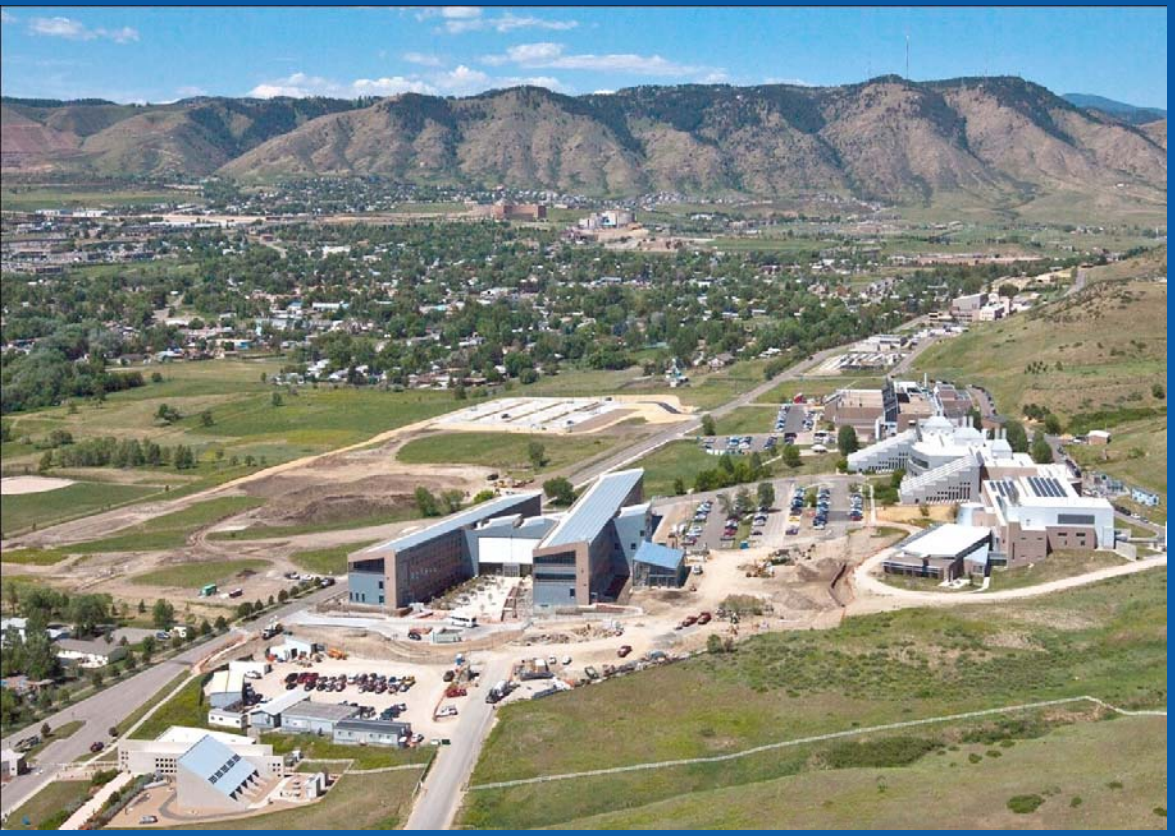
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Status of U.S. FCEV and Infrastructure Learning Demonstration Project



Keith Wipke, Sam Sprik, Jennifer Kurtz, Todd Ramsden, Chris Ainscough, Genevieve Saur

March 1, 2011

JHFC Conference
Tokyo, Japan

JHFC
Japan Hydrogen & Fuel Cell Demonstration Project

NREL/PR-5600-51138

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

Outline

- Project Goals
- Vehicle and H_2 Station Deployment Status
- Critical Performance Compared to Targets
- Highlights of Latest Vehicle and Infrastructure Analysis Results and Progress
- Learning Demo Next Steps
- Other Relevant U.S. Activities
- Cross-Application Fuel Cell Analysis Results
- Summary

Fuel Cell Electric Vehicle Learning Demo Project Objectives, Relevance, and Targets

- Objectives
  - Validate H_2 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_2 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

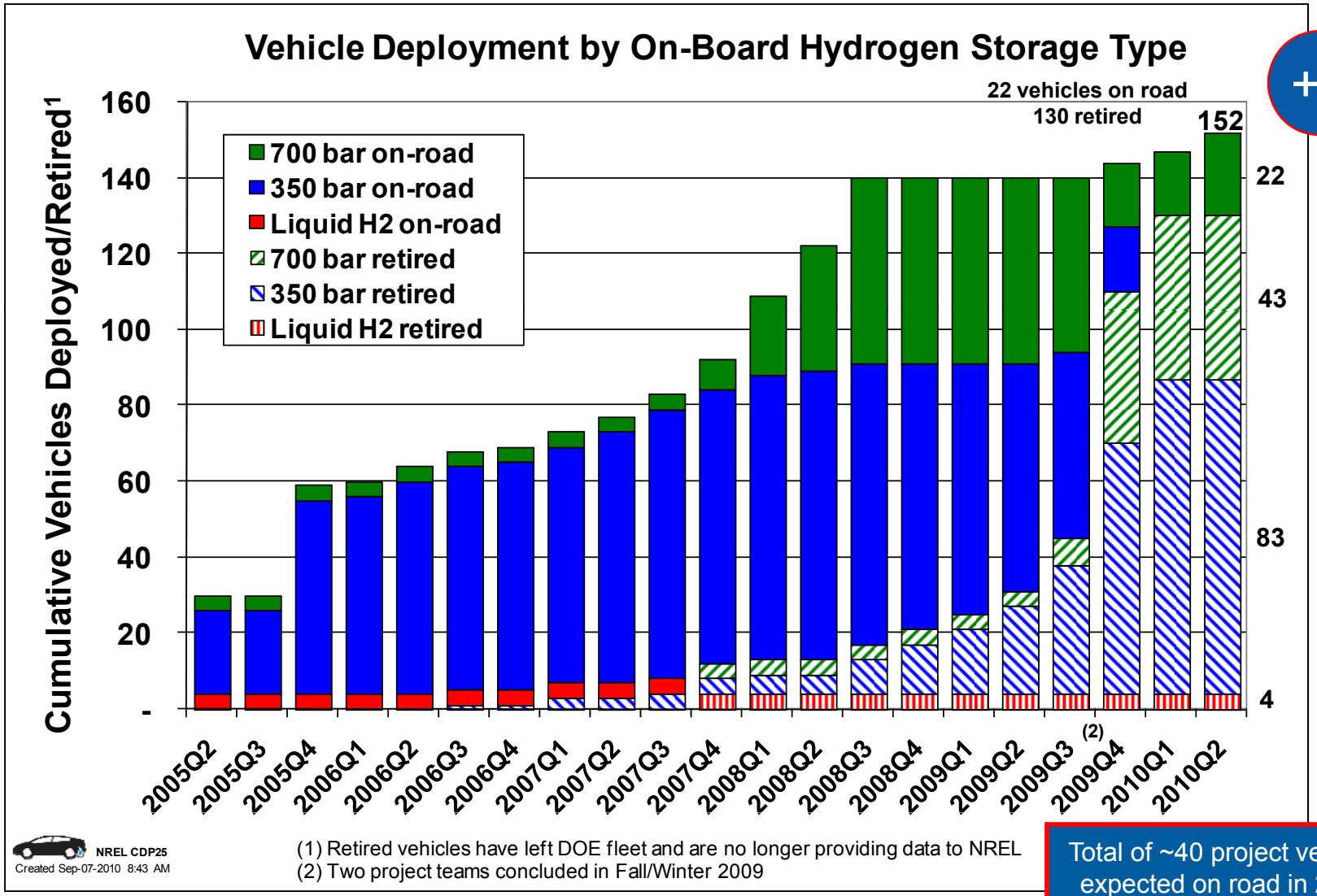
Burbank, CA station. **Photo: NREL**

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

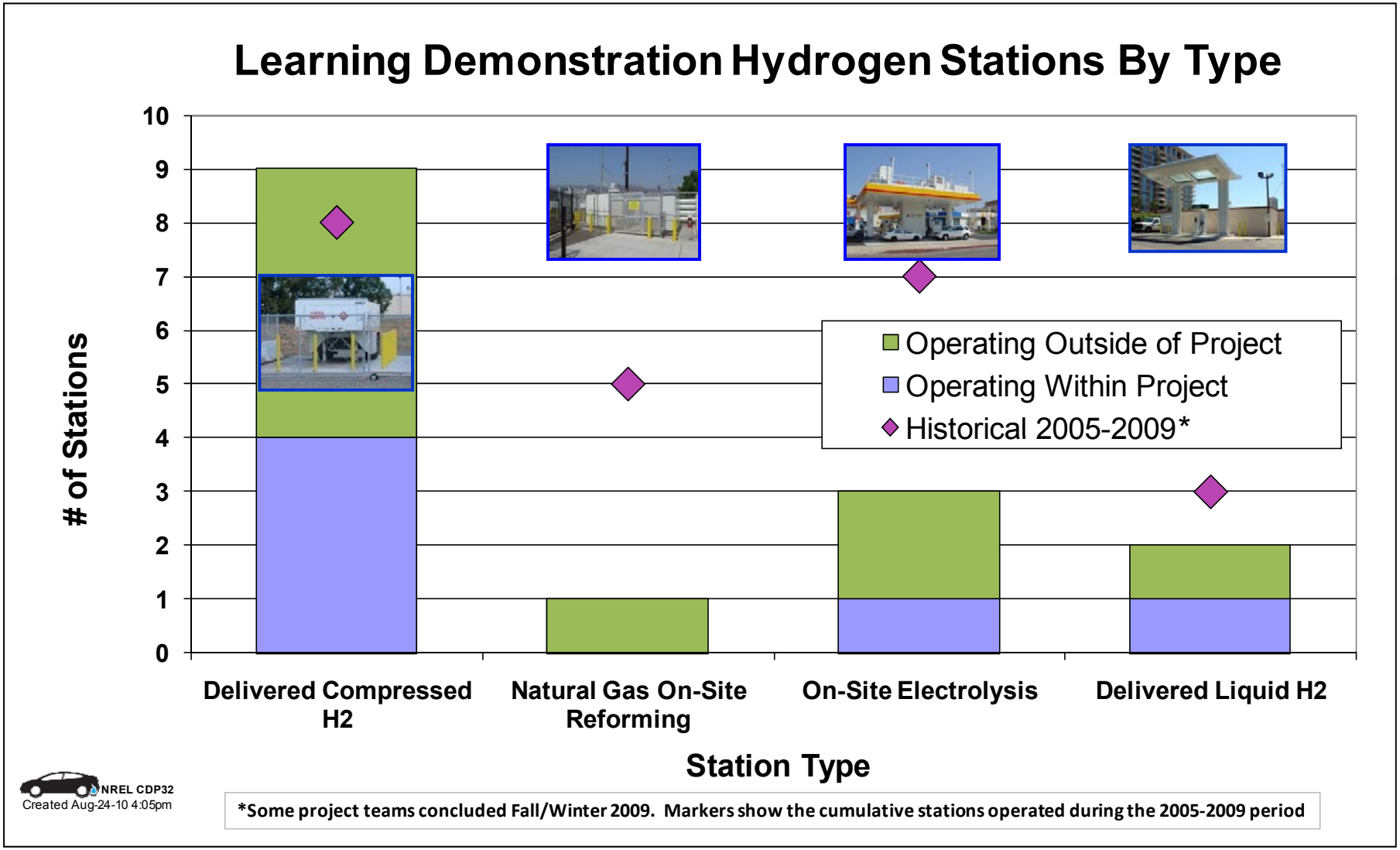
Ford/BP and Chevron/Hyundai-Kia Concluded in 2009

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

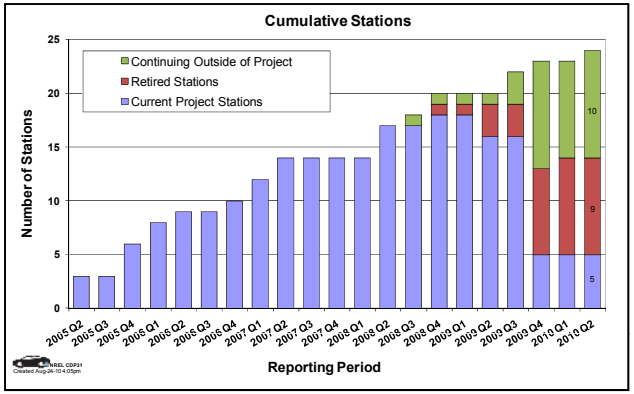
Vehicle Status: All 350 bar Vehicles Retired, Only 700 bar Vehicles Continuing

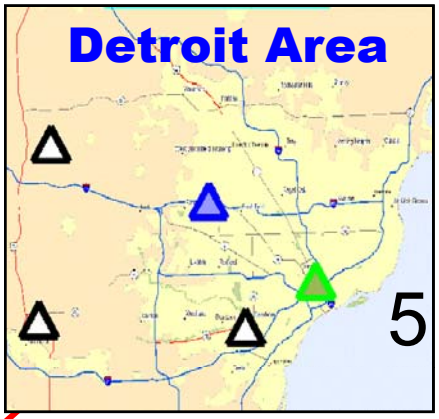


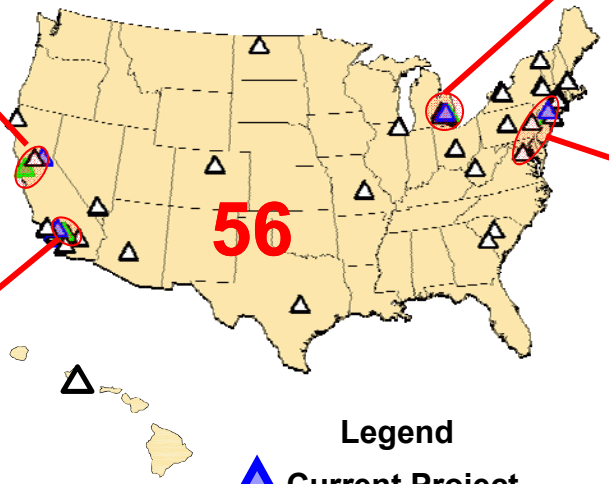
Fueling Station Status: Stations that Continue to Operate are Mostly Delivered Compressed Hydrogen

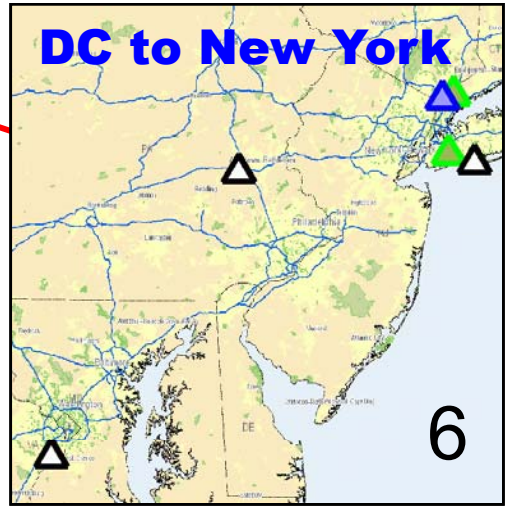


Out of 24 Project Stations, 15 Are Still Operational (2/3 are operating outside of DOE project)









Legend
- Current Project
- Continuing Outside
- Other

Feb-3-2011

Project Achieved Both Technical Goals; Outside Analysis Used for Cost Evaluation

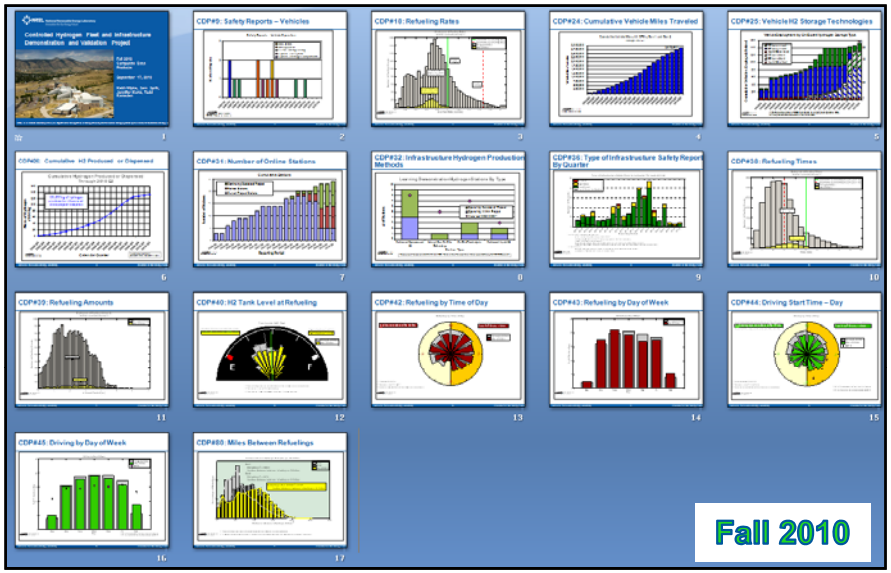
Vehicle Performance Metrics	Gen 1 Vehicle	Gen 2 Vehicle	2009 Target
Fuel Cell Stack Durability			**2000 hours**
Max Team Projected Hours to 10% Voltage Degradation	**1807 hours**	**2521 hours**	
Average Fuel Cell Durability Projection	821 hours	1062 hours	
Max Hours of Operation by a Single FC Stack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

Infrastructure Performance Metrics			2009 Target
H_2 Cost at Station (early market)	On-site natural gas reformation **$7.70 - $10.30**	On-site Electrolysis **$10.00 - $12.90**	**$3/gge**
Average H_2 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)

Outside review panel

What are the Most Recent Project Results? Differences Between Spring & Fall 2010 CDPs



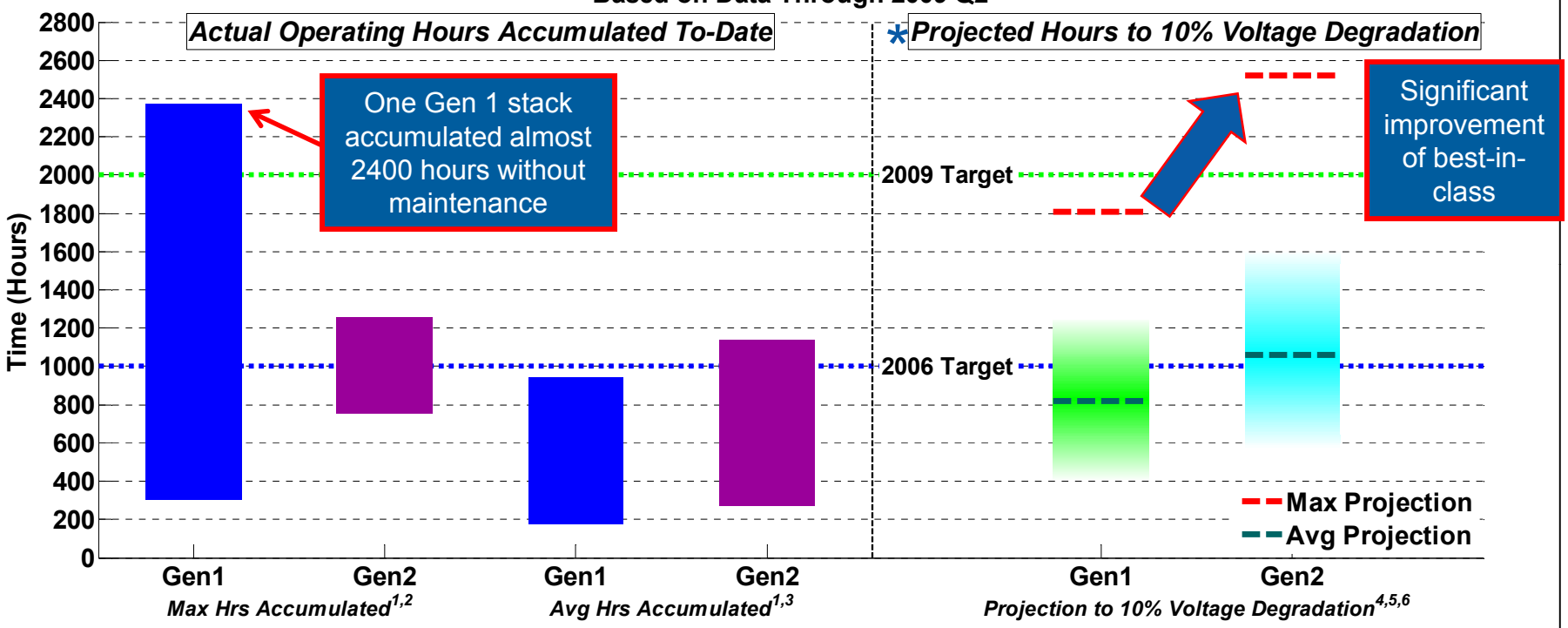
80 Spring 2010 Results

- Most comprehensive set we ever published
- Covers data from all 4 Learning Demo teams + CHIP project over 5 year period

16 Fall 2010 Results

- 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



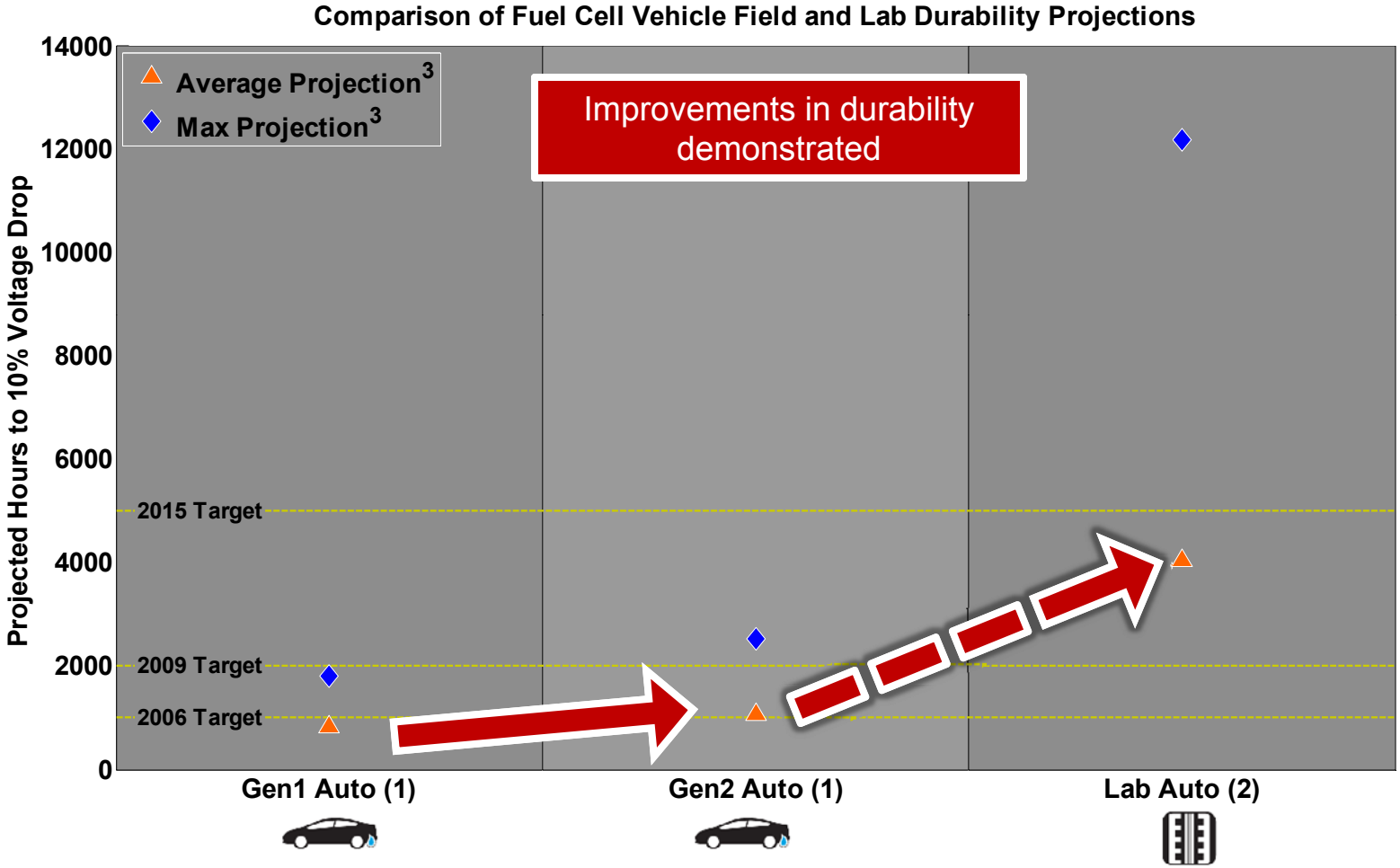
(1) Range bars created using one data point for each OEM. Some stacks have accumulated hours beyond 10% voltage degradation.
(2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
(3) Range (highest and lowest) of the 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 projection bars represents an engineering judgment of the uncertainty on the "Avg Projection" due to data and methodology limitations. Projections will change as additional data are accumulated.
(6) Projection method was modified beginning with 2009 Q2 data, includes an upper projection limit based on demonstrated op hours.

NREL CDP01
Created: Mar-23-10 10:39 AM

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

Spring 2010

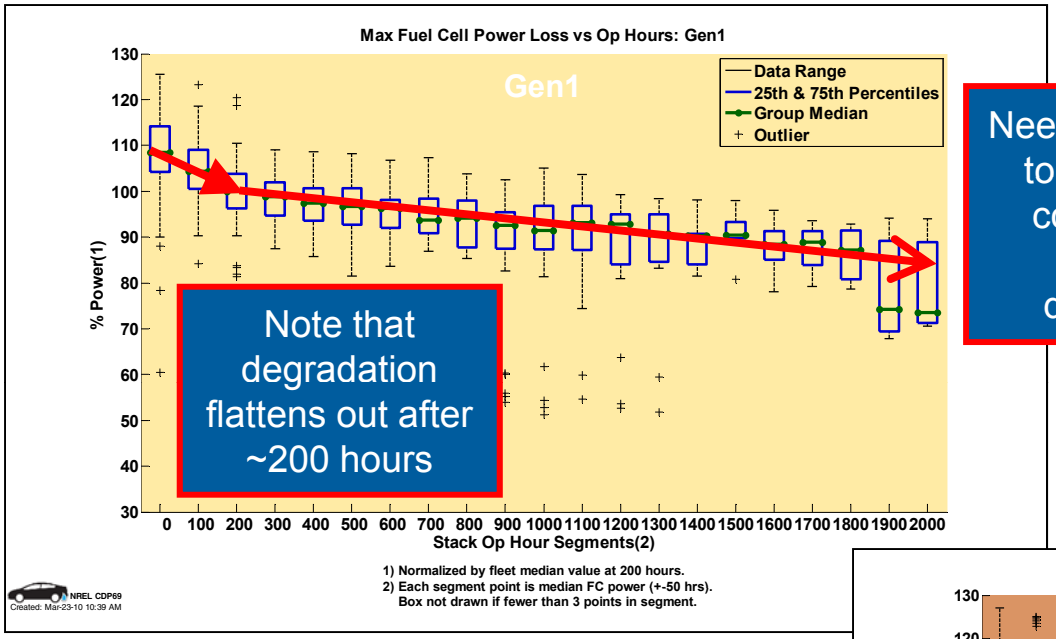
Fuel Cell Durability Comparison between Field and Lab Data Shows Potential Gains



NREL cdplab03
Created: Jun-01-10 4:00 PM

(1) Gen1 and Gen2 Data from DOE's Learning Demonstration (2005 - 2010)
(2) Lab data providers may not be the same as participants in DOE's Learning Demonstration. 56% of data are full active area short stacks.
(3) The DOE 10% voltage degradation metric is used for assessing voltage degradation; it may not be the same as end-of-life criteria and does not address catastrophic failure modes.

Completed Final Analysis of Gen 1 Fuel Cell System Power Degradation

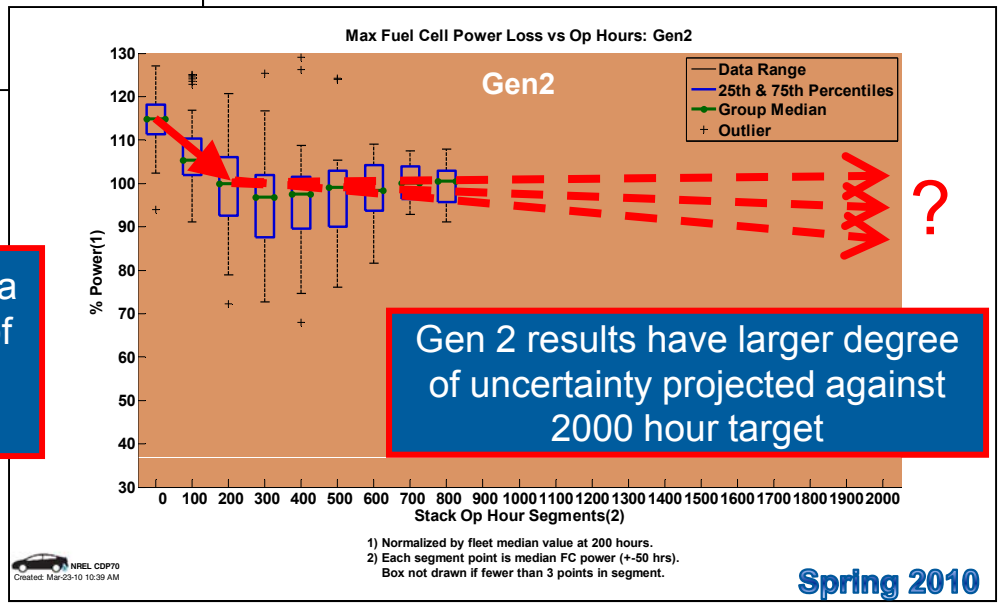


Note that degradation flattens out after ~200 hours

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

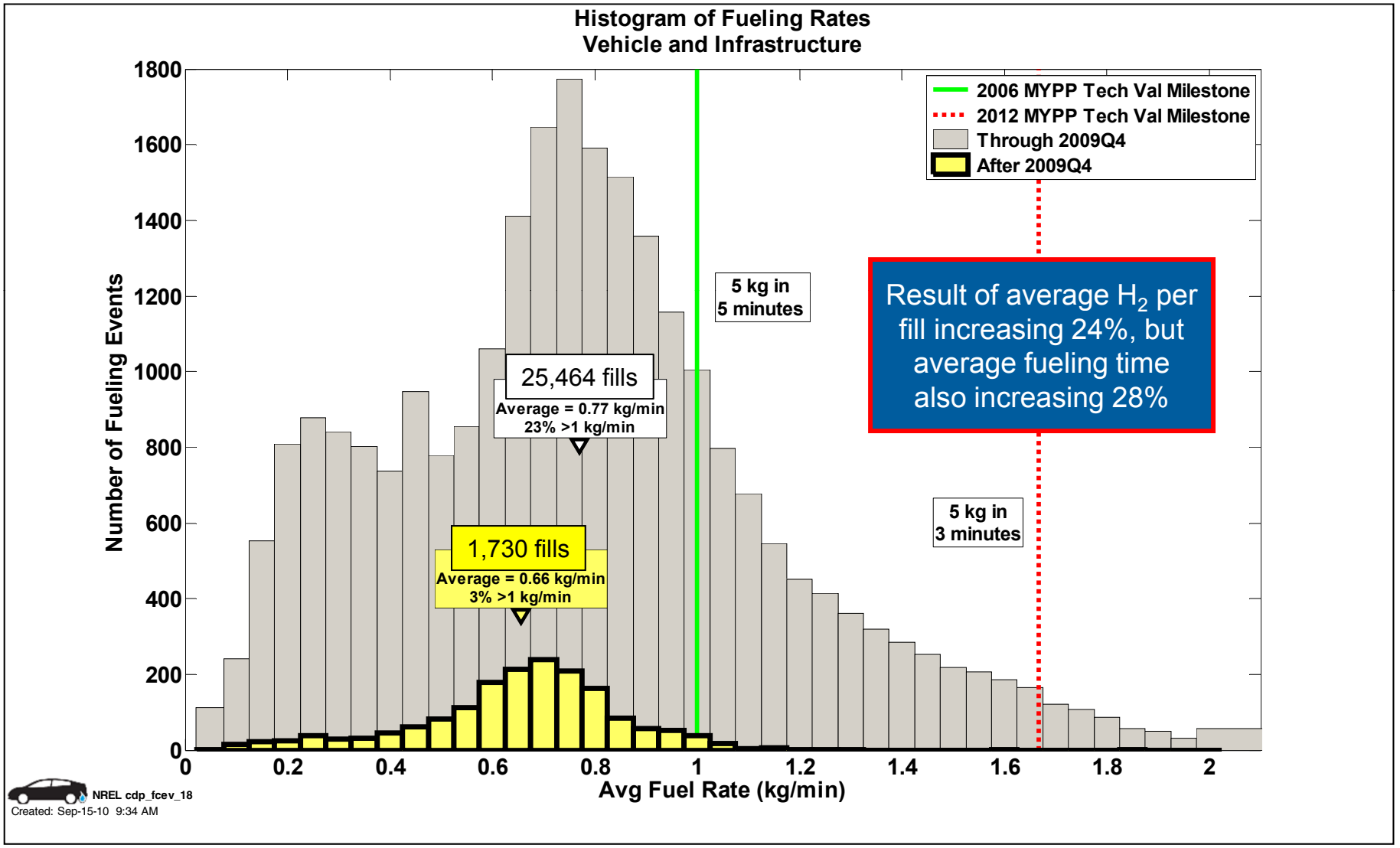
All vehicles continuing in the project will be Gen 2 vehicles

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



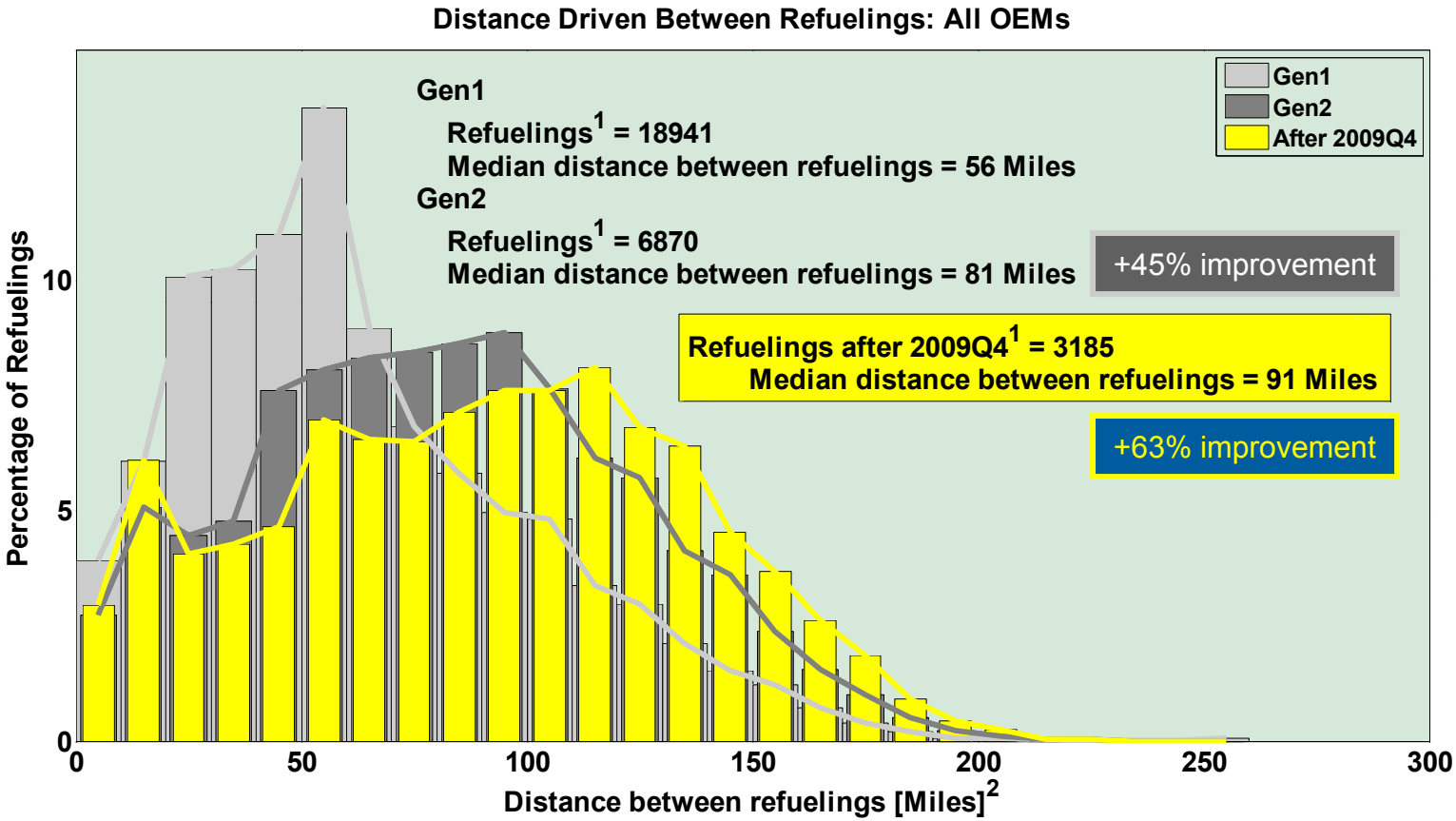
Gen 2 results have larger degree of uncertainty projected against 2000 hour target

Changes in Refueling Rate Trends: Average Refueling Rate Decreased 14%



Fall 2010

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



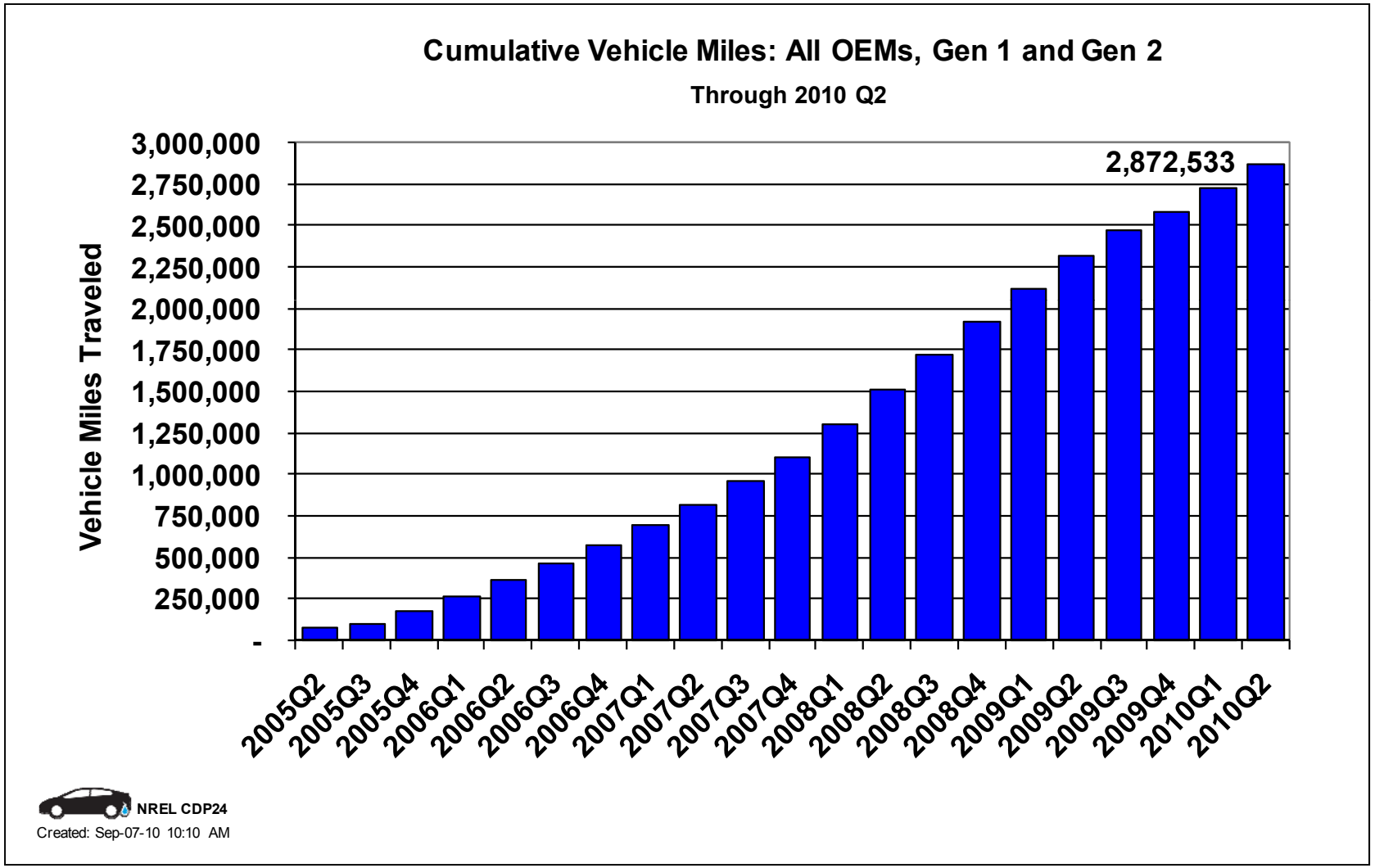
1. Some refueling events are not detected/reported due to data noise or incompleteness.
2. Distance driven between refuelings is indicative of driver behavior and does not represent the full range of the vehicle.

NREL cdp_fcev_80
Created: Sep-07-10 9:16 AM

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

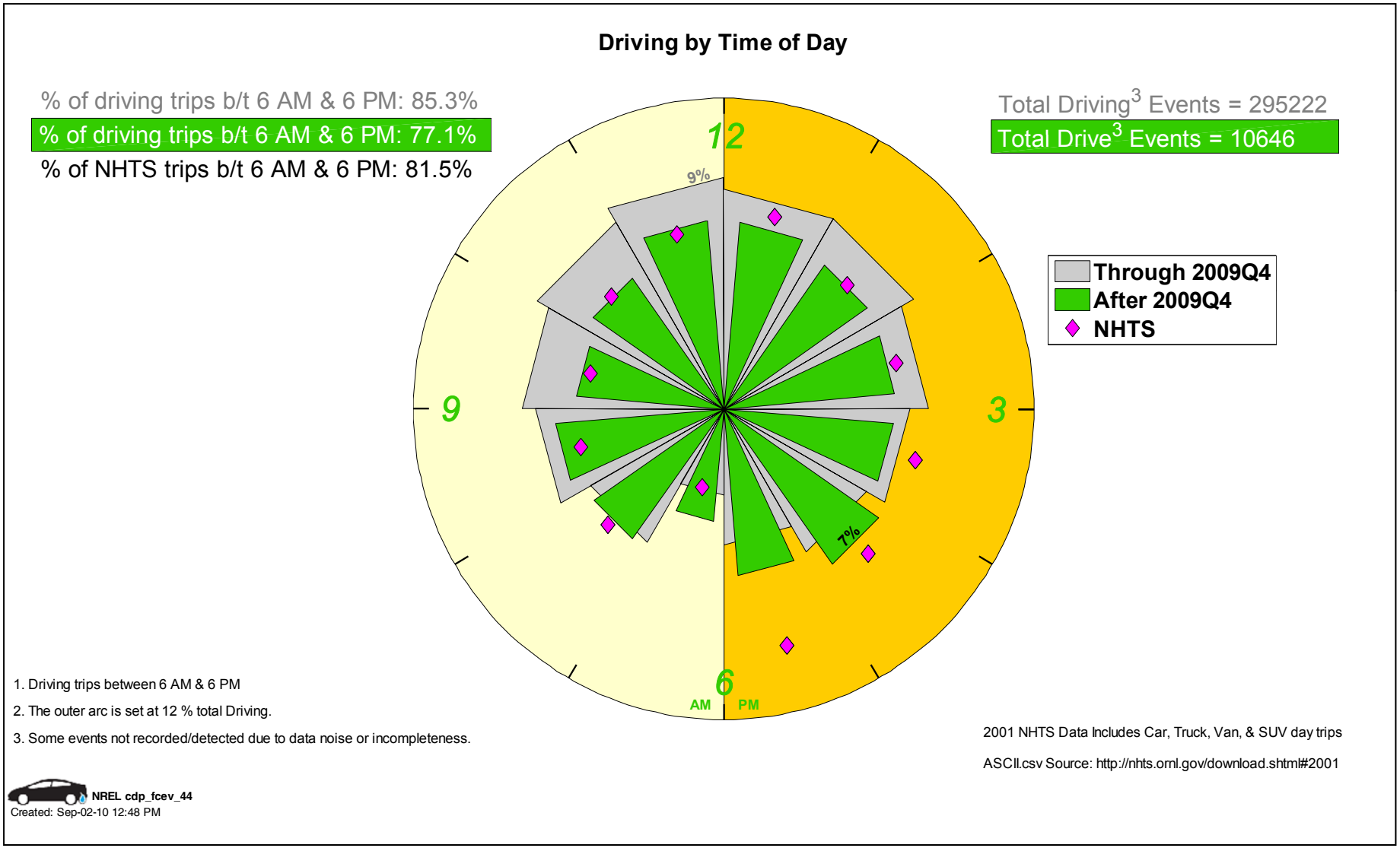
Fall 2010

Rate of Mileage Accumulation Has Decreased in the Last Year, But Vehicles Still Added 550,000 Miles



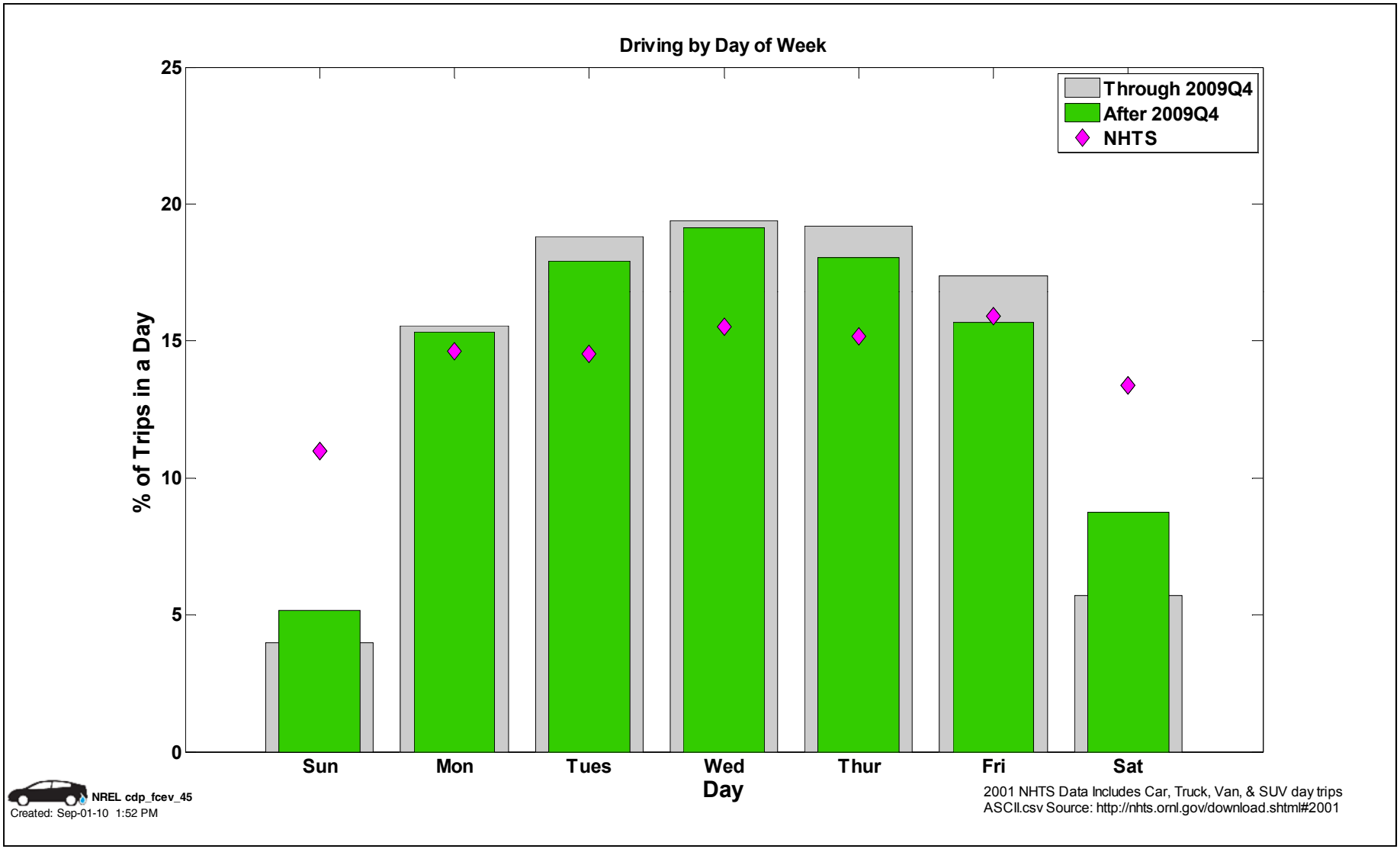
Fall 2010

Driving Behavior (Timing) in Last 6 Months Much More Similar to U.S. National Average



Fall 2010

More Weekend Driving Observed in Last Six Months – Still Much Less than National Avg.



Fall 2010

Learning Demo Next Steps

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- Currently analyzing July – December 2010 data
- Spring 2011 CDPs published in March, presented at DOE AMR in May
- Publish one or two more Learning Demo CDP sets after that
- Begin receiving fueling data from Burbank station and others

- Partners scheduled to provide data through September 2011
- Participating in many other demonstration and pre-commercial activities outside of this project

Other Relevant U.S. Activities

GM – LOU for Hawaii Hydrogen Initiative

GM

The New York Times

December 8, 2010, 2:11 pm

G.M. Has Hydrogen Hopes for Hawaii

By JIM MOTAVALLI

Steve Fecht for General Motors The General Motors Fuel Cell vehicle on the coast of Oahu. The ideal early market for hydrogen fuel-cell cars is small, self-contained, facing exorbitant fossil fuel prices and has an abundant supply of renewable energy on tap, according to Charles Freese, executive director of General Motors' fuel-cell activities.

Iceland, which fits that description, had actually announced its intentions to be the world's first hydrogen energy economy, but access to fuel-cell cars proved to be a crippling barrier. The Hawaiian island of Oahu, with a population of one million, may be over that hurdle.

On Wednesday, G.M. announced the Hawaii Hydrogen Initiative (or H2I in marketing speak) in Honolulu. It's a new partnership with, among others, Aloha Petroleum (which operates filling

General Motors LLC	Charles Freese Executive Director Fuel Cell Activities	GM
The Gas Company LLC	[illegible] President and Chief Executive Officer	HAWAIIGAS
The State of Hawaii	Theodore A. Peck Administrator State Energy Office	
PACOM	George Kailiwai III Director, Resources and Assessment	
The U.S. Department of Energy	Steven G. Chalk Chief Operating Officer and Acting Deputy Assistant Secretary for Renewable Energy	
National Renewable Energy Laboratory, managed and operated by Alliance for Sustainable Energy, LLC	Dan Arvizu Laboratory Director and Alliance President	NREL
University of Hawaii	Richard Rocheleau Director Hawaii Natural Energy Institute	

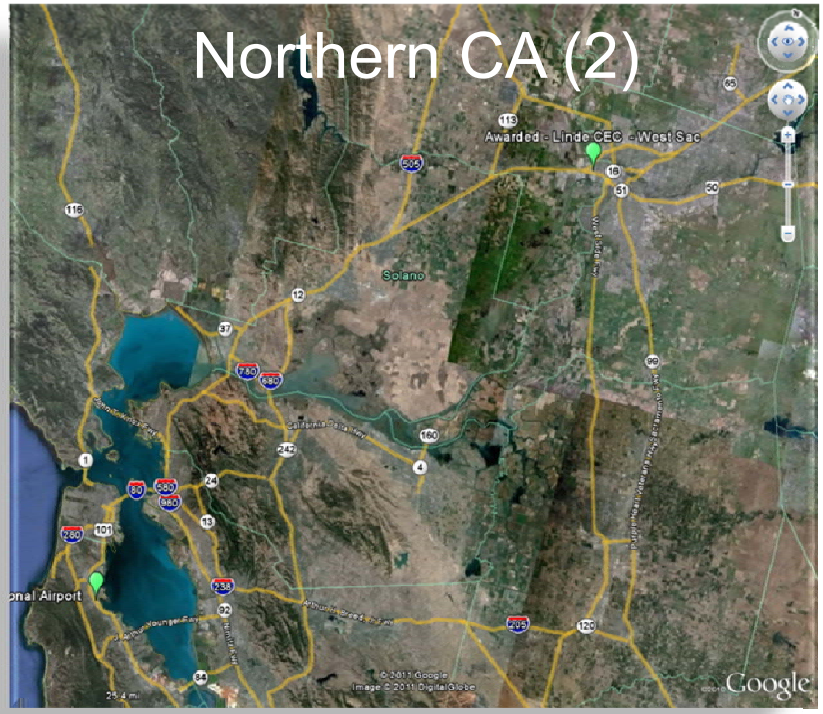
4

The County of Hawaii	Randy Kurohara Director Department of Research and Development	
University of California at Irvine	Scott Samuelsen Director National Fuel Cell Research Center	
FuelCell Energy	Christopher Bentley Executive Vice President	
The Louis Berger Group	Keith Eastin Vice President Strategic Initiatives	
Aloha Petroleum	Richard Parry Chief Executive Officer	

Other Relevant U.S. Activities

State of California Supporting 11 H_2 stations

- 11 H_2 station awards announced by CEC in Oct.
  - 8 new stations, 3 upgrades
  - Air Products planning 8 stations: 7 new, 1 upgrade – all in Southern CA
  - Linde planning 3 stations: 1 new, 2 upgrades

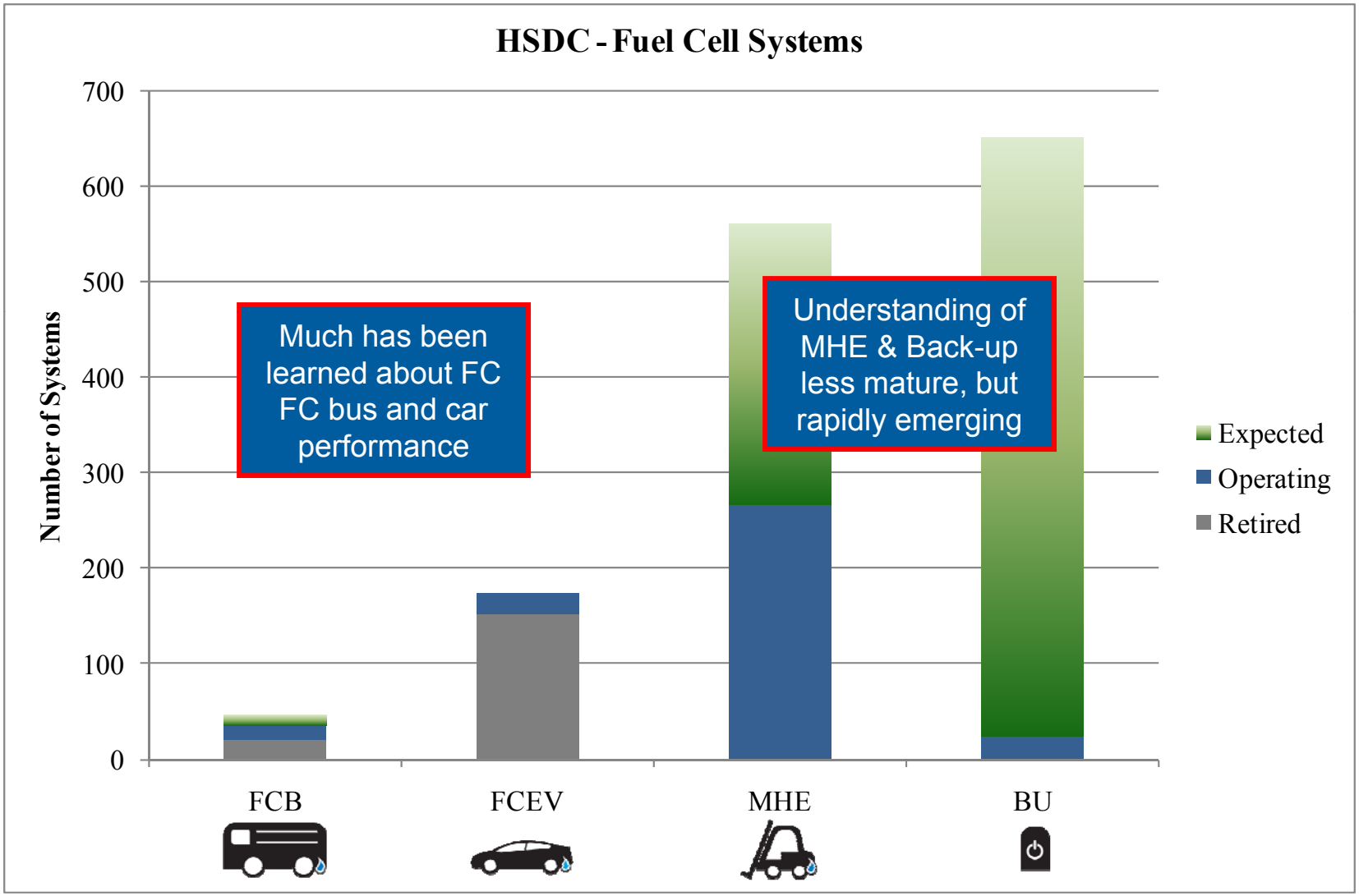


NREL Also Publishes Results from Analyzing Multiple Applications

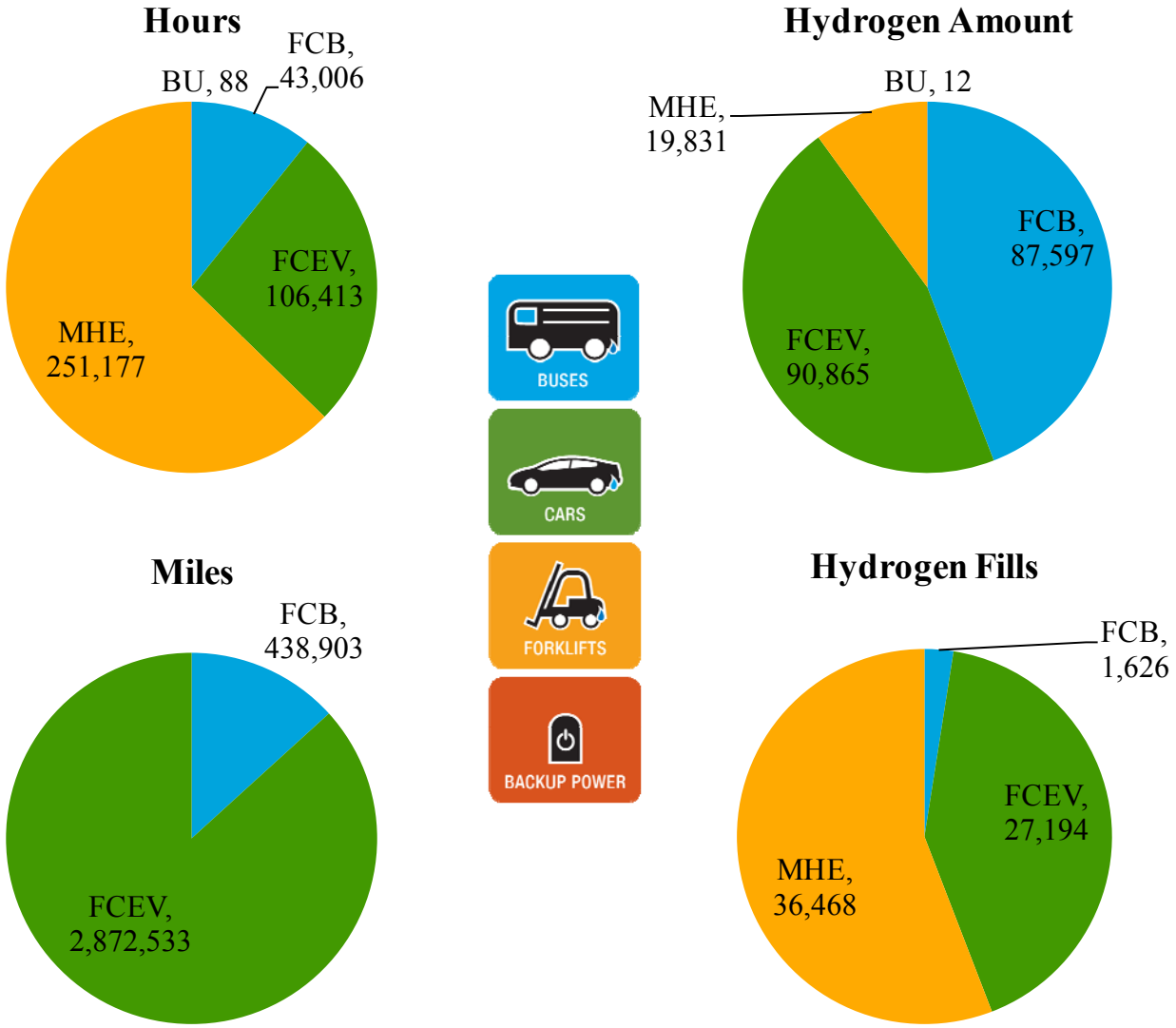
HSDC

NREL's Hydrogen Secure Data Center

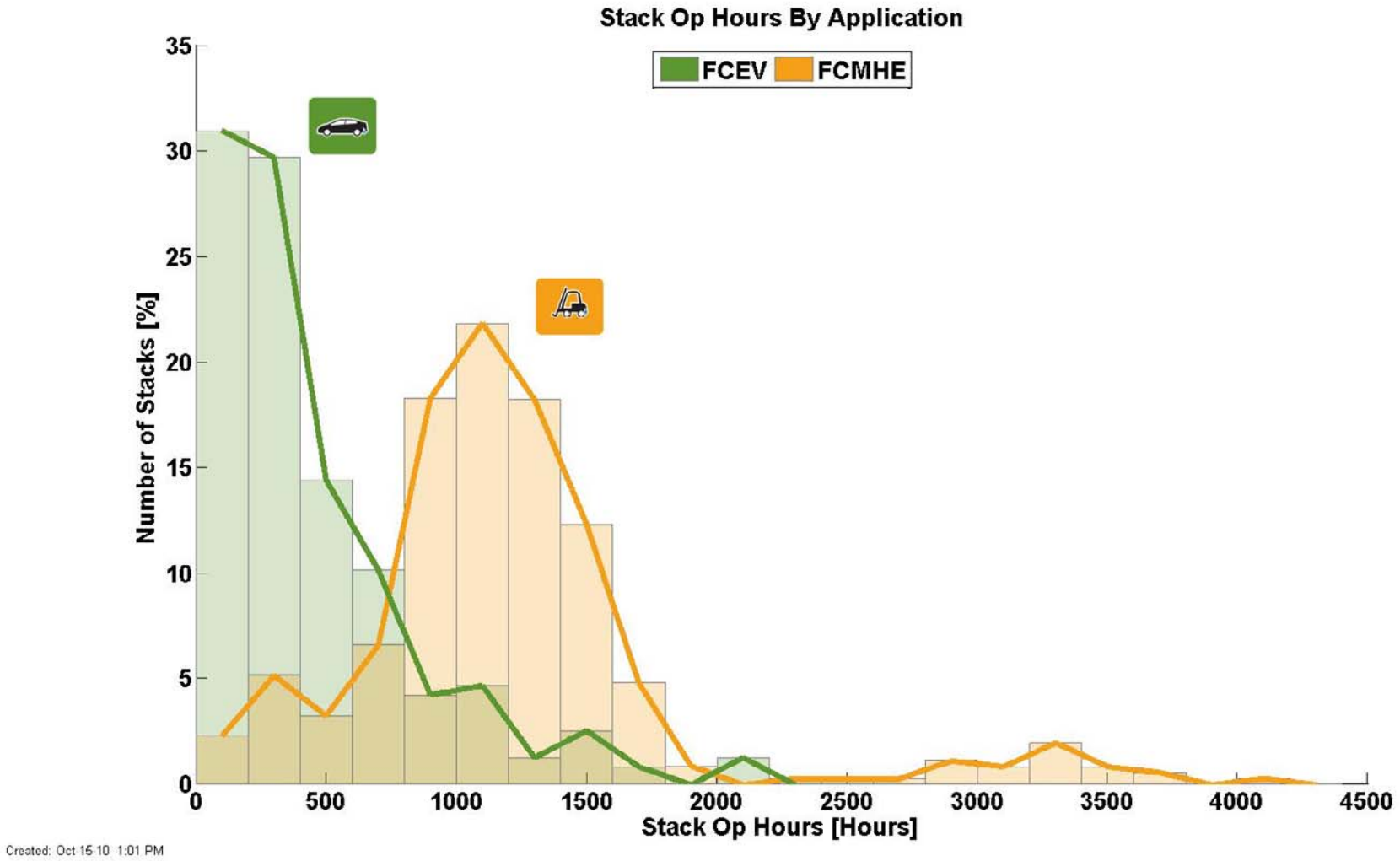
Number of Fuel Cell Units Being Evaluated and Providing Data to NREL



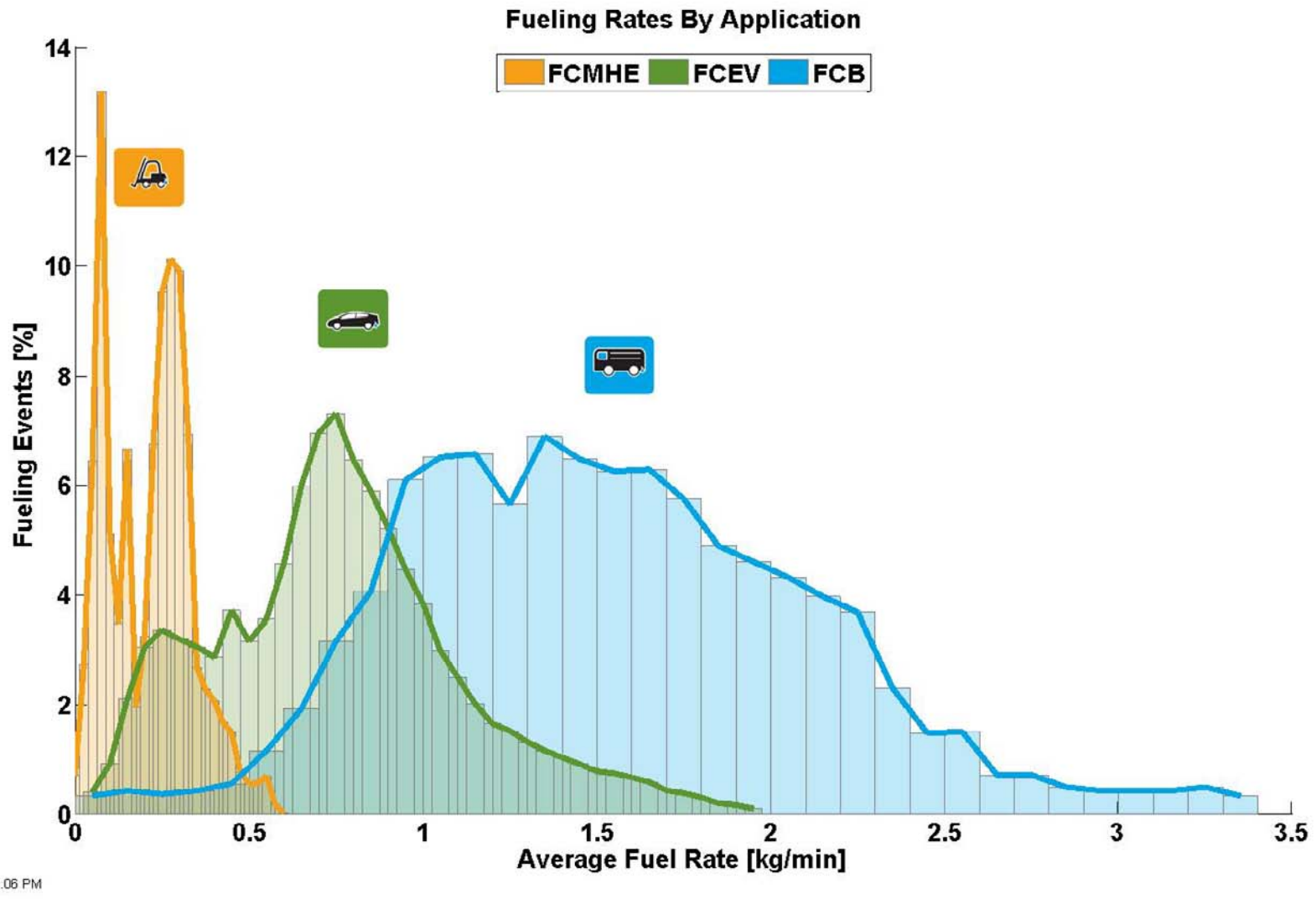
Each Fuel Cell Application Has Different Requirements and Operation



Forklifts Acquire Data Very Rapidly – Data from 5 Years of Cars, 2 Years of Forklifts



Fueling Rates Vary By Application, Primarily Driven by Constraints on Pressure, Volume, Time



Summary

- Project has completed ~6 years of validation
- Vehicle operation: 114,000 hours, 2.87 million miles, 436,000 trips
- H_2 station operation: 134,000 kg produced or dispensed, 27,000 fuelings
- DOE Key Technical Targets Met: FC Durability and Range
- Data reporting and analysis continues through remainder of this year
- New CA fueling stations planned for inclusion in future NREL infrastructure analysis as they come online and provide data

Contact Info. and Web Resources

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