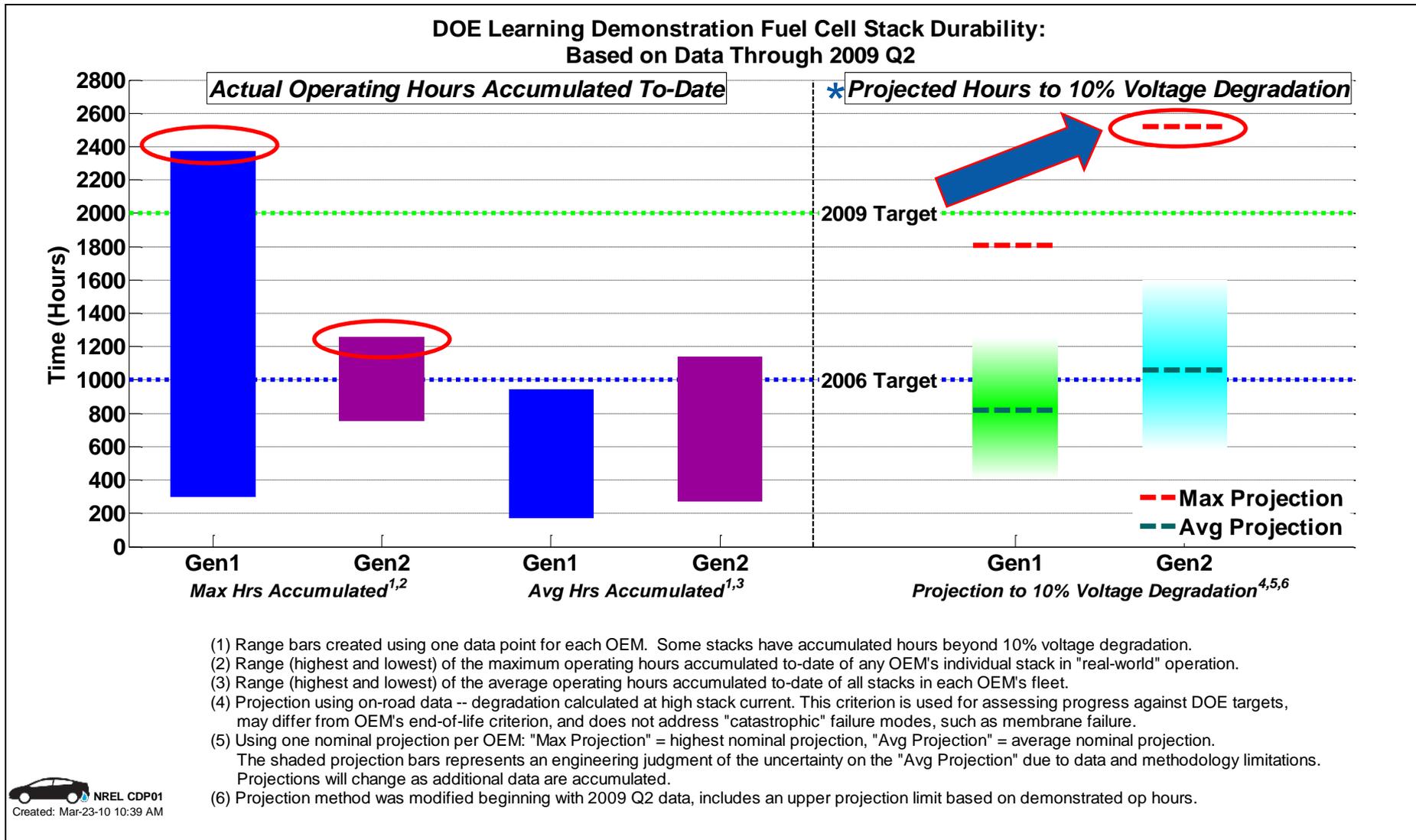
Some Vehicles Have Logged >45,000 Miles

Vehicle Miles: All OEMs, Gen 1 and 2
Through 2011 Q2



(1) Retired vehicles have left DOE fleet and are no longer providing data to NREL
Some project teams concluded in Fall/Winter 2009

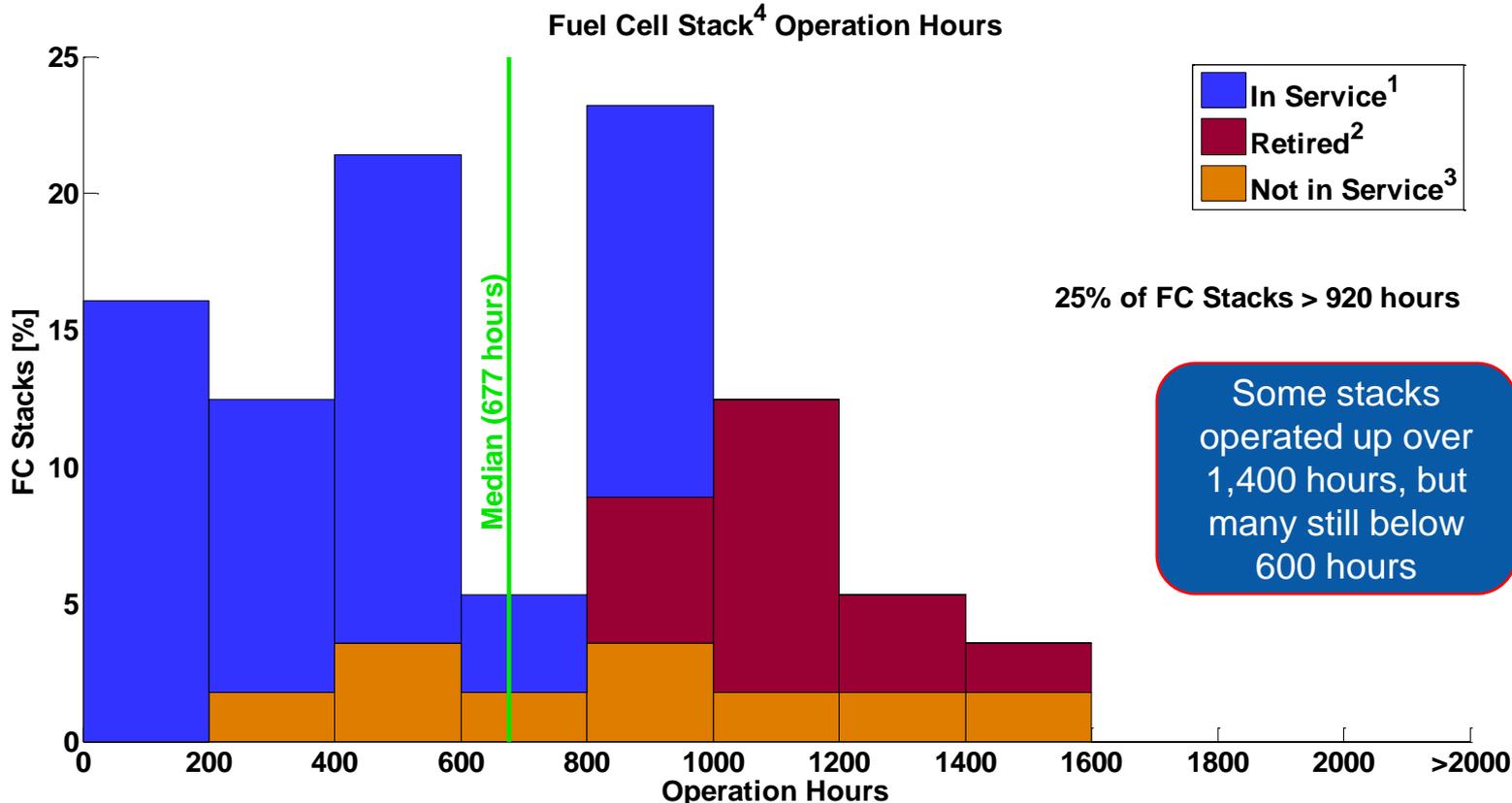
For Reference: FC Durability Target of 2000 Hours Met By Gen 2 Projections (2009 Q4)



* Durability is defined by DOE as projected hours to 10% voltage degradation

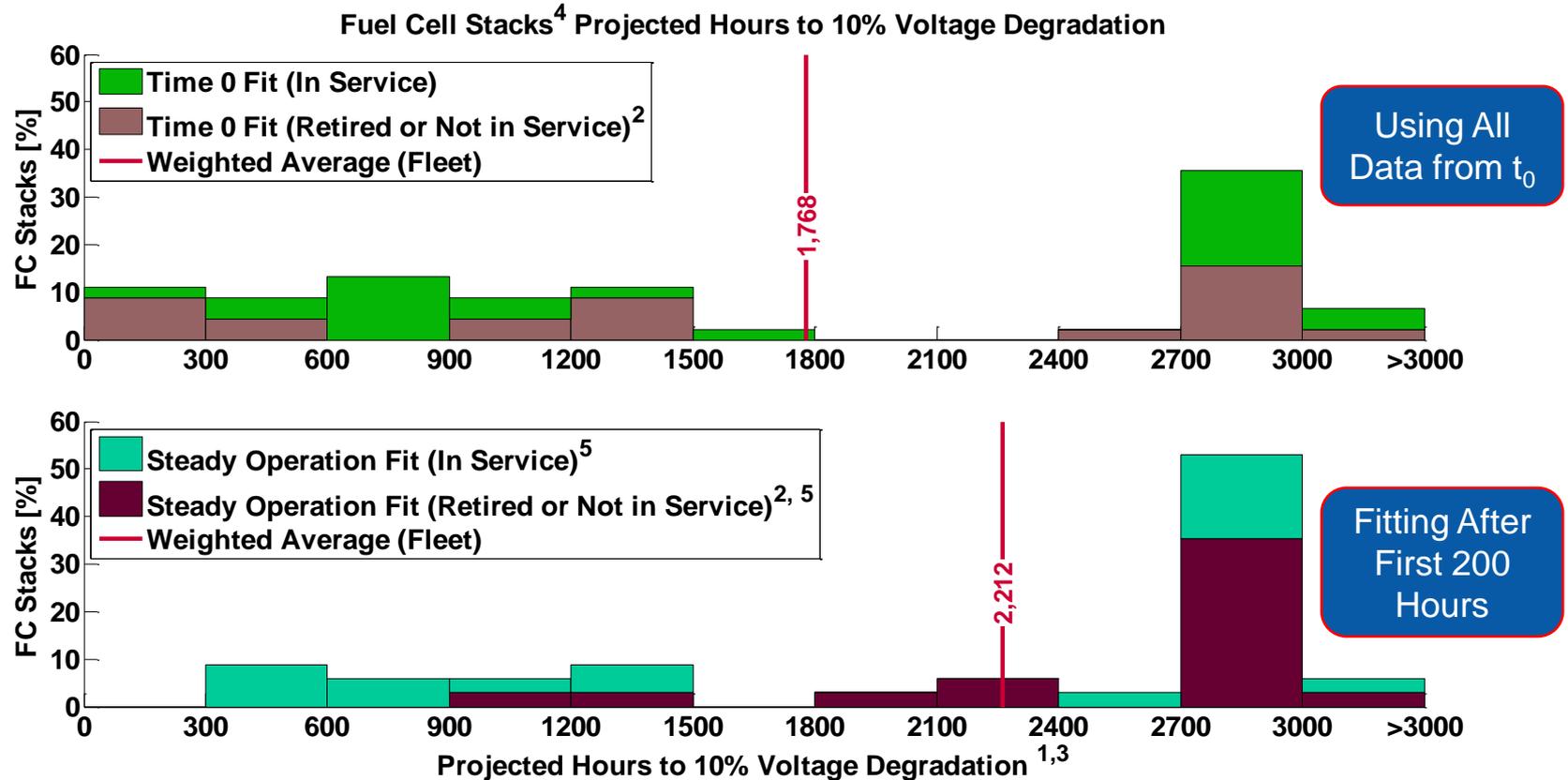
Spring 2010

Data from FCEVs After 2009 Q4: Fuel Cell Stack Operation Hours



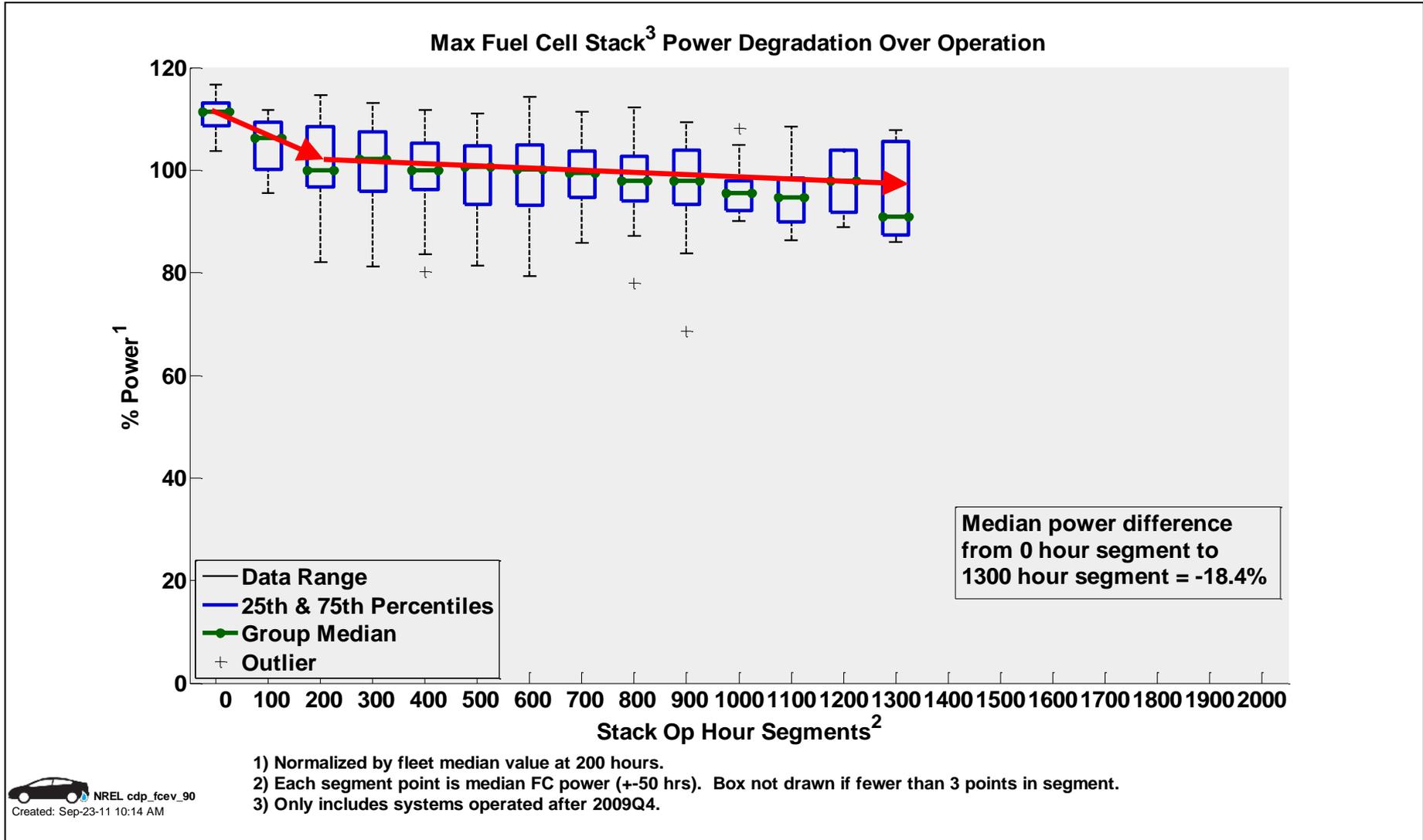
1) Stacks that are in service and accumulating operation hours.
 2) Stacks retired due to low-performance or catastrophic failure.
 3) Indicates stacks that are no longer accumulating hours either a) temporarily or b) have been retired for non- stack performance related issues or c) removed from DOE program.
 4) Only includes systems operating after 2009Q4.

Fuel Cell Stacks Projected Hours to 10% Voltage Degradation; Two Fits

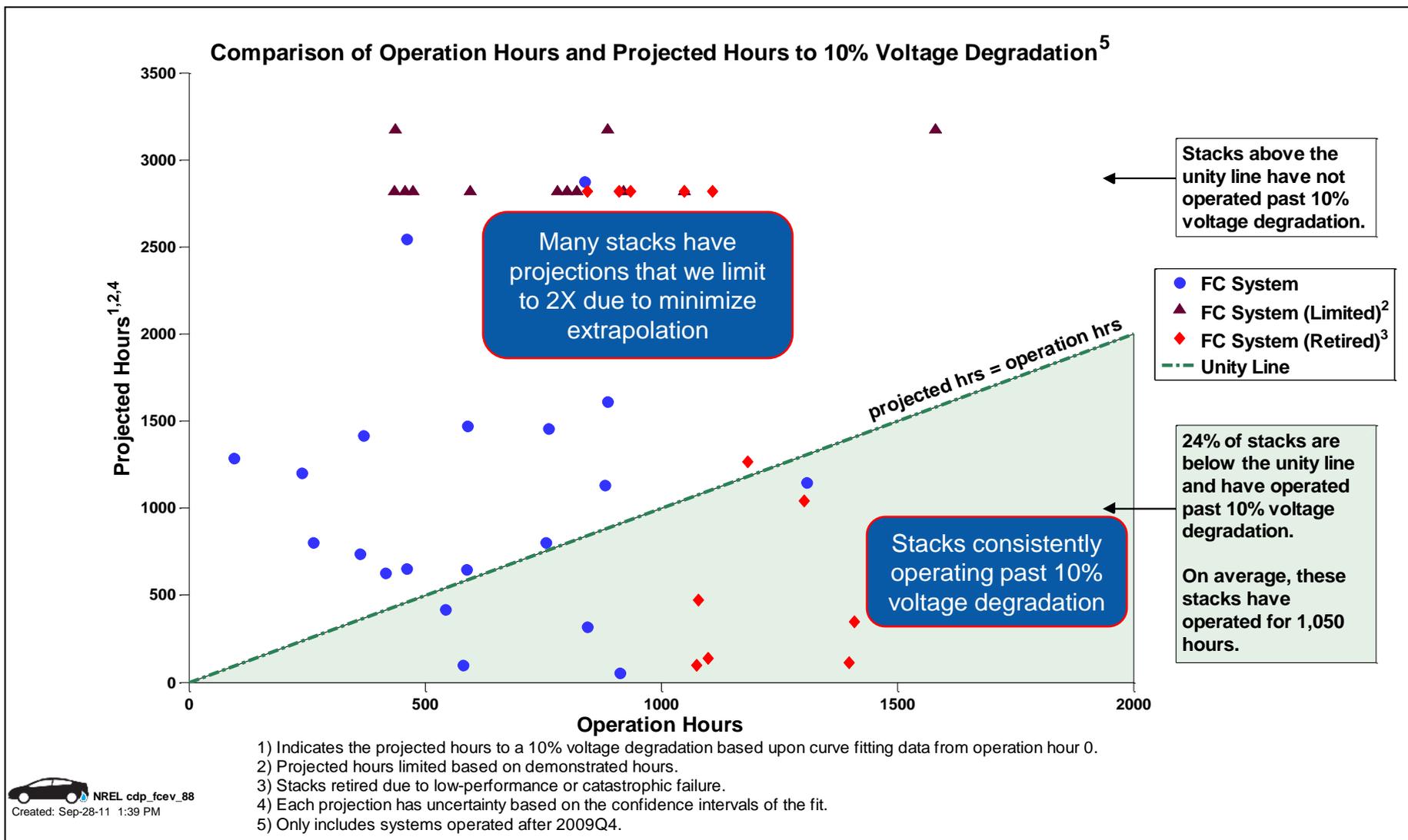


- 1) Projection using field data, calculated at high stack current, from operation hour 0 or a steady operation period. Projected hours may differ from an OEM's end-of-life criterion and does not address "catastrophic" failure modes.
- 2) Indicates stacks that are no longer accumulating hours either a) temporarily or b) have been retired for non-stack performance related issues or c) removed from DOE program.
- 3) Projected hours limited based on demonstrated hours.
- 4) Only includes systems operating after 2009Q4.
- 5) Not all stacks have a steady operation fit which is calculated from data after 200 hr break-in period. The steady operation starting hour is an approximation of the period after initial break-in where degradation levels to a more steady rate.

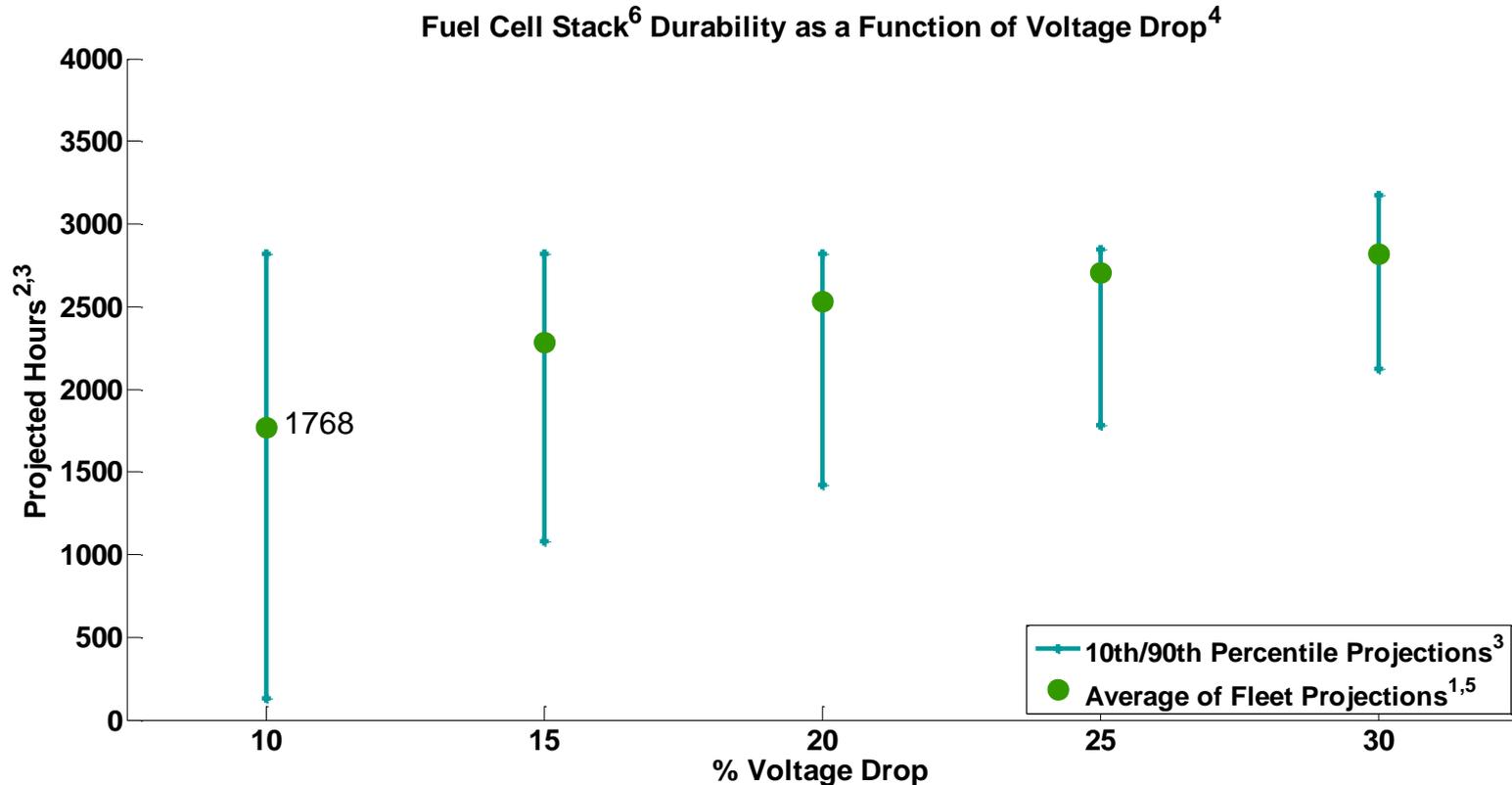
Why Did We Pick 200 Hours? Inflection Point. Max FC Power Degradation Rate Drops with Aging



Comparison of Fuel Cell Operation Hours and Projected Hours to 10% Voltage Degradation



What If We Allowed a Greater Voltage Drop in Our Analysis than 10%?



- 1) 10% Voltage degradation is a DOE metric for assessing fuel cell performance not an indication of an OEM's end-of-life criteria.
- 2) Projections using field data and calculated at high stack current.
- 3) 10th and 90th percentiles spans the range of stack projection. The included stacks satisfy a minimum number of operation hours and weighting factor.
- 4) The projected hours vary based on the percentage of voltage degradation, but the projected hours do not imply that all stacks will (or do) operate to these voltage degradation levels.
- 5) Each fleet has one voltage projection value that is the weighted average of the fleet's fuel cell stack projections.
- 6) Only includes systems operated after 2009Q4.

Learning Demo Data Concluding This Year

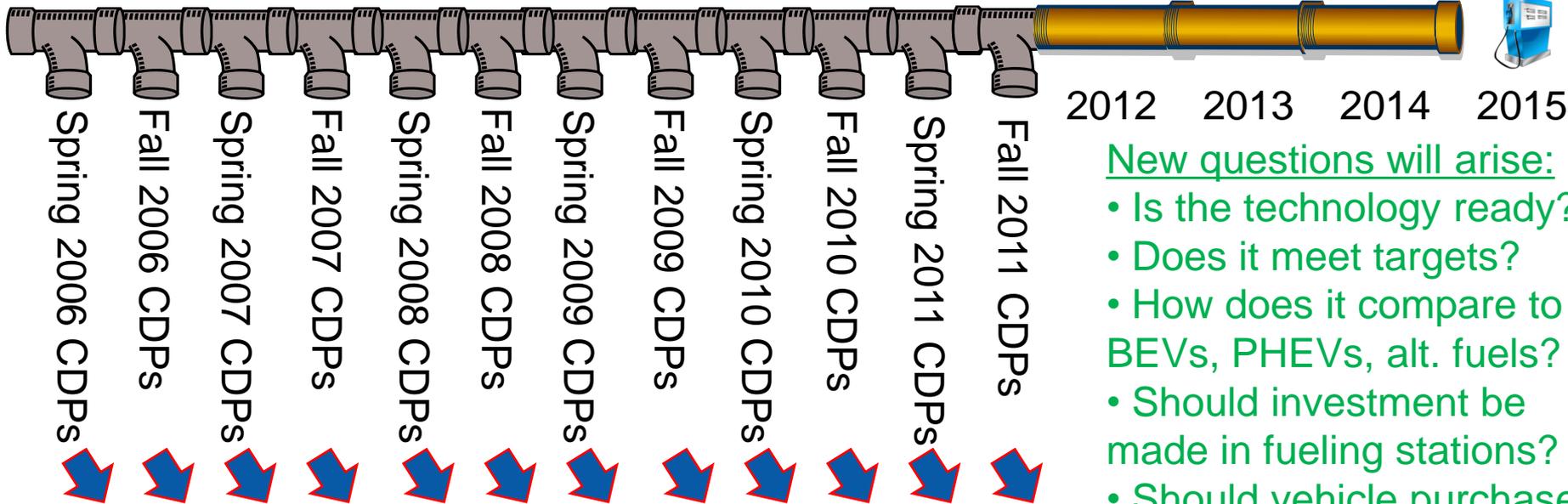
- Partners just provided last data sets under Learning Demo (Nov. 1)
- Currently analyzing July – September 2011 data
- Will publish Winter 2011 CDPs in December/January
- Draft final report in March 2012, published in April
- Continuing to receive data on H2 infrastructure with support from DOE
- Vehicle validation next steps: being discussed now (next slide)

Learning Demo Feeds Pipeline of Objective Info for Decision Makers; Trying to Avoid Approaching Gap



Learning Demo Ends in 2011

Next steps under discussion



- New questions will arise:
- Is the technology ready?
 - Does it meet targets?
 - How does it compare to BEVs, PHEVs, alt. fuels?
 - Should investment be made in fueling stations?
 - Should vehicle purchase incentives be provided?

**OBJECTIVE CREDIBLE EVALUATIONS
LEAD TO INFORMED DECISIONS**

**POTENTIAL DELAYS OF
INVESTMENT BY DECISION-
MAKERS DUE TO UNCERTAINTY**

Technical Summary

- Project has completed ~7 years of real-world validation
- Vehicle operation: 170 vehicles, 146,000 hours, 3.4 million miles, 493,000 trips
- H₂ station operation: 25 stations, 147,000 kg produced or dispensed, 32,000 fuelings
- DOE Key Technical Targets Validated and Met:
 - FC Durability >2,000 hours and Range >250 miles
- New CA fueling stations being included in NREL infrastructure analysis as they come online and provide data

Questions and Discussion



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