

Entering a New Stage of Learning from the U.S. Fuel Cell Electric Vehicle Demonstration Project



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Outline

- Project Goals
- Vehicle and H2 Station Deployment Status
- Performance Compared to Targets
- Highlights of Latest Results and Progress
- Summary and Future work

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

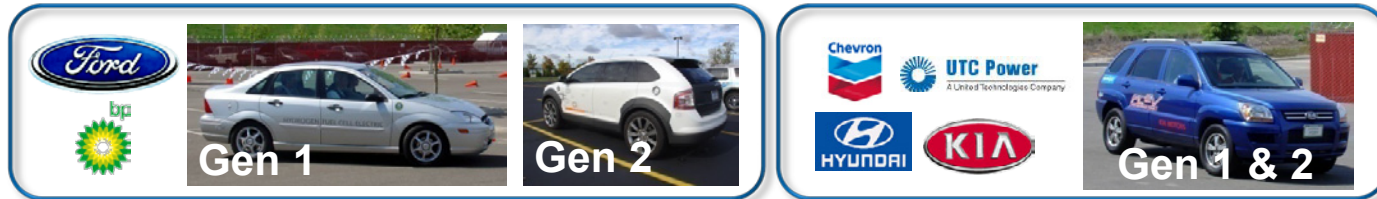
Note: Project extended 2 years to 2011



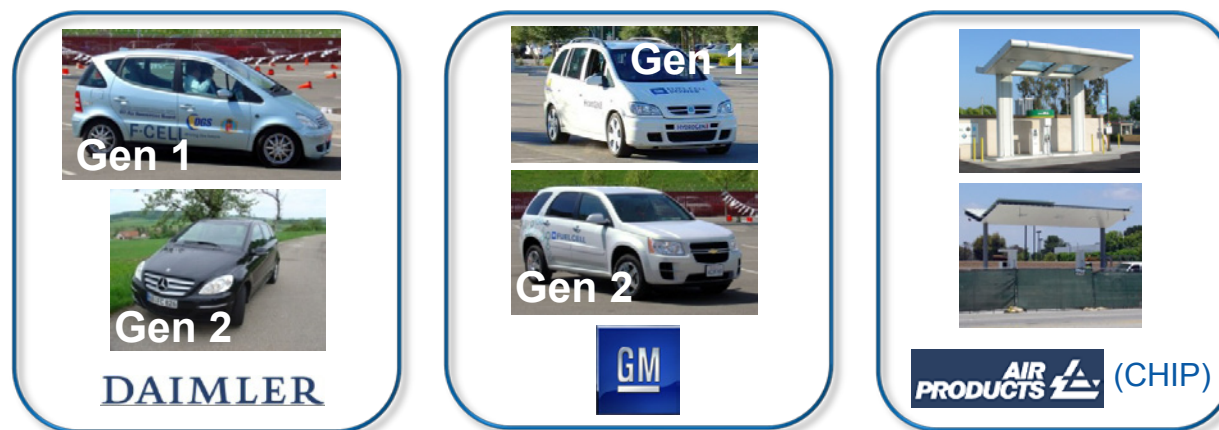
Burbank, CA station. Photo: NREL

Two Teams Concluded Their Projects in 2009, Three are Continuing through 2011

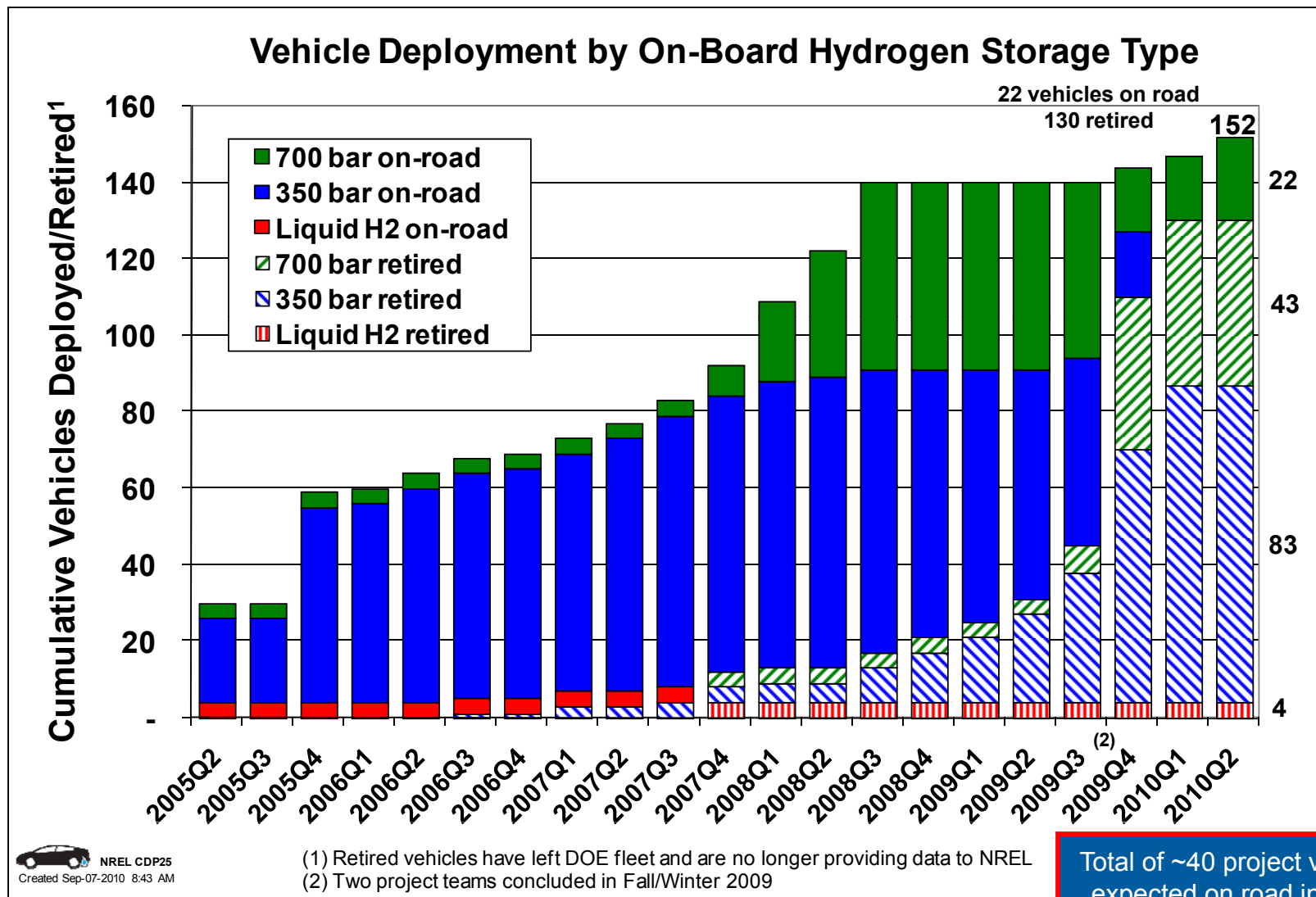
Ford/BP and Chevron/Hyundai-Kia Concluded in 2009



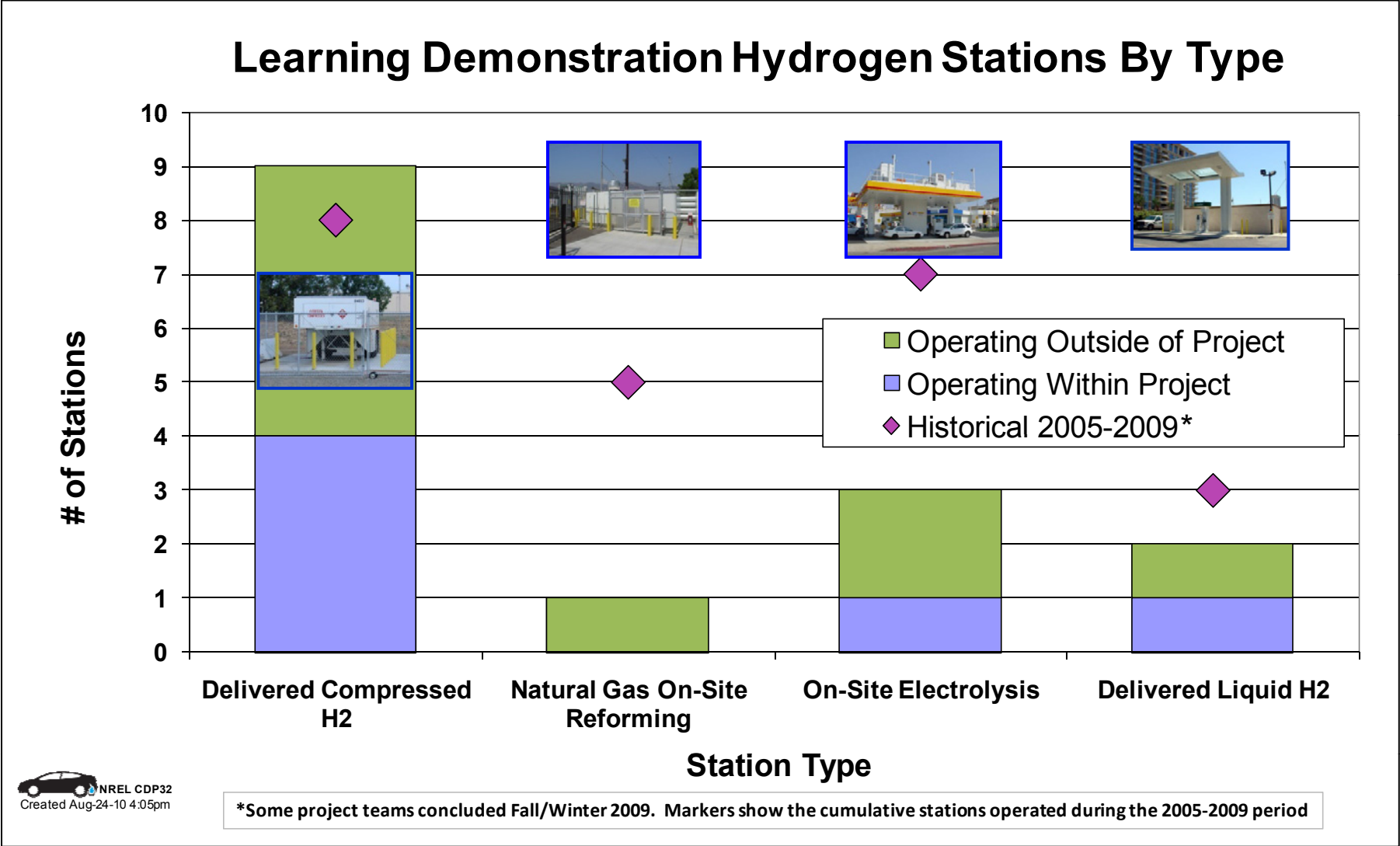
Daimler, GM, and Air Products Continue to Demonstrate Vehicles/Stations within Project through 2011



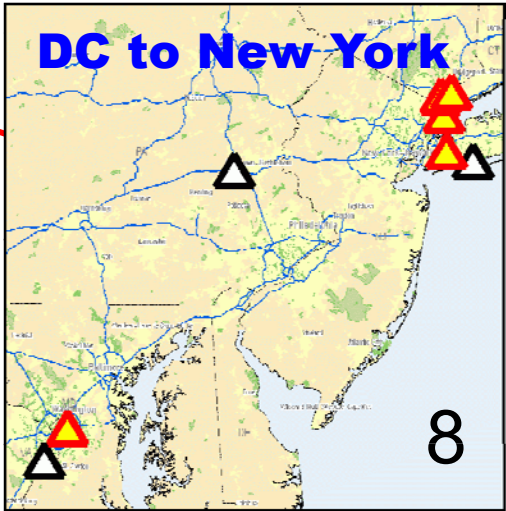
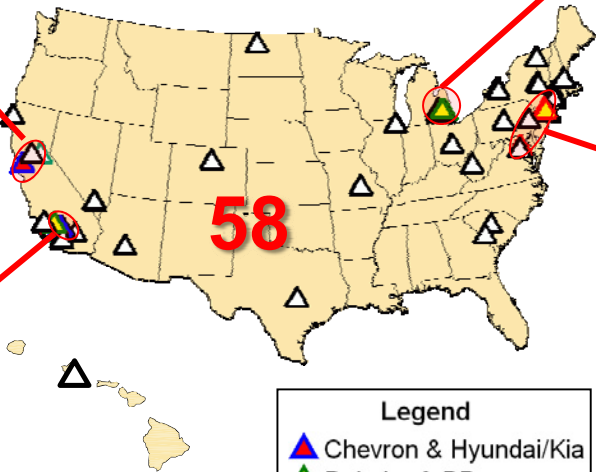
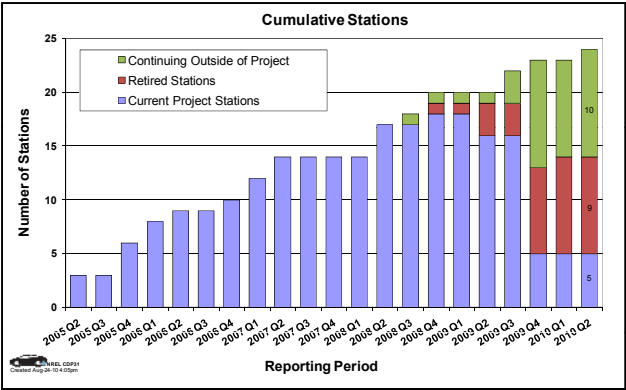
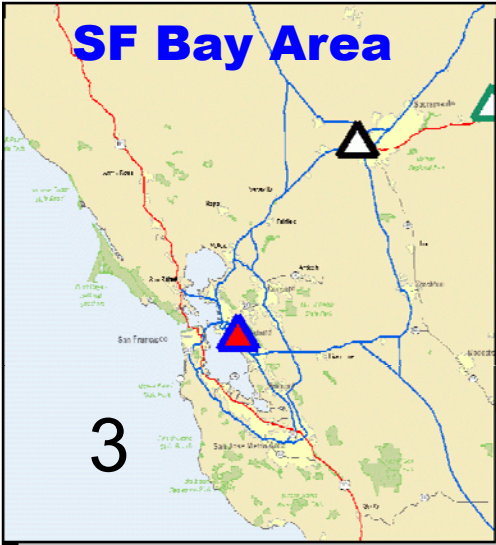
Vehicle Status: All 350 bar Vehicles Retired, Only 700 bar Vehicles Continuing



Fueling Station Status: Stations that Continue to Operate are Mostly Delivered Compressed Hydrogen



Out of 24 Project Stations, 15 Are Still Operational (2/3 outside of DOE project)



Evaluation Against 3 Primary Metrics: Project Met All Major Technical Goals

Vehicle Performance Metrics	Gen 1 Vehicle	Gen 2 Vehicle	2009 Target
<i>Fuel Cell Stack Durability</i>			2000 hours
Max Team Projected Hours to 10% Voltage Degradation	1807 hours	<u>2521</u> hours 	
Average Fuel Cell Durability Projection	821 hours	1062 hours	
Max Hours of Operation by a Single FC Stack to Date	2375 hours	1261 hours	
<i>Driving Range</i>	103-190 miles	196-<u>254</u> miles 	250 miles
<i>Fuel Economy (Window Sticker)</i>	42 – 57 mi/kg	43 – 58 mi/kg	no target
<i>Fuel Cell Efficiency at ¼ Power</i>	51 - 58%	53 - <u>59</u> %	60%
<i>Fuel Cell Efficiency at Full Power</i>	30 - 54%	42 - <u>53</u> %	50%

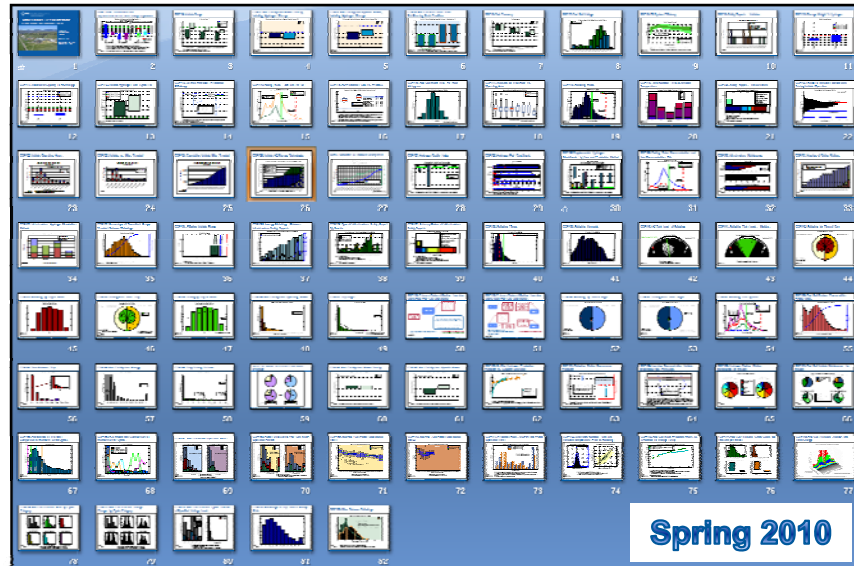
Infrastructure Performance Metrics			2009 Target
<i>H₂ Cost at Station (early market)</i>	On-site natural gas reformation \$7.70 - \$10.30	On-site Electrolysis \$10.00 - \$12.90	\$3/gge
<i>Average H₂ Fueling Rate</i>	0.77 kg/min		1.0 kg/min

Outside of this project, DOE independent panels concluded at 500 replicate stations/year:
 Distributed natural gas reformation at 1500 kg/day: **\$2.75-\$3.50/kg** (2006)
 Distributed electrolysis at 1500kg/day: **\$4.90-\$5.70** (2009)

Outside
review
panel

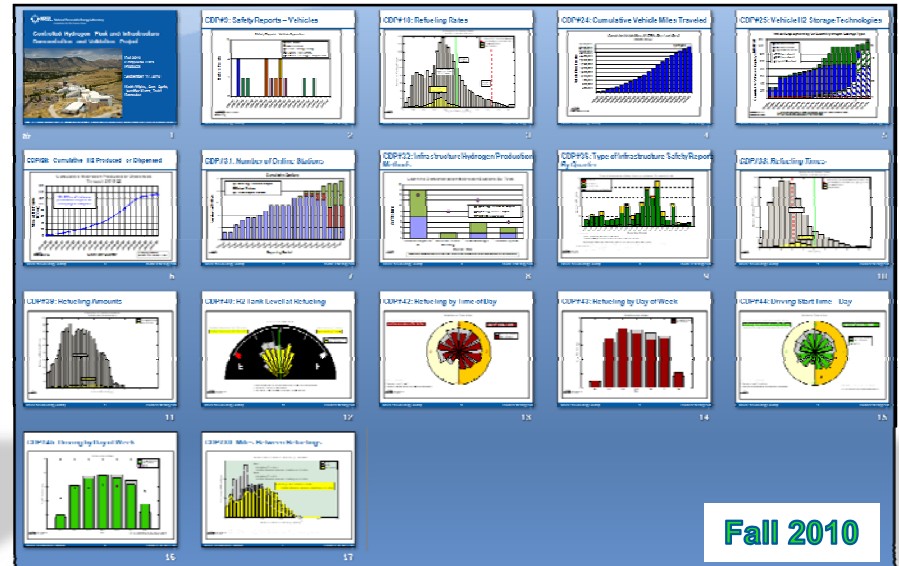


With Fewer Industry Partners Providing Data, Analysis Takes on a New Dimension



80 Spring 2010 Results

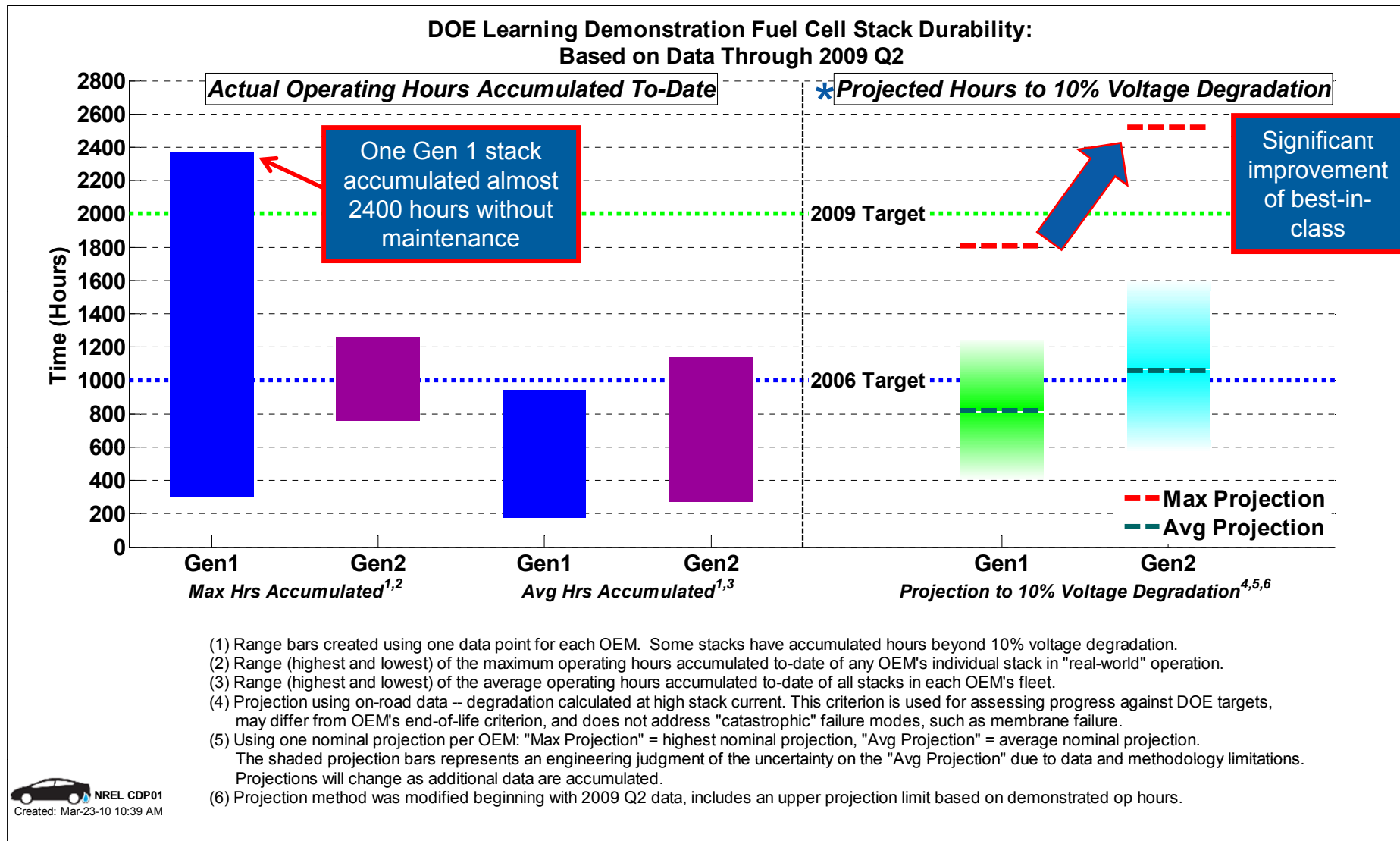
- Most comprehensive set we ever published
- Includes durability, range, fuel economy, etc.
- Covers data from all 4 Learning Demo teams + CHIP project over 5 year period
- Majority of these will now stay static, serving as a historical record of Gen 1 & Gen 2 comparisons.



16 Fall 2010 Results

- No “new” CDPs, but we updated 16 previously published CDPs with data from the last 6 months
- Results on most recent durability, range, fuel economy, not yet possible to publish until more data accumulated (in 2011)
- Covers data from 2 Learning Demo OEMs + CHIP project
- Emphasized changes observed in last 6 months through use of gray (old) and colors (new)

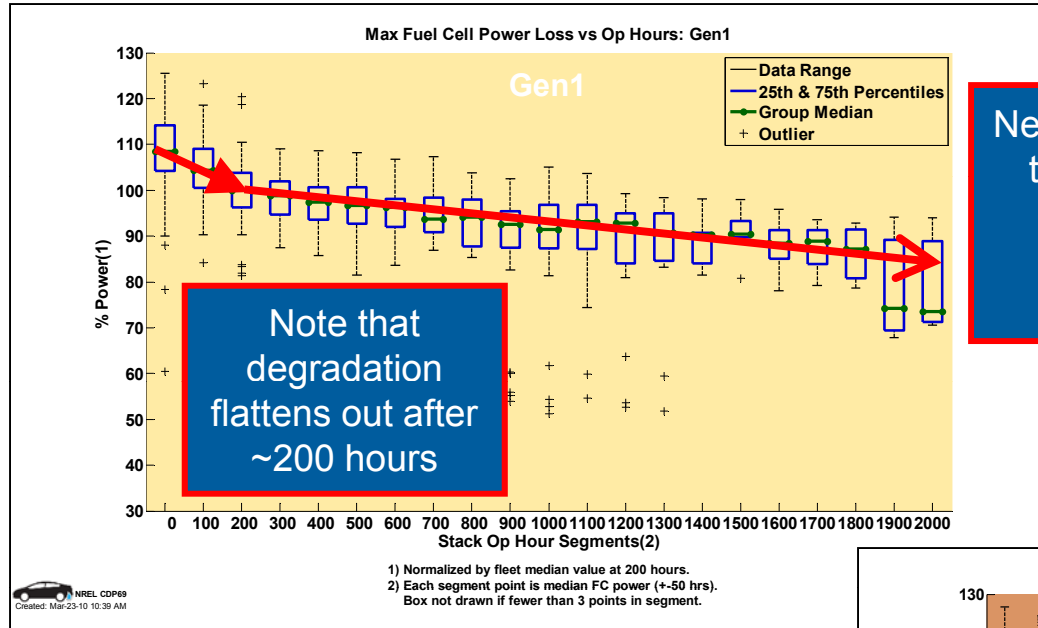
Quantified Gen 2 Fuel Cell System Durability* Improvement from Gen 1



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

Spring 2010

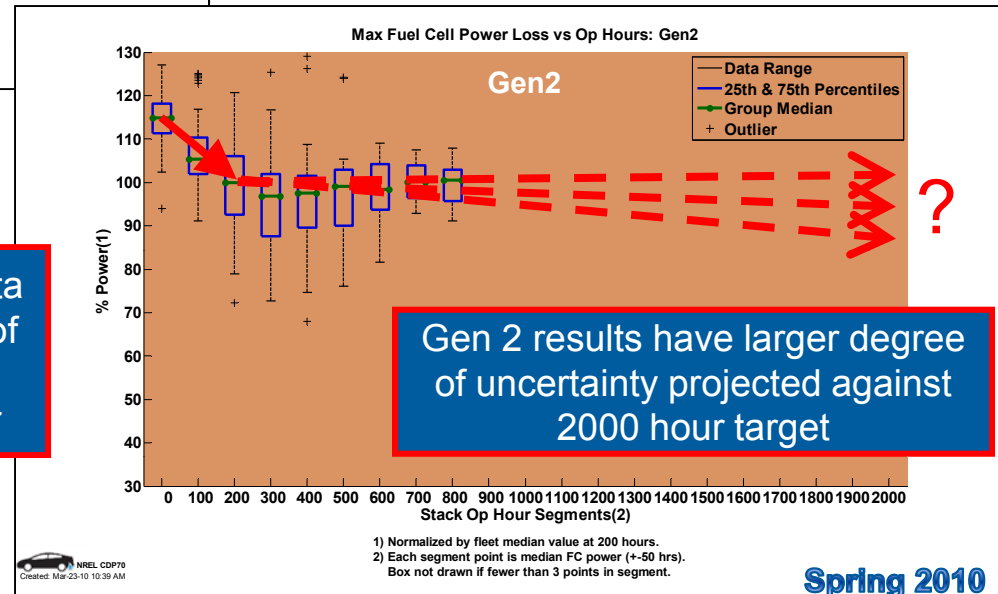
Completed Final Analysis of Gen 1 Fuel Cell System Power Degradation



Need ~1000 hours to have higher confidence in slope of degradation

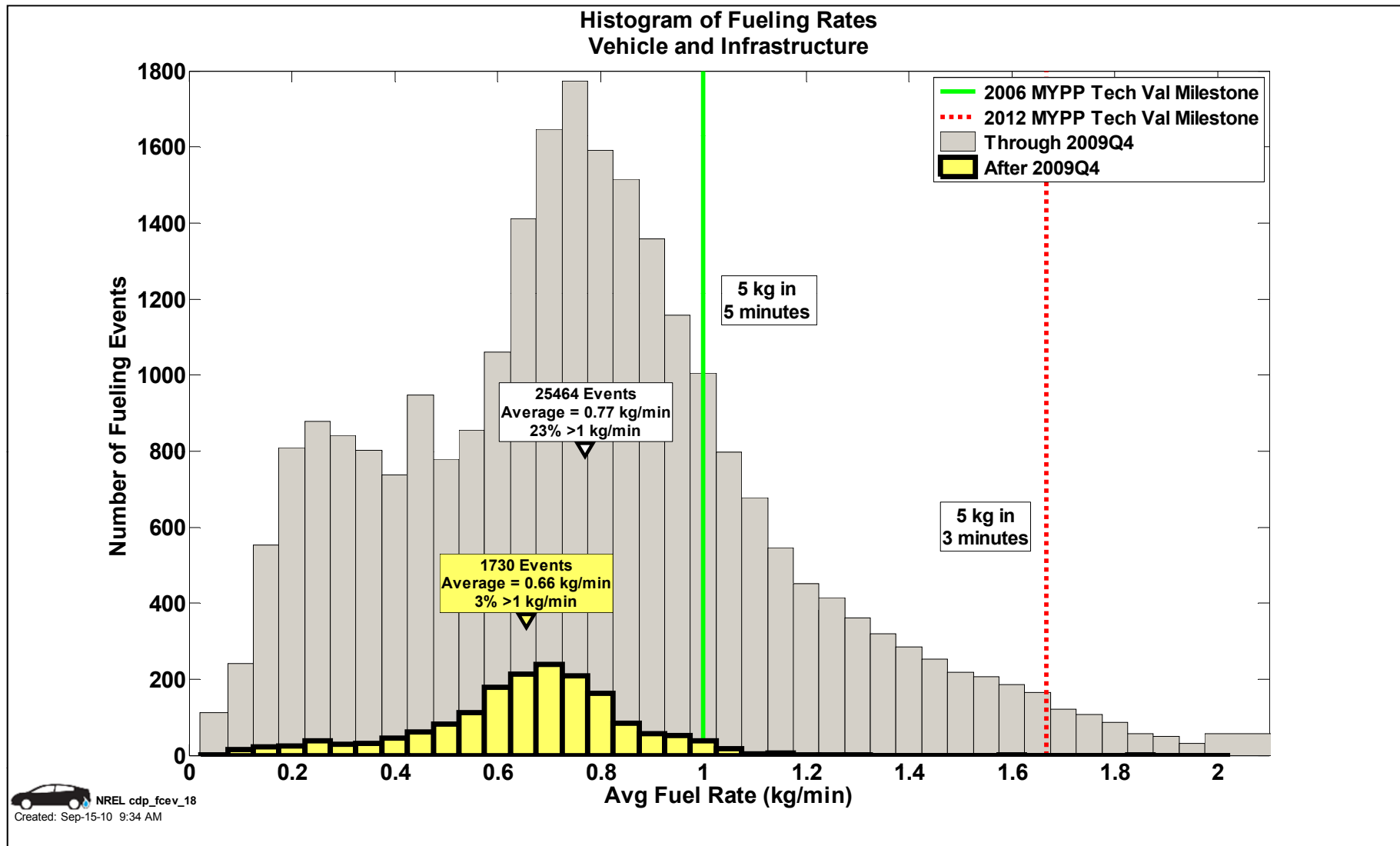
All vehicles continuing in the project will be Gen 2 vehicles

From limited Gen 2 data received so far, trend of flattening after 200 hours appears similar



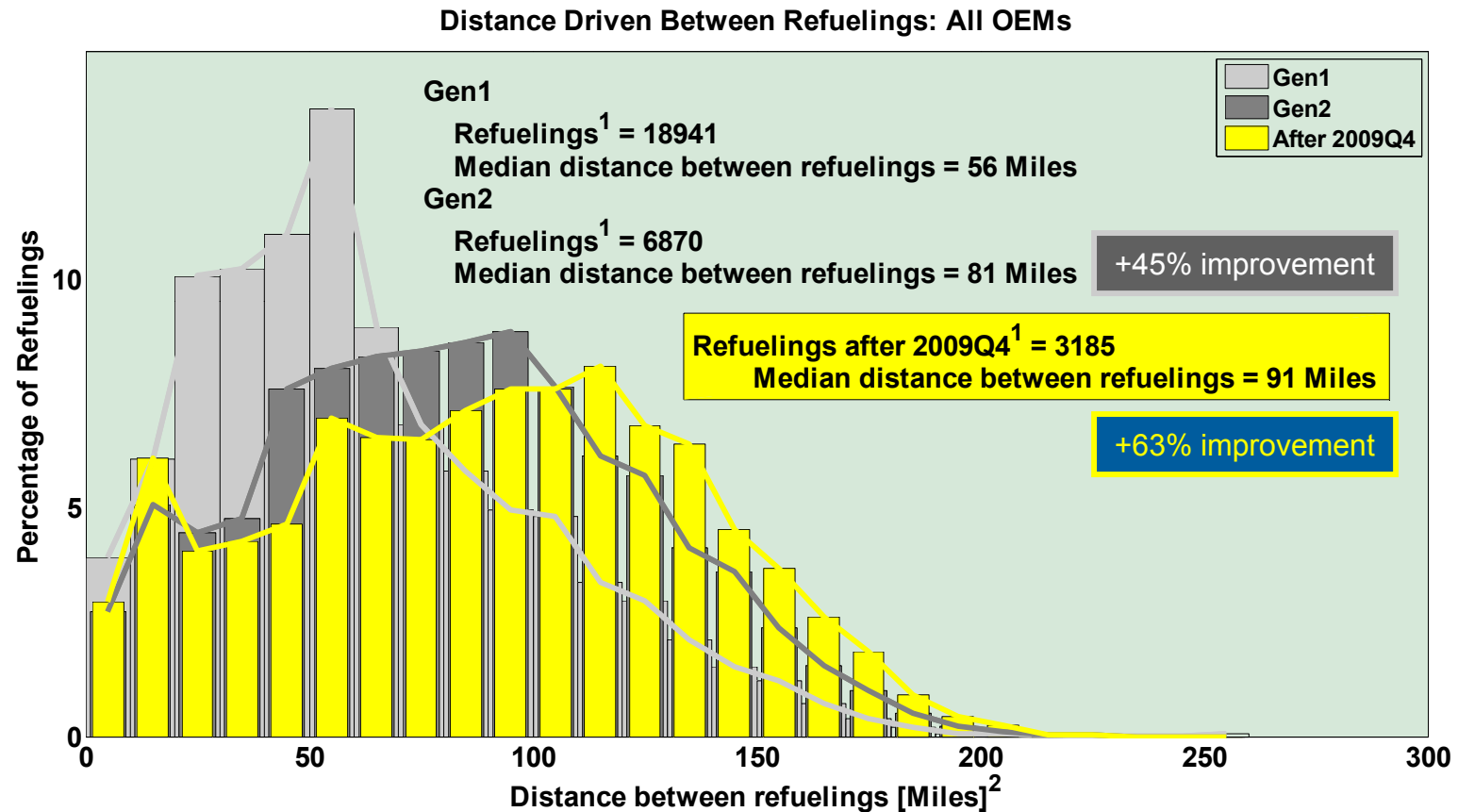
Spring 2010

Based on Limited Data from Last 6 Months, Average Fueling Rate Decreased 14%



Fall 2010

Real-World Driving Range Between Refuelings Continues to Improve as Demonstration Progresses



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.

“window-sticker” range
from adjusted dyno
tests is 196-254 miles

Driving Behavior in Last 6 Months

Much More Similar to U.S. National Average

Driving by Time of Day

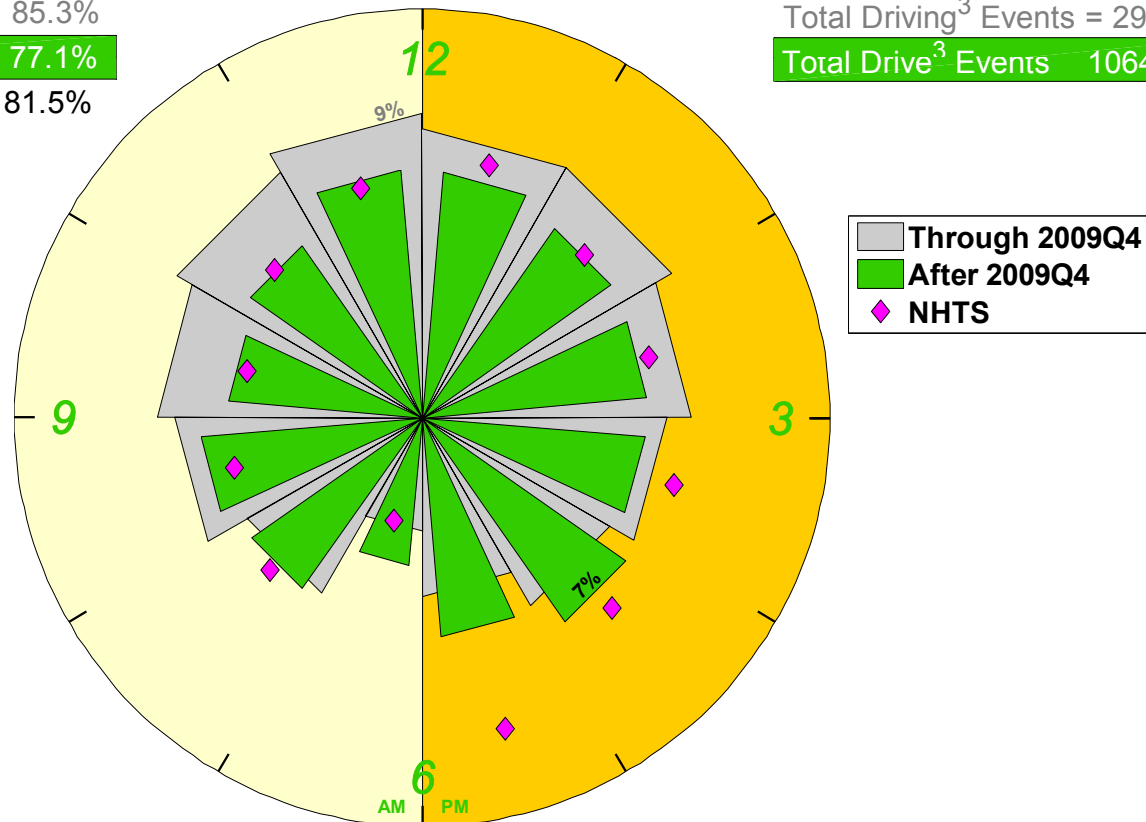
% of driving trips b/t 6 AM & 6 PM: 85.3%

% of driving trips b/t 6 AM & 6 PM: 77.1%

% of NHTS trips b/t 6 AM & 6 PM: 81.5%

Total Driving³ Events = 295222

Total Drive³ Events = 10646



1. Driving trips between 6 AM & 6 PM

2. The outer arc is set at 12 % total Driving.

3. Some events not recorded/detected due to data noise or incompleteness.

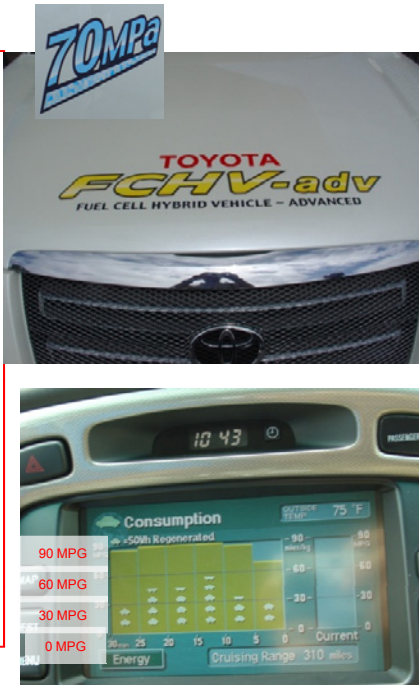
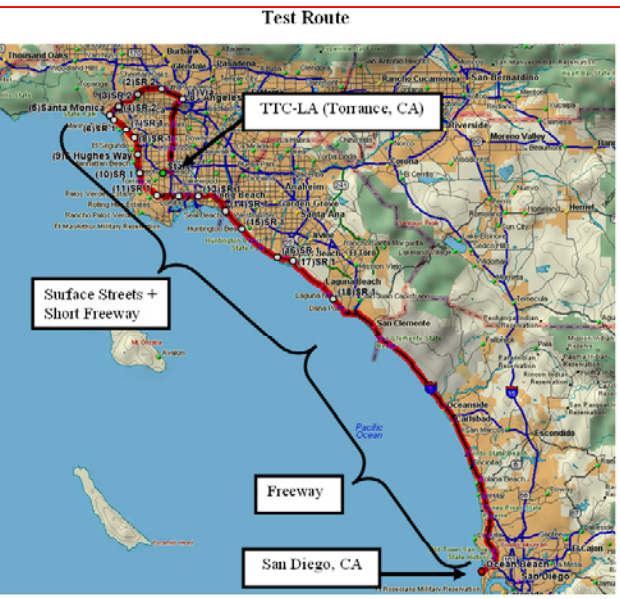
 NREL cdp_fcev_44
Created: Sep-02-10 12:48 PM

2001 NHTS Data Includes Car, Truck, Van, & SUV day trips

ASCII.csv Source: <http://nhts.ornl.gov/download.shtml#2001>

Fall 2010

Range: NREL/SRNL Verified Toyota FCHV-adv Driving Range >400-Mile (Without Refueling) on June 30, 2009



	Average trip distance (miles)	H ₂ consumed (kg)	Remaining usable H ₂ (kg)	Calculated remaining range (miles)	(miles)	(miles)
Vehicle #1	331.50	4.8255	1.4854	102.04	433.55	431
Vehicle #2	331.45	4.8751	1.4328	97.41	428.87	

SRNS-STI-2009-00446

Evaluation of Range Estimates for Toyota FCHV-adv Under Open Road Driving Conditions

Keith Wipke¹, Donald Anton², Sam Sprik¹

August 10, 2009
PTS-05 of SRNS CRADA No. CR-04-003

¹ National Renewable Energy Laboratory
² Savannah River National Laboratory

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Summary and Future Work

- Project has completed >5 full years of operation
- Vehicle operation: 114,000 hours, 2.87 million miles, 436,000 trips
- H2 station operation: 134,000 kg produced or dispensed, 27,000 refuelings
- DOE Key Technical Targets Met: FC Durability and Range
- Future Work:
 - Progress to be tracked over final 2 years of project
 - Additional collaboration with remaining auto OEM teams
 - New CA fueling stations planned for inclusion in future results as data becomes available

Questions and Discussion



Project 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