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

**November 8, 2010**

**EVS-25 Shenzhen, China**

**Keith Wipke, Sam Sprik, Jennifer Kurtz, Todd Ramsden, John Garbak**

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



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Jennifer Kurtz, Todd  
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# Outline

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- 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 H<sub>2</sub> FC Vehicles and Infrastructure in Parallel
- Identify Current Status and Evolution of the Technology

- Relevance

- Objectively Assess Progress Toward Technology Readiness
- Provide Feedback to H<sub>2</sub> 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: A red circle highlights the 2009 and 2015 columns. Two blue checkmarks are placed over the 2009 and 2015 values for Fuel Cell Stack Durability and Vehicle Range. A box labeled 'Outside review panel' is placed over the 2009 and 2015 values for Hydrogen Cost at Station.*

*Note: Project extended 2 years to 2011*



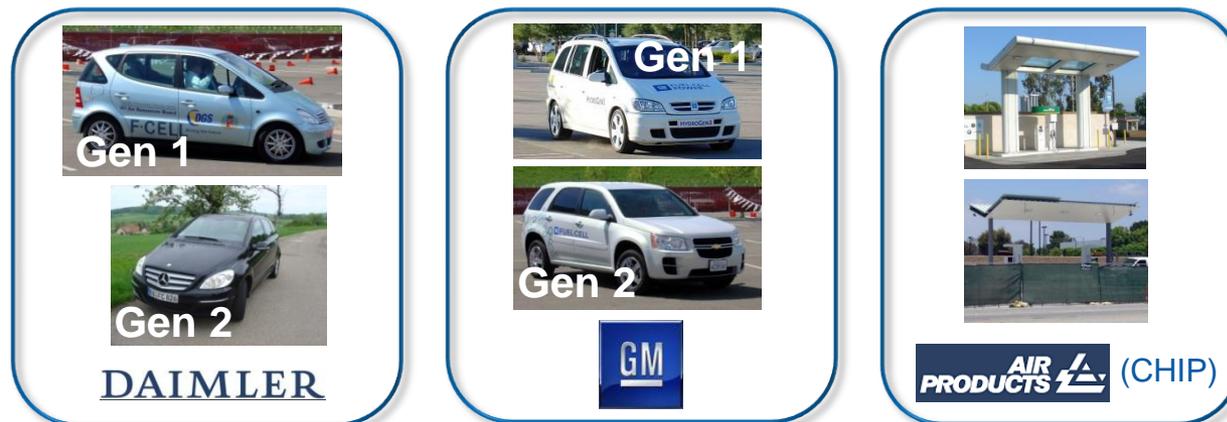
Burbank, CA station. Photo: NREL

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

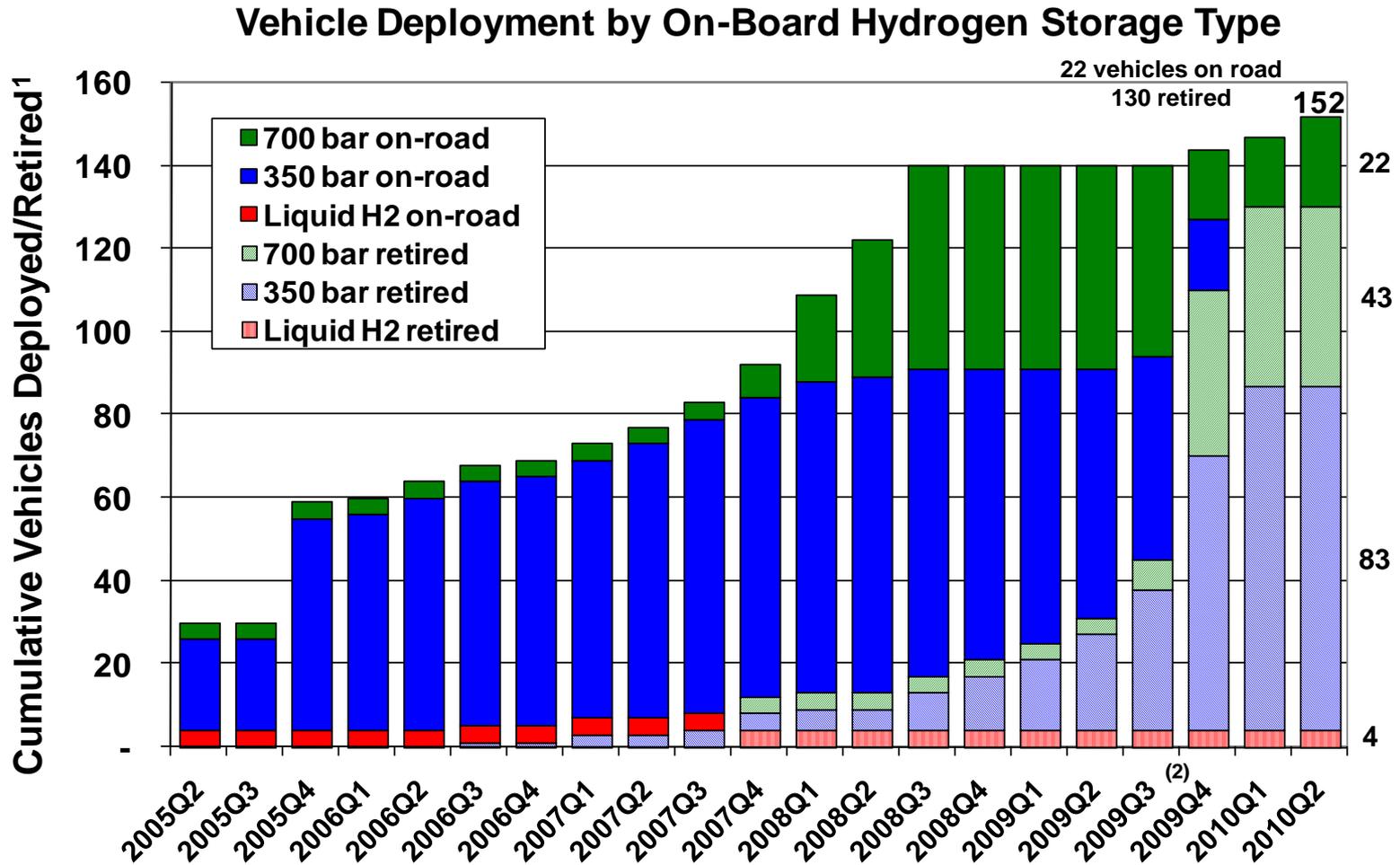
Ford/BP and Chevron/Hyundai-Kia Concluded in 2009



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



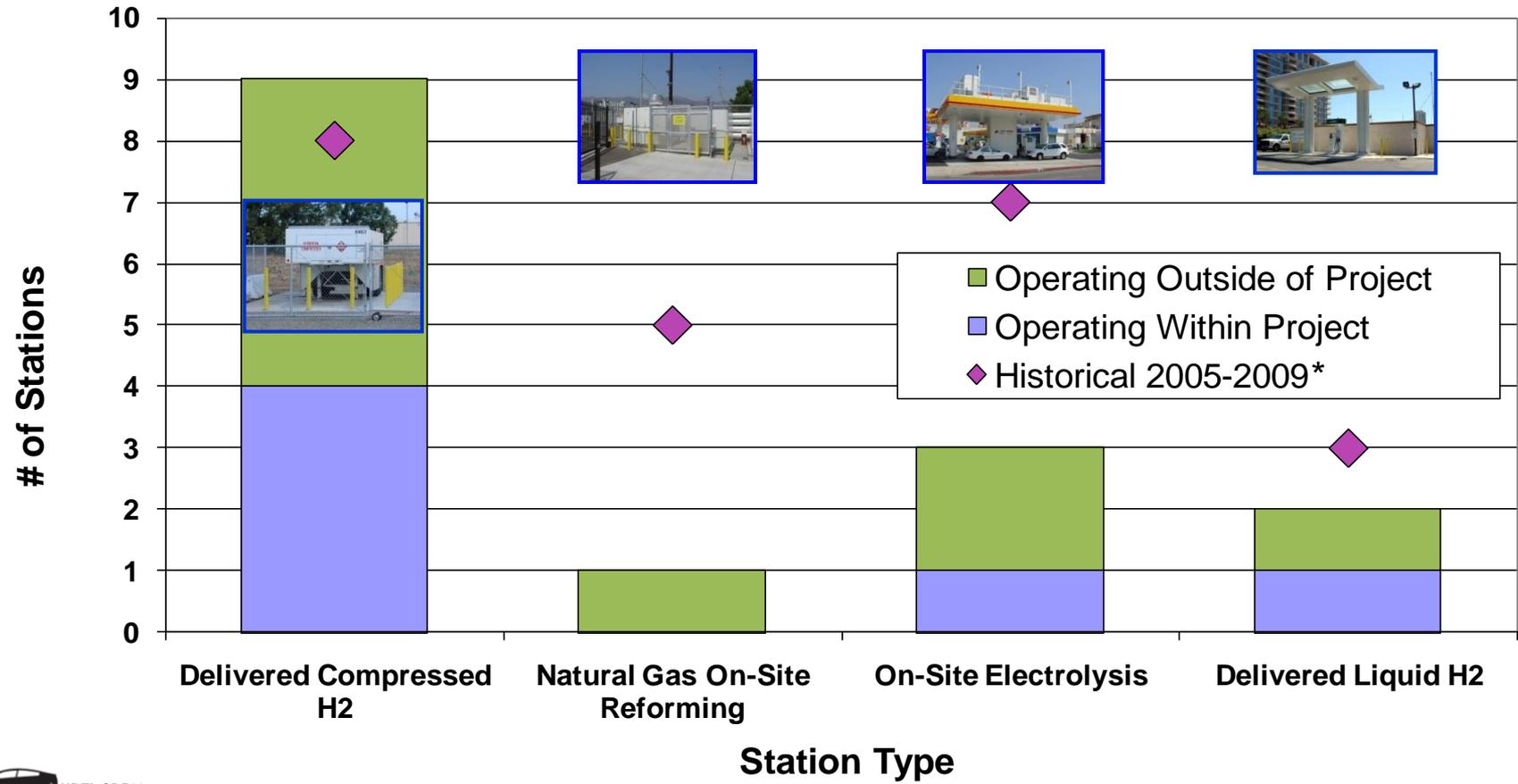
 NREL CDP25  
Created Sep-07-2010 8:43 AM

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

Total of ~40 project vehicles expected on road in 2011, for total of ~170 deployed

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

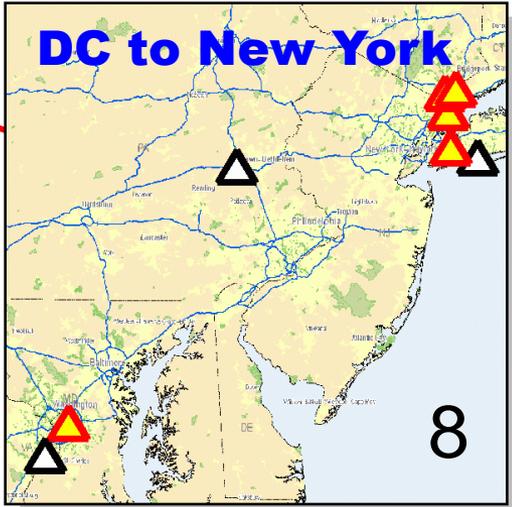
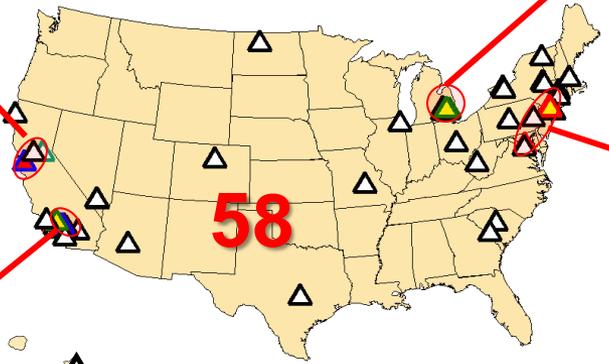
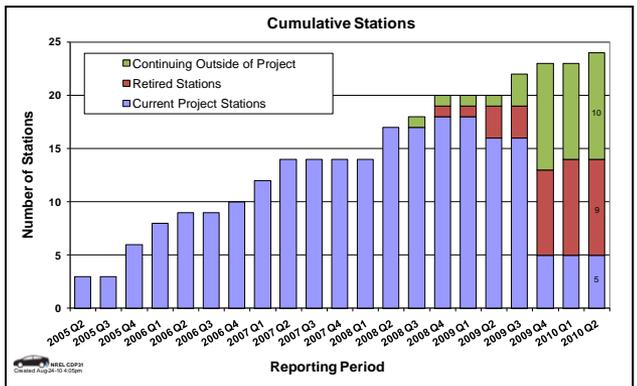
## Learning Demonstration Hydrogen Stations By Type



NREL CDP32  
Created Aug-24-10 4:05pm

\*Some project teams concluded Fall/Winter 2009. Markers show the cumulative stations operated during the 2005-2009 period

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

Infrastructure Performance Metrics			2009 Target
<b>H<sub>2</sub> Cost at Station (early market)</b>	On-site natural gas reformation <b>\$7.70 - \$10.30</b>	On-site Electrolysis <b>\$10.00 - \$12.90</b>	<b>\$3/gge</b>
Average H <sub>2</sub> Fueling Rate	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)

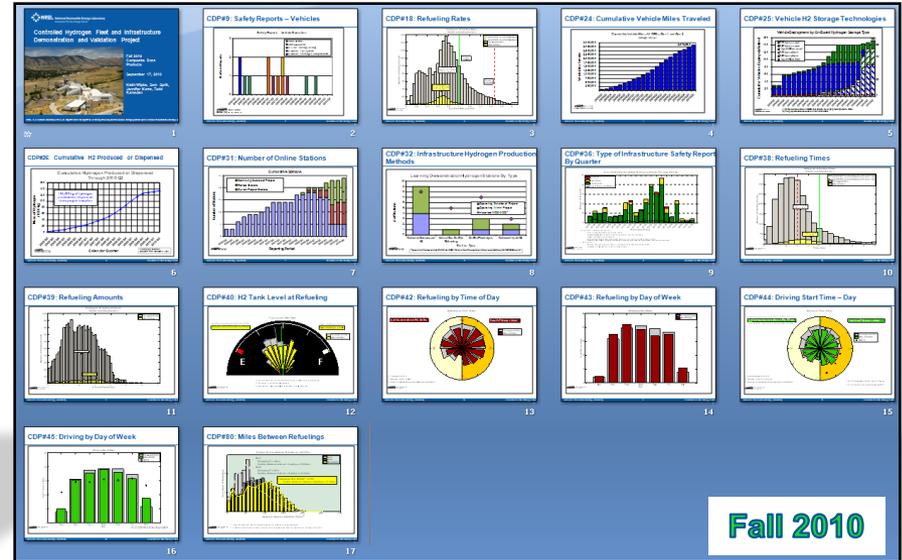


# With Fewer Industry Partners Providing Data, Analysis Takes on a New Dimension



## 80 Spring 2010 Results

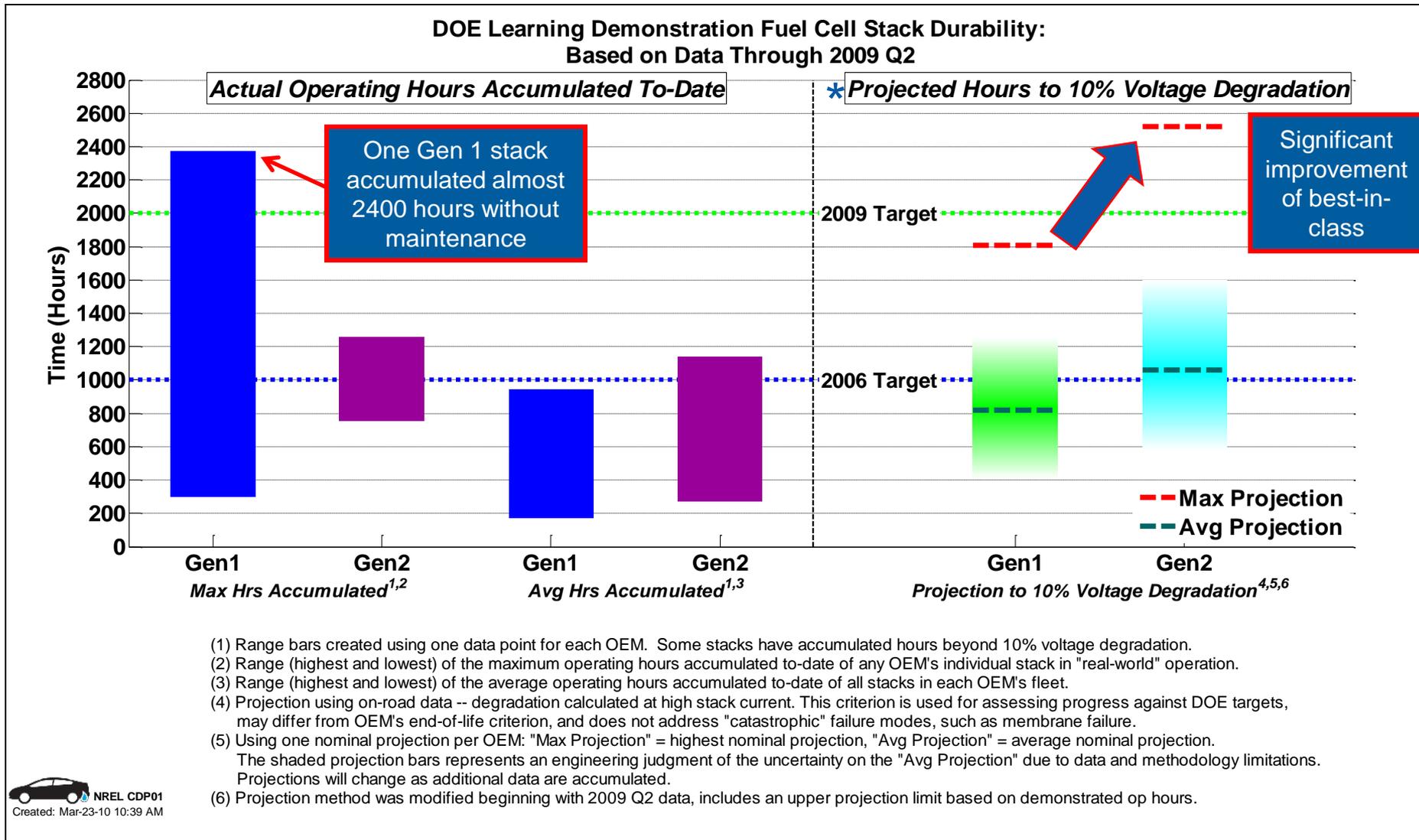
- Most comprehensive set we ever published
- Includes durability, range, fuel economy, etc.
- Covers data from all 4 Learning Demo teams + CHIP project over 5 year period
- Majority of these will now stay static, serving as a historical record of Gen 1 & Gen 2 comparisons.



## 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)

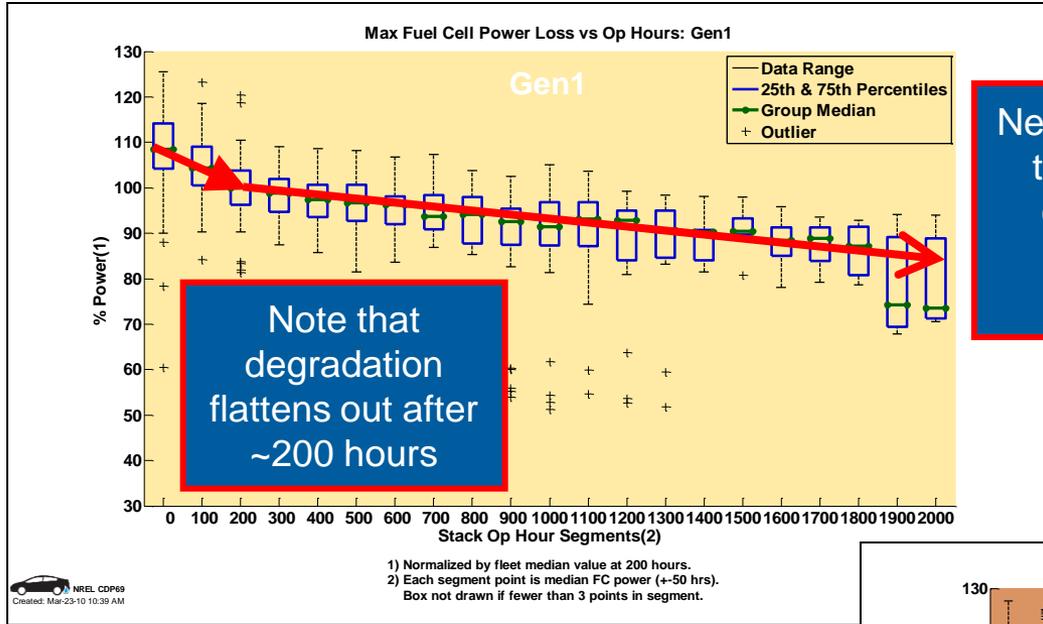
# Quantified Gen 2 Fuel Cell System Durability\* Improvement from Gen 1



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

Spring 2010

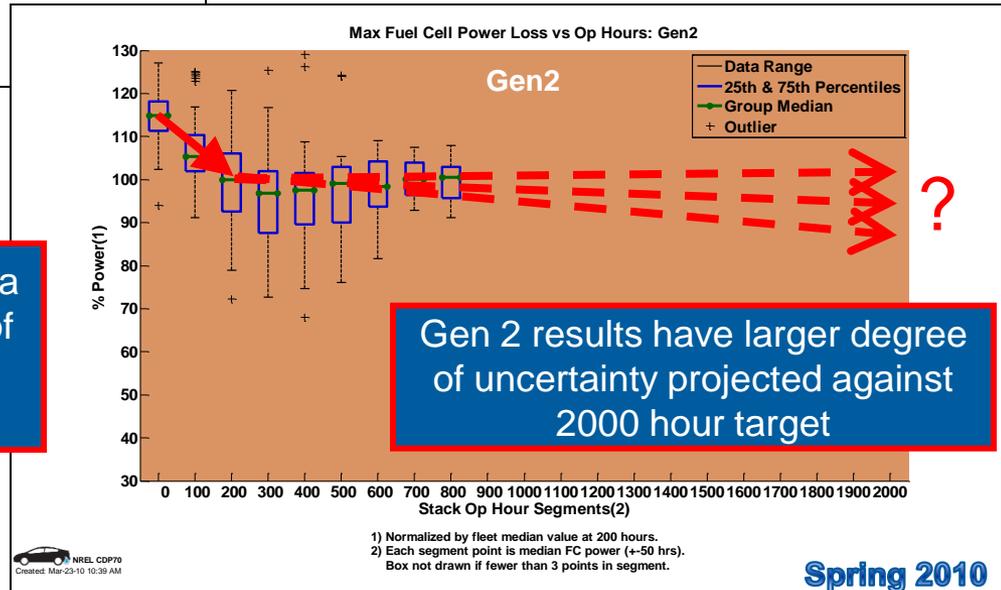
# Completed Final Analysis of Gen 1 Fuel Cell System Power Degradation



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

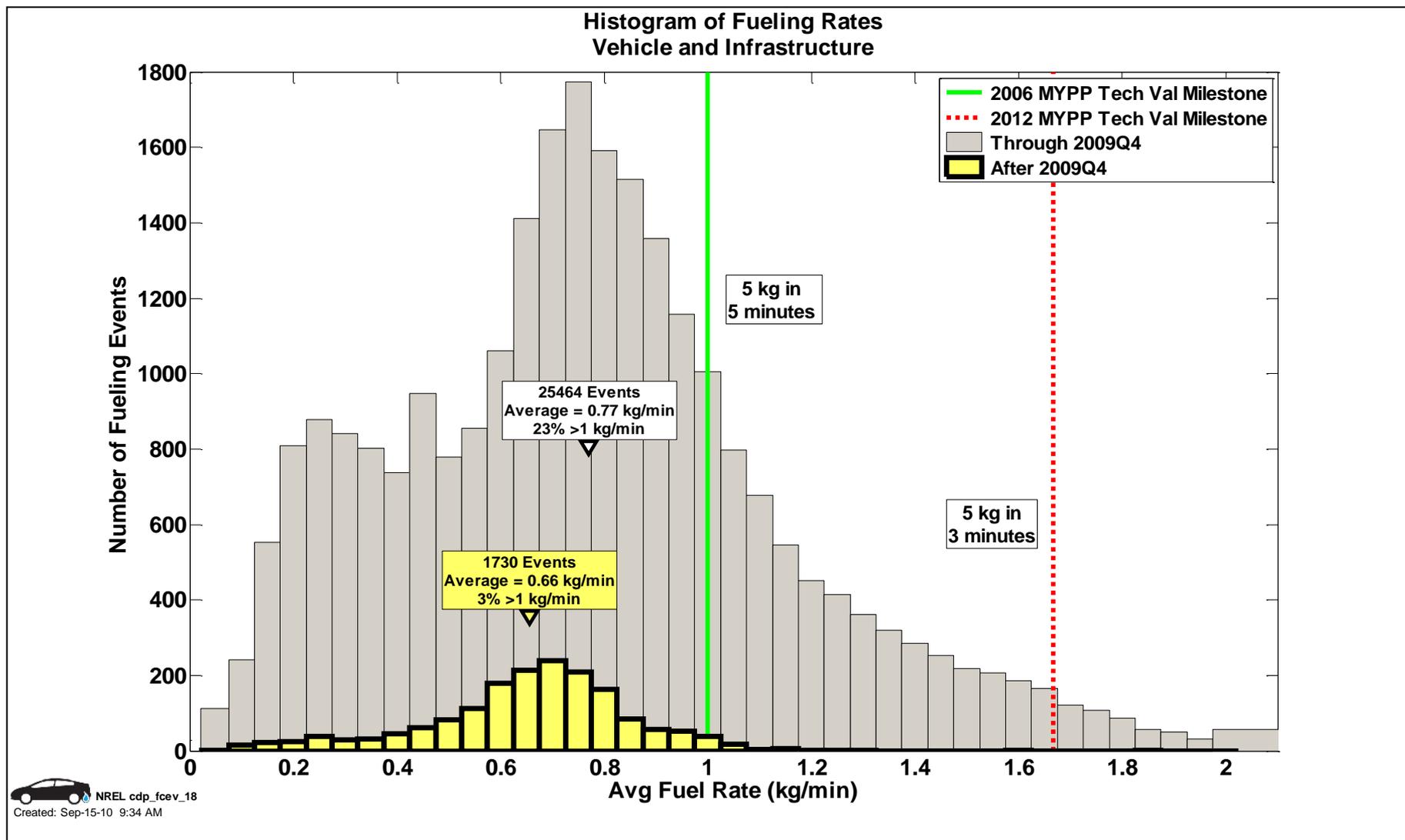
All vehicles continuing in the project will be Gen 2 vehicles

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

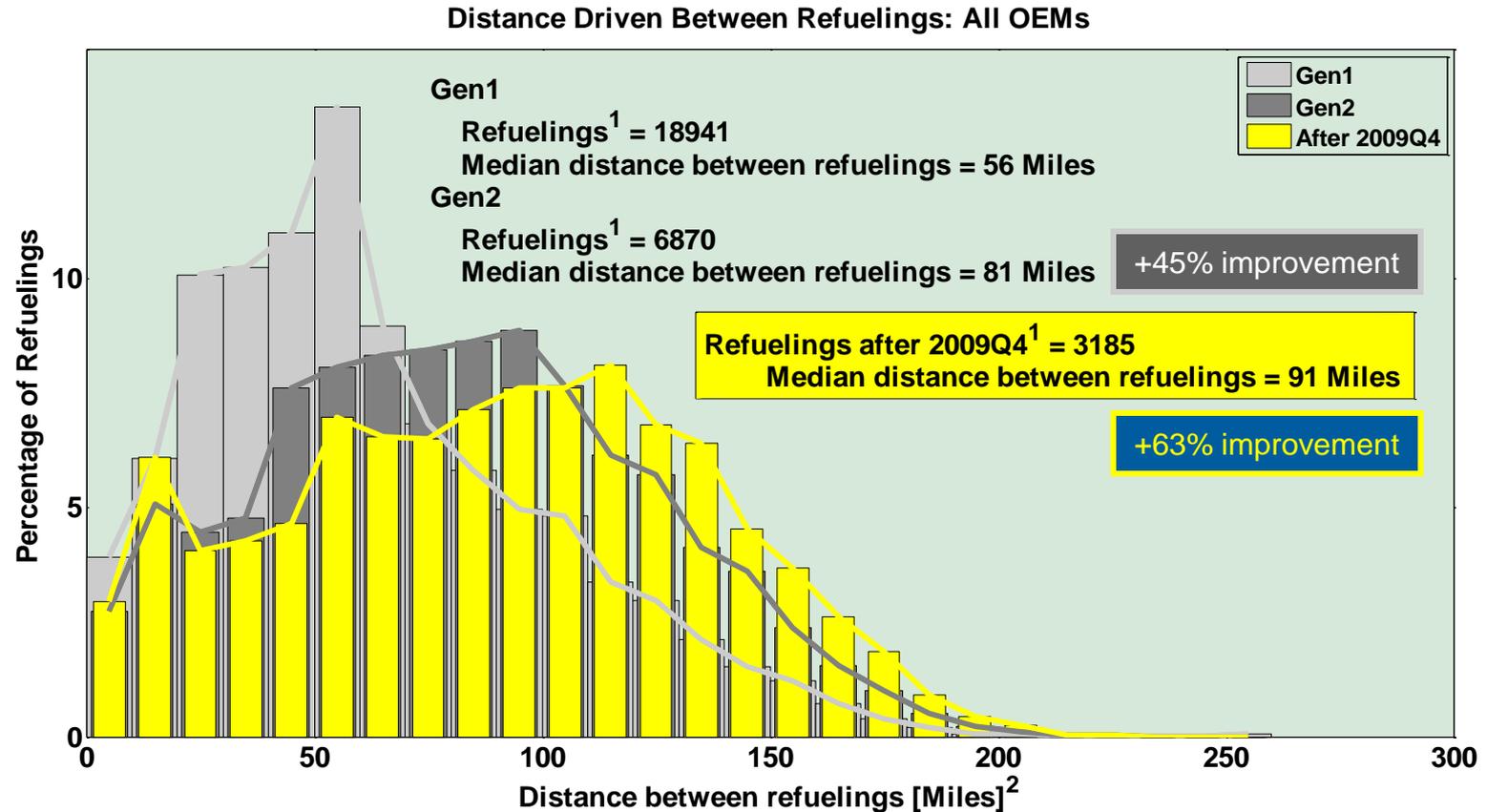


Spring 2010

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



# 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

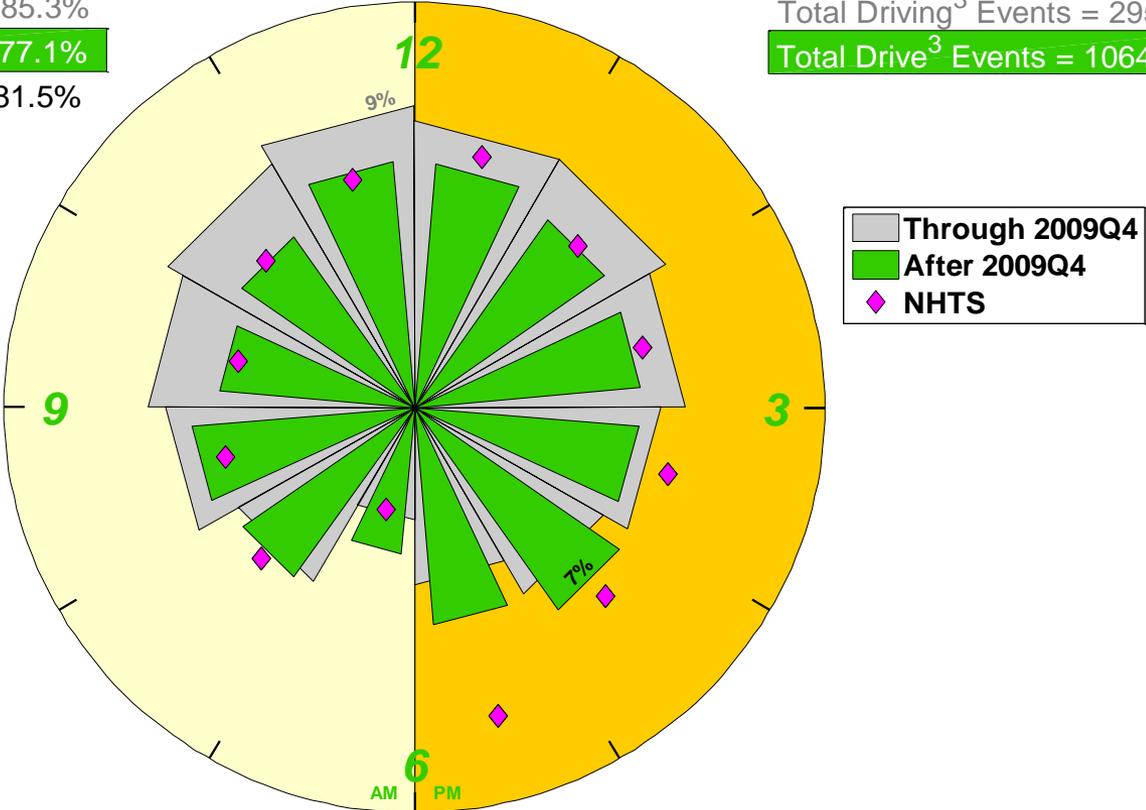
% of driving trips b/t 6 AM & 6 PM: 85.3%

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

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

Total Driving<sup>3</sup> Events = 295222

**Total Drive<sup>3</sup> Events = 10646**

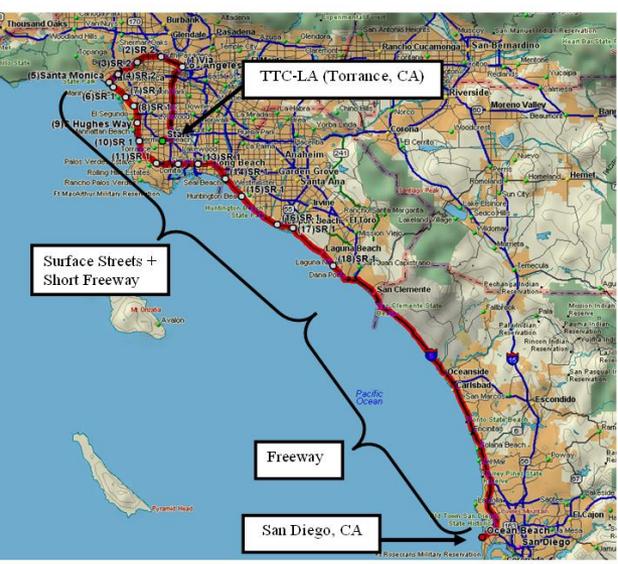


1. Driving trips between 6 AM & 6 PM
2. The outer arc is set at 12 % total Driving.
3. Some events not recorded/detected due to data noise or incompleteness.

2001 NHTS Data Includes Car, Truck, Van, & SUV day trips  
ASCII.csv Source: <http://nhts.ornl.gov/download.shtml#2001>

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

Test Route



	Average trip distance (miles)	H <sub>2</sub> consumed (kg)	Remaining usable H <sub>2</sub> (kg)	Calculated remaining range (miles)	(miles)	(miles)
Vehicle #1	331.50	4.8255	1.4854	102.04	433.55	<b>431</b>
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 Wipke<sup>1</sup>, Donald Anton<sup>2</sup>, Sam Sprik<sup>1</sup>

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



<sup>1</sup> National Renewable Energy Laboratory  
<sup>2</sup> Savannah River National Laboratory

# Summary and Future Work

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- 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  
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All public Learning Demo papers and presentations are available  
online at [http://www.nrel.gov/hydrogen/proj\\_tech\\_validation.html](http://www.nrel.gov/hydrogen/proj_tech_validation.html)