

Session TA.5 – Demonstration Projects, Costs, and Market Introduction



Review Lecture

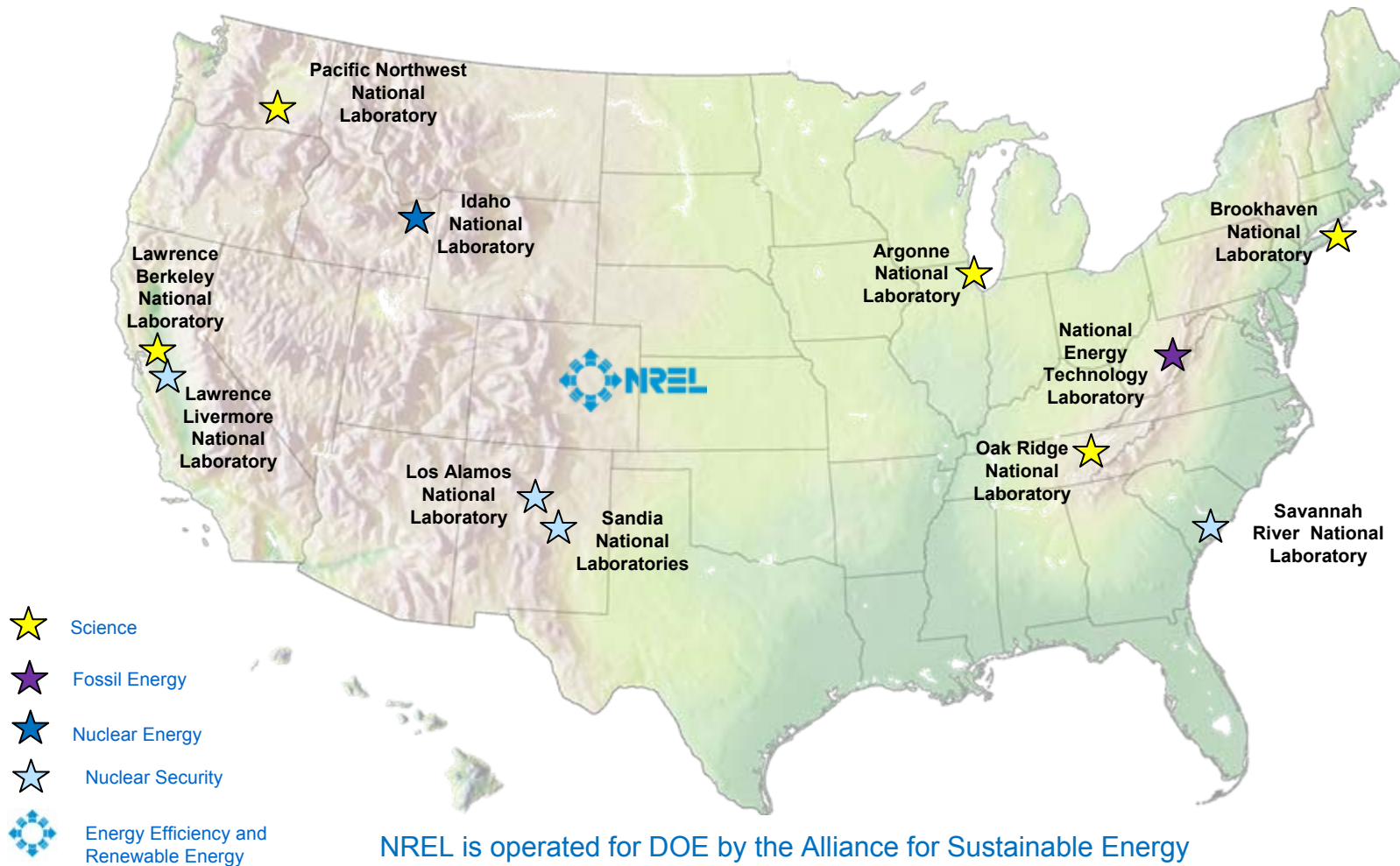
Keith Wipke

Todd Ramsden, Sam
Sprik, Jen Kurtz

May 19, 2010

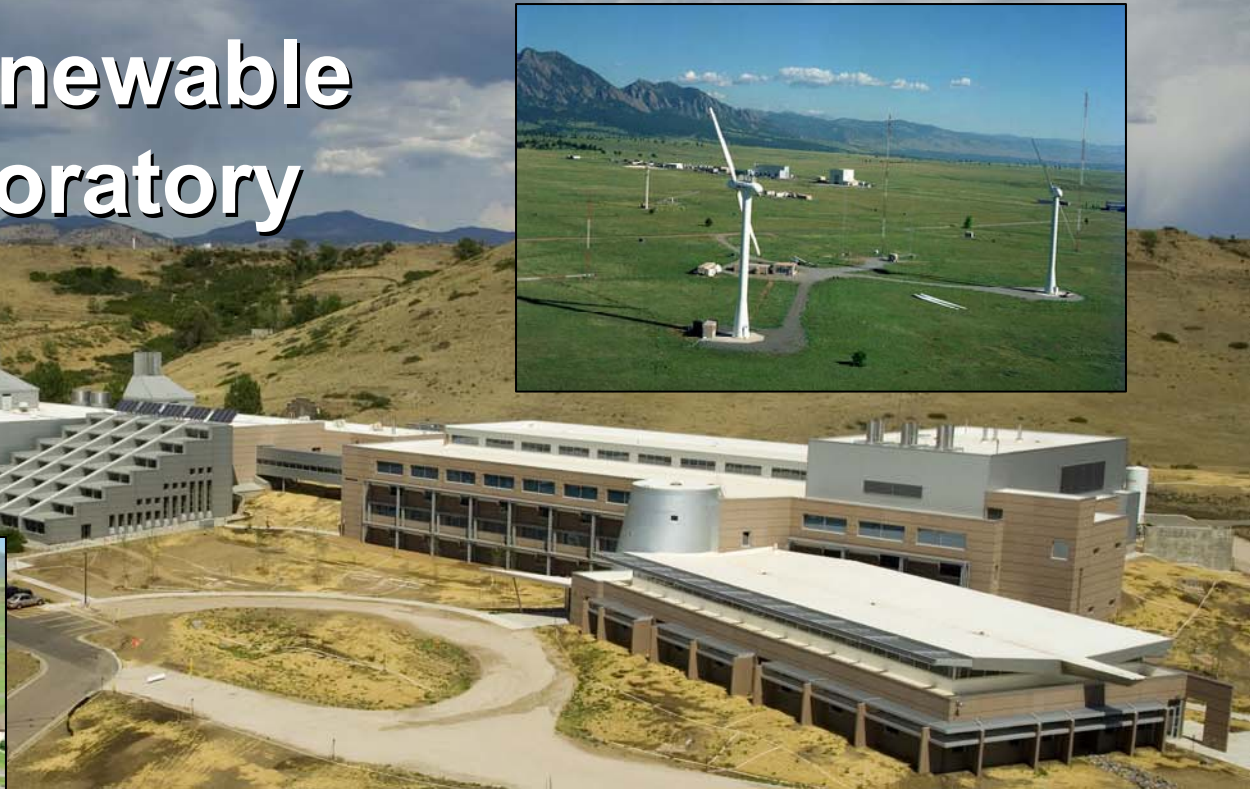
WHEC 2010
Messe Essen, Germany

NREL is One of 12 U.S. Department of Energy National Laboratories



NREL is operated for DOE by the Alliance for Sustainable Energy (Midwest Research Institute and Battelle)

National Renewable Energy Laboratory



- Only national lab dedicated to renewable energy and energy efficiency R&D
- Research spans fundamental science to technology solutions
- Collaboration with industry and university partners is a hallmark
- Research programs linked to market opportunities

Outline

- Who/What is NREL?
- Brief Highlights of Select International Fuel Cell Car Introduction Plans in:
 - Germany
 - Japan
 - Korea
- Highlights from United States
 - Car, bus, forklift, and others
- Review of Today's Schedule and Timing

September 2009 OEM Letter of Understanding

Discusses Worldwide Introduction, but Focused on Germany

DAIMLER



HONDA



RENAULT NISSAN

TOYOTA

Letter of Understanding

on the Development and Market Introduction of Fuel Cell Vehicles

To: Oil and Energy Companies, Government Organizations and NOW GmbH

From: Daimler, Ford, GM/Opel, Honda, Hyundai/KIA, the Alliance Renault/Nissan, Toyota

Preamble

Road traffic has been steadily increasing in recent years and vehicle ownership is expected to grow. As a result, there will be increased priority on low and zero emission vehicles and an increase in overall CO₂ reduction goals. Over the last decade, governments, OEMs and the energy sector have given special attention to the introduction of hydrogen as a fuel

“Based on current knowledge and subject to a variety of prerequisites and conditions, the signing OEMs strongly anticipate that **from 2015 onwards a quite significant number of fuel cell vehicles could be commercialised**. This number is aimed at a **few hundred thousand units** over life cycle on a worldwide basis.”

““The signing OEMs strongly support the idea of building-up a hydrogen infrastructure in **Europe**, with **Germany** as starting point and at the same time developing similar concepts for the market penetration of hydrogen infrastructure in other regions of the world, with one **US market, Japan and Korea** as further starting points.”

Germany

National Innovation Program (NIP) Overview

Preparing Hydrogen and Fuel Cell Markets: National Innovation Programme (NIP)



Politics

Industry

BMVBS / BMWi / BMBF / BMU

500 million €
for demonstration

+ 200 million €
for R&D

+ 700 million €
Co-payment from industry

in discussion: 180 projects /
€815 Mio. budget



approved: 69 projects /
€351 Mio. budget

1,4 billion €

10-year-programme till 2016

- Preparing hydrogen & fuel cell markets
- Focus on R&D combined with everyday demonstration
- hydrogen & fuel cells driven by applications and markets: transport, stationary energy supply, special markets

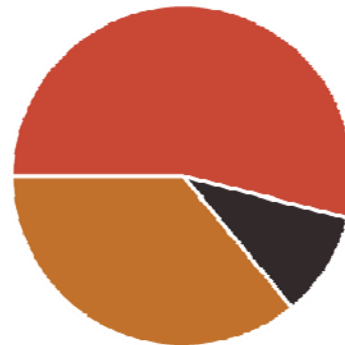
NIP: Preparing Markets



Transport:

- 54% of the NIP
- incl. H₂-production and H₂-infrastructure

- extension of vehicle fleet (passenger cars and buses) and H₂-infrastructure, starting from key regions (Berlin, Hamburg)



Stationary applications:

- 36% of the NIP
- FC-heating-applications in privately owned homes
- FC in industrial CHP

Special markets:

- 10% of the NIP
- critical energy supply, IT, telecommunication
- logistics, leisure and tourism markets

Bloomberg Businessweek
Friday May 14, 2010 | Home | Finance | Technology

Bloomberg

Toyota Targets \$50,000 Price for First Hydrogen Car (Update2)

May 06, 2010, 4:14 PM EDT

(Updates with closing ADR price in seventh paragraph.)

By Alan Ohnsman

May 6 (Bloomberg) -- Toyota Motor Corp., the biggest seller of hybrid cars, said it has cut the cost of making fuel-cell vehicles by about 90 percent since the mid-2000s and may be able to price its first retail hydrogen model at about \$50,000.

The first model will be a sedan with driving range equal to a gasoline-powered car, "with some extra cost," Yoshihiko Masuda, Toyota's managing director for advanced autos, said in an interview. The Japanese carmaker has cut production costs to about one-tenth of earlier estimates that ran as high as \$1 million a car and would need to reduce current expenses by about half before starting retail sales, he said.

MORE FROM BUSINESSWEEK
[GM Says No Plan to Sell Hydrogen as It Ramps Up Volt](#)
[GM to Maintain Focus on Plug-In Volt R](#)
[Toyota Leads Industry in April Vehicle Sales](#)
[Toyota Extends Production Plan to Two We](#)
[NEC to Spend \\$5 Billion Raising Lithium-Ion \(Update 1\)](#)

STORY TOOLS
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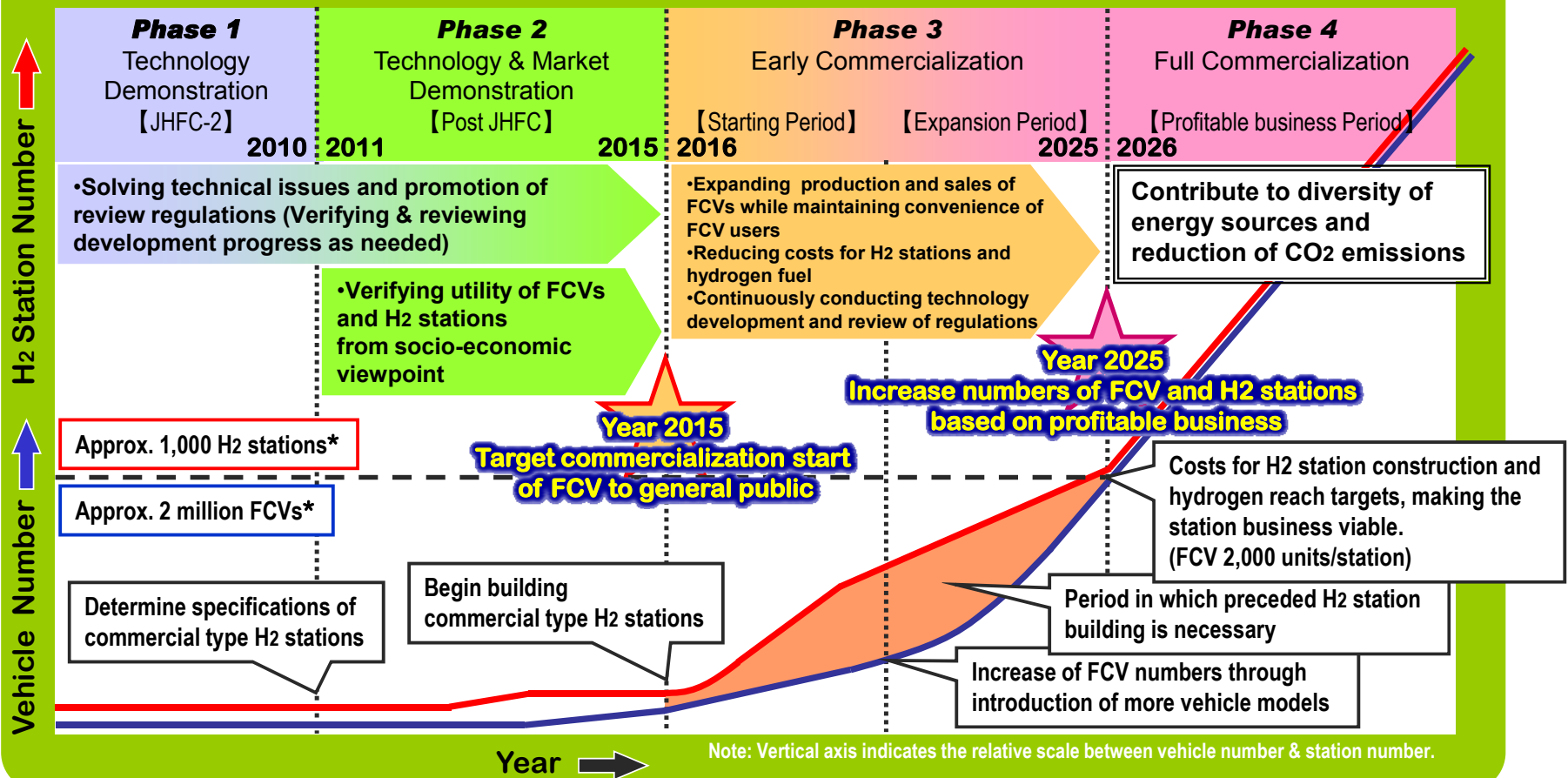
“Our target is, we **don't lose money** with introduction of the vehicle... Production cost should be covered within the price of the vehicle.”

– *Yoshihiko Masuda, Toyota*

Japan

FCV Commercialization Plans Hold for 2015

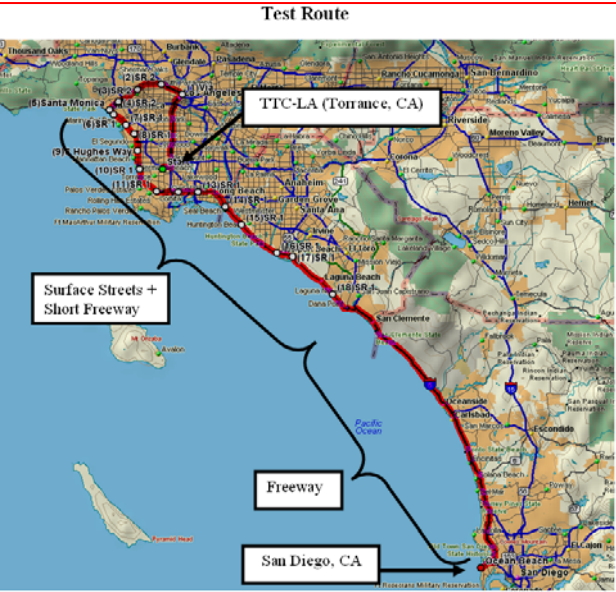
Commercialization Scenario for FCVs and H2 Stations



* Precondition: Benefit for FCV users (price/convenience etc.) are secured, and FCVs are widely and smoothly deployed

Source: Shoji Tange (JARI)

Japan (progress): 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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Korea

Plans Consistent with Japan and Germany

The screenshot shows the Automobile.com website interface. At the top, there's a red banner with the 'Automobile' logo and a 'SUBSCRIBE TODAY' button. Below that, navigation links for 'NEW CARS', 'USED CARS', 'CLASSIFIEDS', 'RUMORS', and 'AUTO SHOWS' are visible. The article title is 'Kia's Big Fuel Cell Plans', posted on July 8, 2009, by Joe DeMatio. The main image is a map of California displayed on a car's infotainment screen, showing a red route from San Francisco to Los Angeles. Key landmarks like the Golden Gate Bridge and Hollywood are labeled. A caption below the map reads 'San Francisco to L.A. on a single charge'. At the bottom left of the article, there is a 'Buyer's Guide' section with a red background and white text.

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Blogs | Forums

Home » Blogs » **Kia's Big Fuel Cell Plans**

Kia's Big Fuel Cell Plans
Posted July 8 2009 09:12 AM by Joe DeMatio
Filed under: Green, Joe DeMatio, Kia, Hydrogen

San Francisco to L.A. on a single charge

San Francisco Golden Gate Bridge

Hollywood Los Angeles

Check Dealer Pricing On a New Kia

Buyer's Guide A quick drive in a Kia Borrego gives us a read o Hyundai-Kia's fuel-cell development.

“Hyundai-Kia expects to enter **small-scale production of FCEVs by 2012**, when it says about 9000 vehicles will be sold in the United States, mostly to municipalities (by all manufacturers of FCEVs). By 2015, it thinks about 48,000 FCEVs will be sold annually in the States, a number that could leap to 280,000 by 2018.”

Source: Automobile

Innovation for Our Energy Future

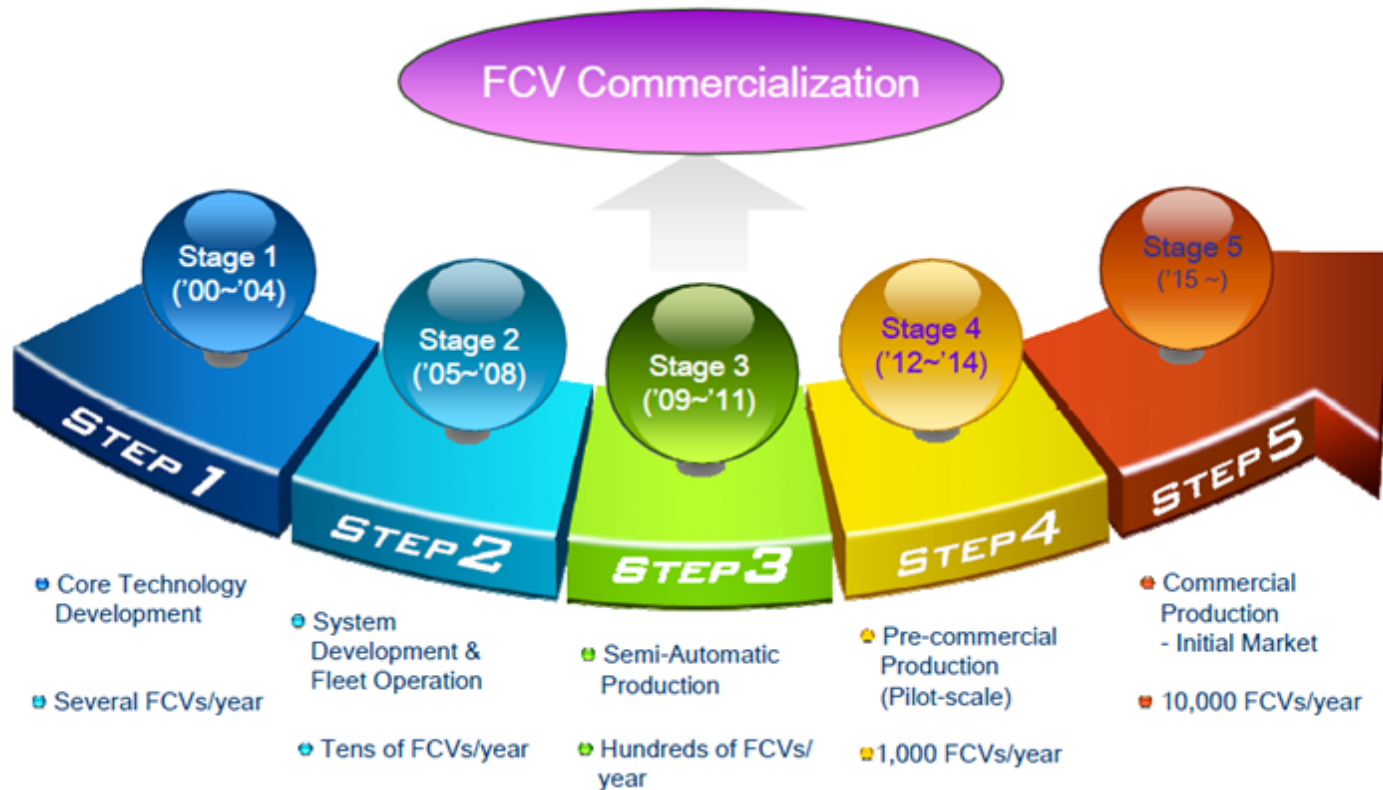
Korea

Hyundai-Kia Roadmap

EDTA Presentation / 2010.01.27



Roadmap for FCV Development



Source: Todd Suckow, EDTA conf, 2010-01-27

4th Generation FCV

2012 Series Production

- Small scale production
- 100kW PEMFC with metallic bipolar plate
- Lithium Polymer battery
- more than 60% system efficiency
- -20°C cold startup capability

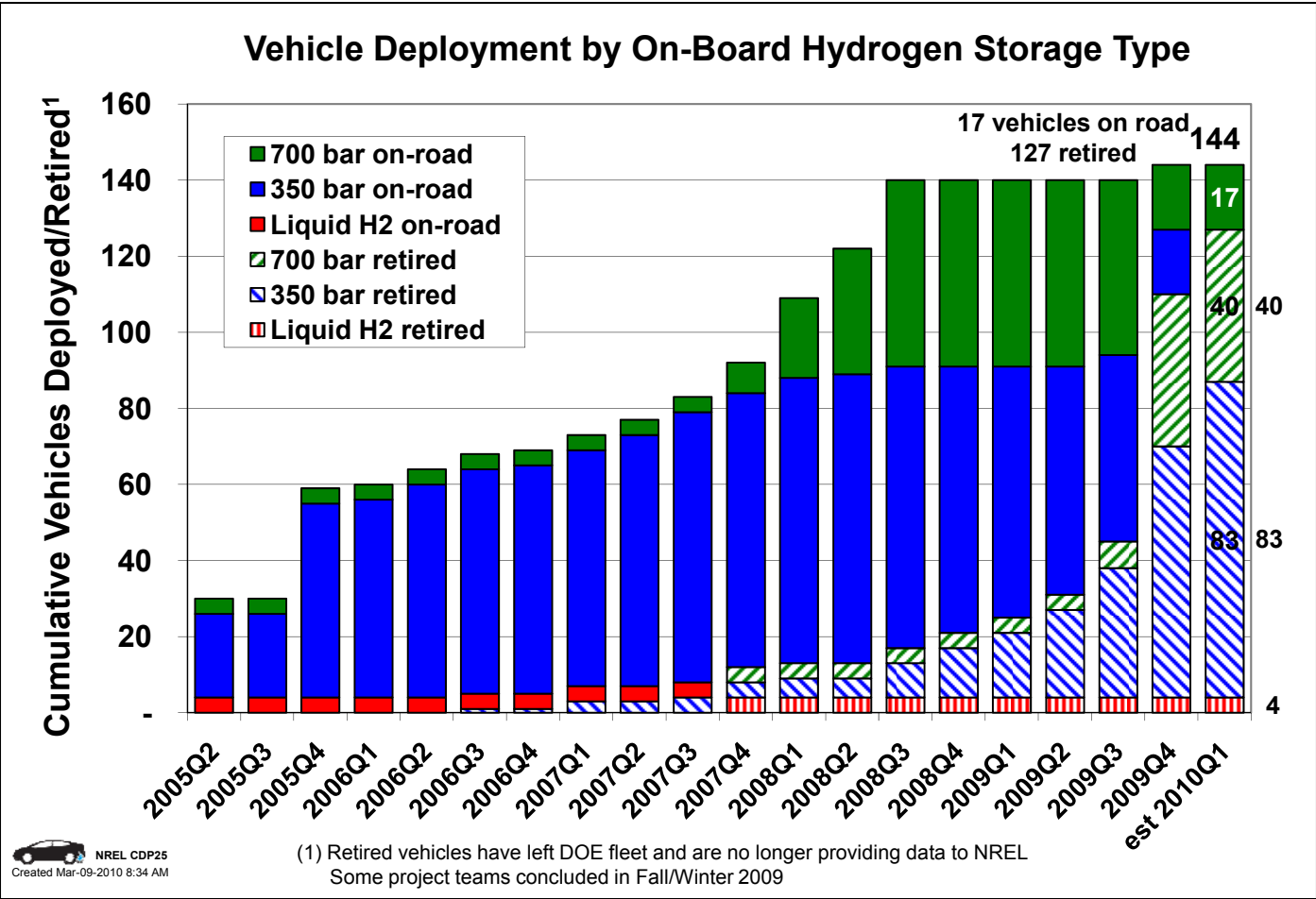


Source: Todd Suckow, EDTA conf, 2010-01-27

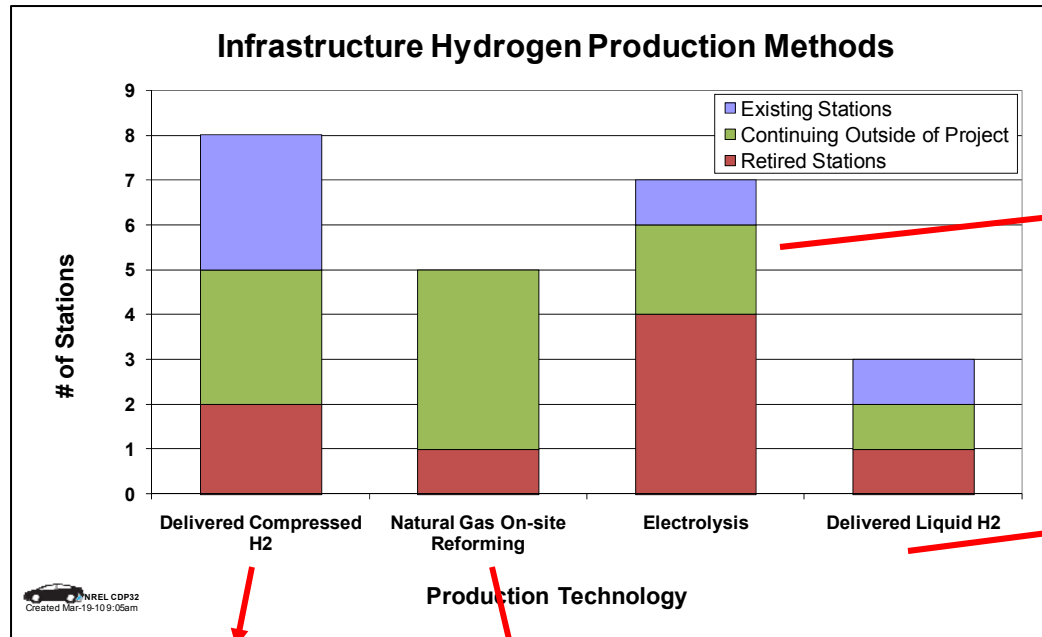
United States of America

- Fuel Cell Cars – Learning Demonstration
- Fuel Cell Buses
- Fuel Cell Forklifts
 - DOE
 - DOD

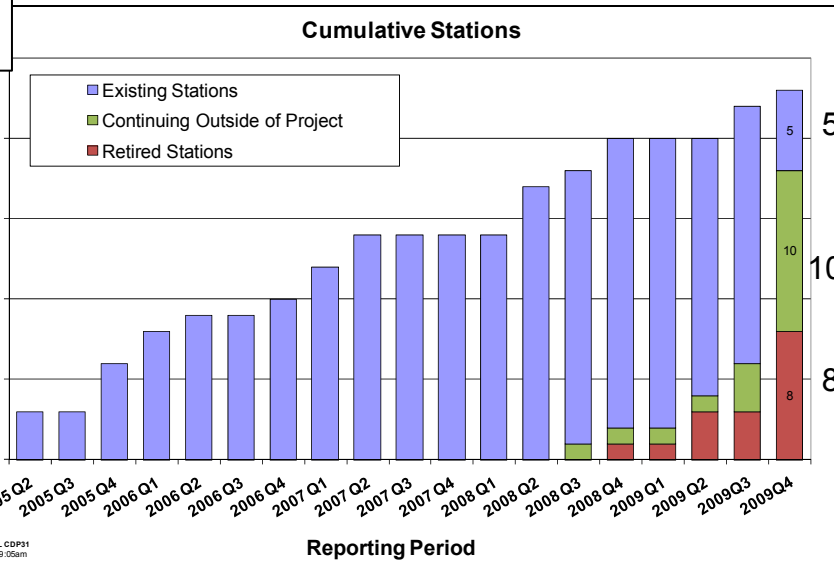
U.S Fuel Cell Vehicle Learning Demonstration Industry Partners and Vehicle Deployment Status



U.S Fuel Cell Vehicle Learning Demonstration Infrastructure Status



Total of 130,000 kg H₂ produced or dispensed from the 23 stations



U.S. Hydrogen Refueling Stations in Operation



- Legend**
- ▲ Chevron & Hyundai/Kia
 - ▲ DaimlerChrysler & BP
 - ▲ Ford & BP
 - ▲ General Motors & Shell
 - ▲ Air Products
 - ▲ Other Companies

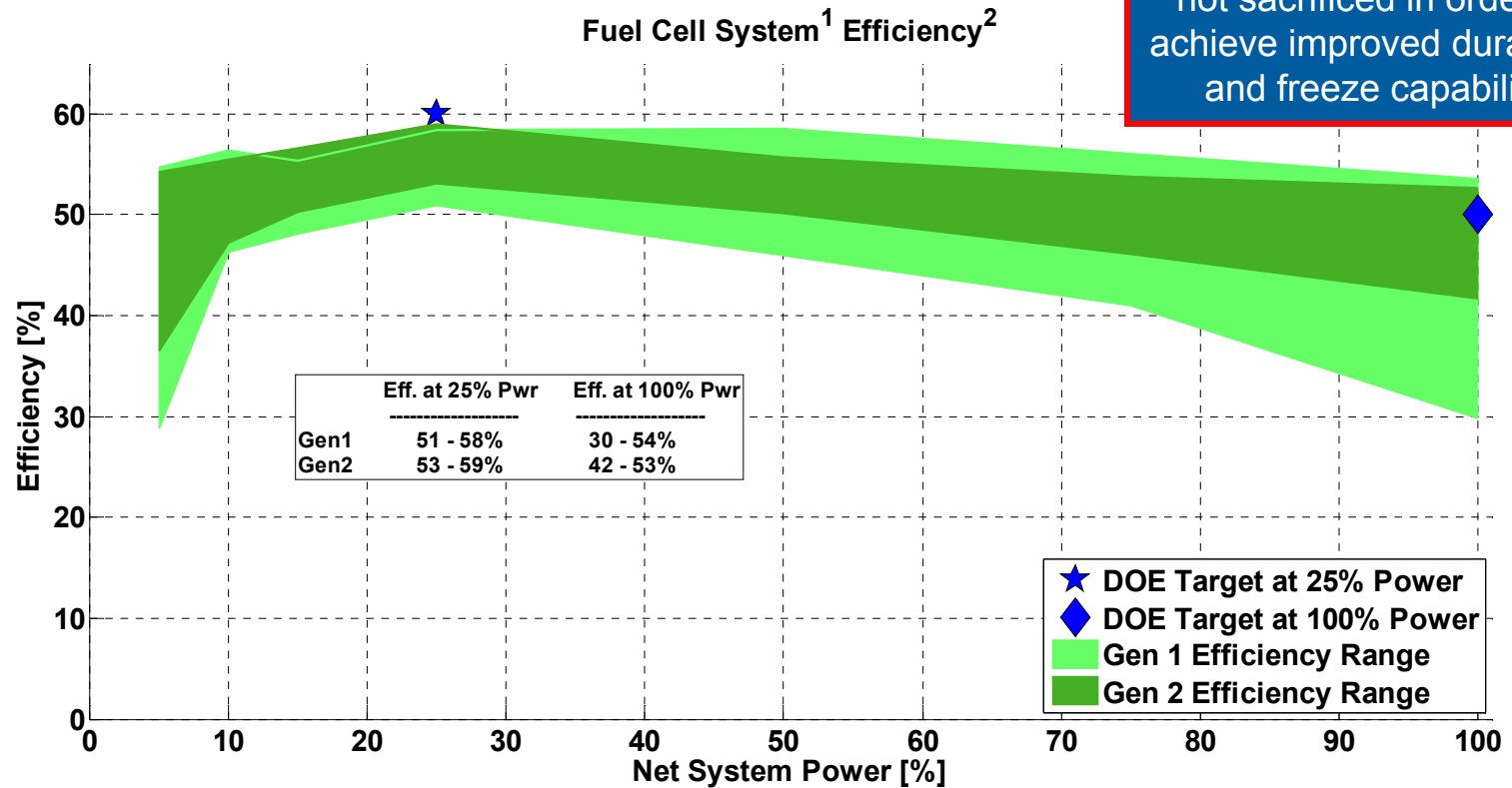
<http://mapserve3.nrel.gov/Hydrogen/HydrogenViewer.html>

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



Results presented at:
FC Seminar, NHA, EVS

Verified High Gen 2 Fuel Cell System Efficiency Maintained (Compared to Gen 1)

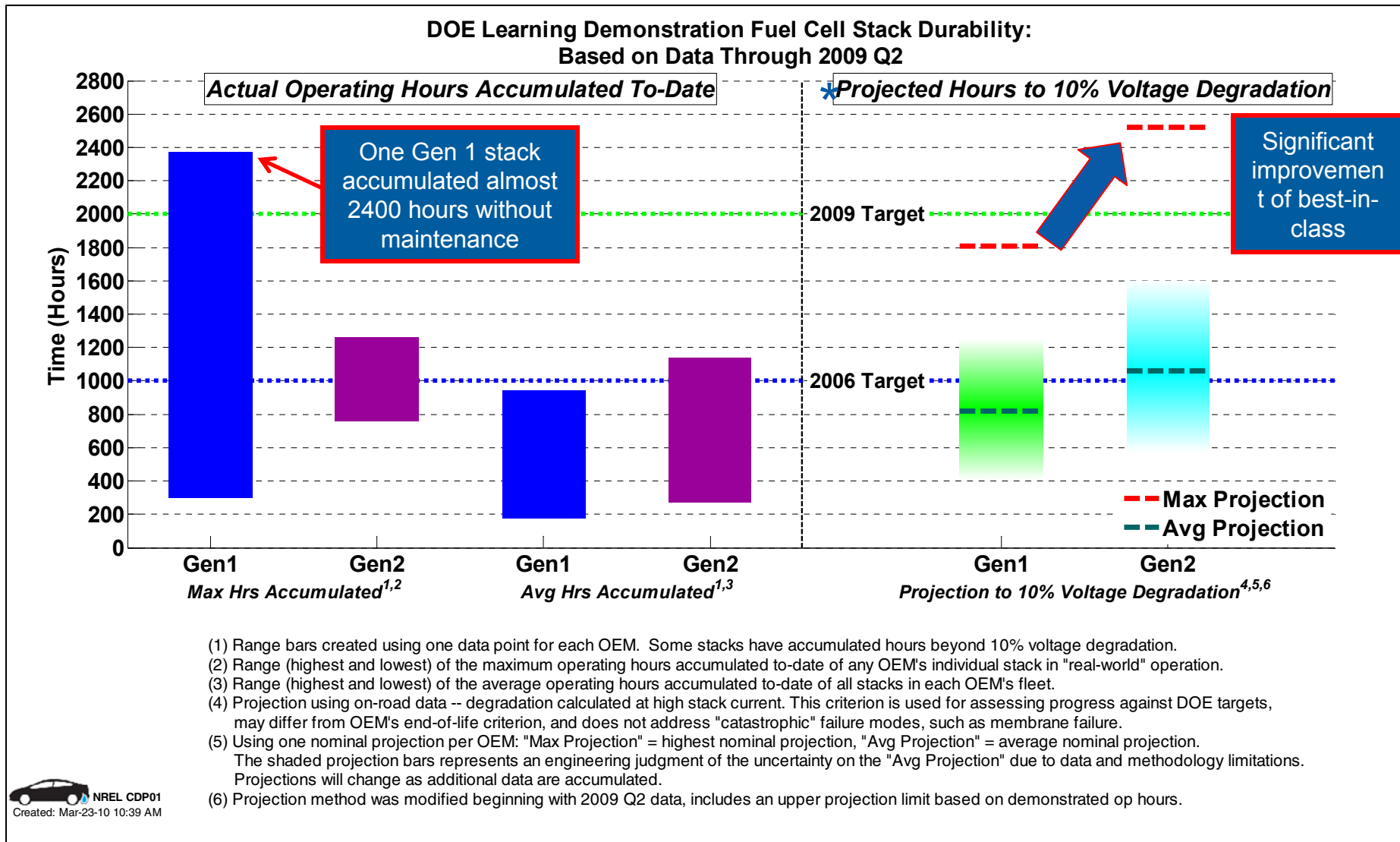


¹ Gross stack power minus fuel cell system auxiliaries, per DRAFT SAE J2615. Excludes power electronics and electric drive.

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.

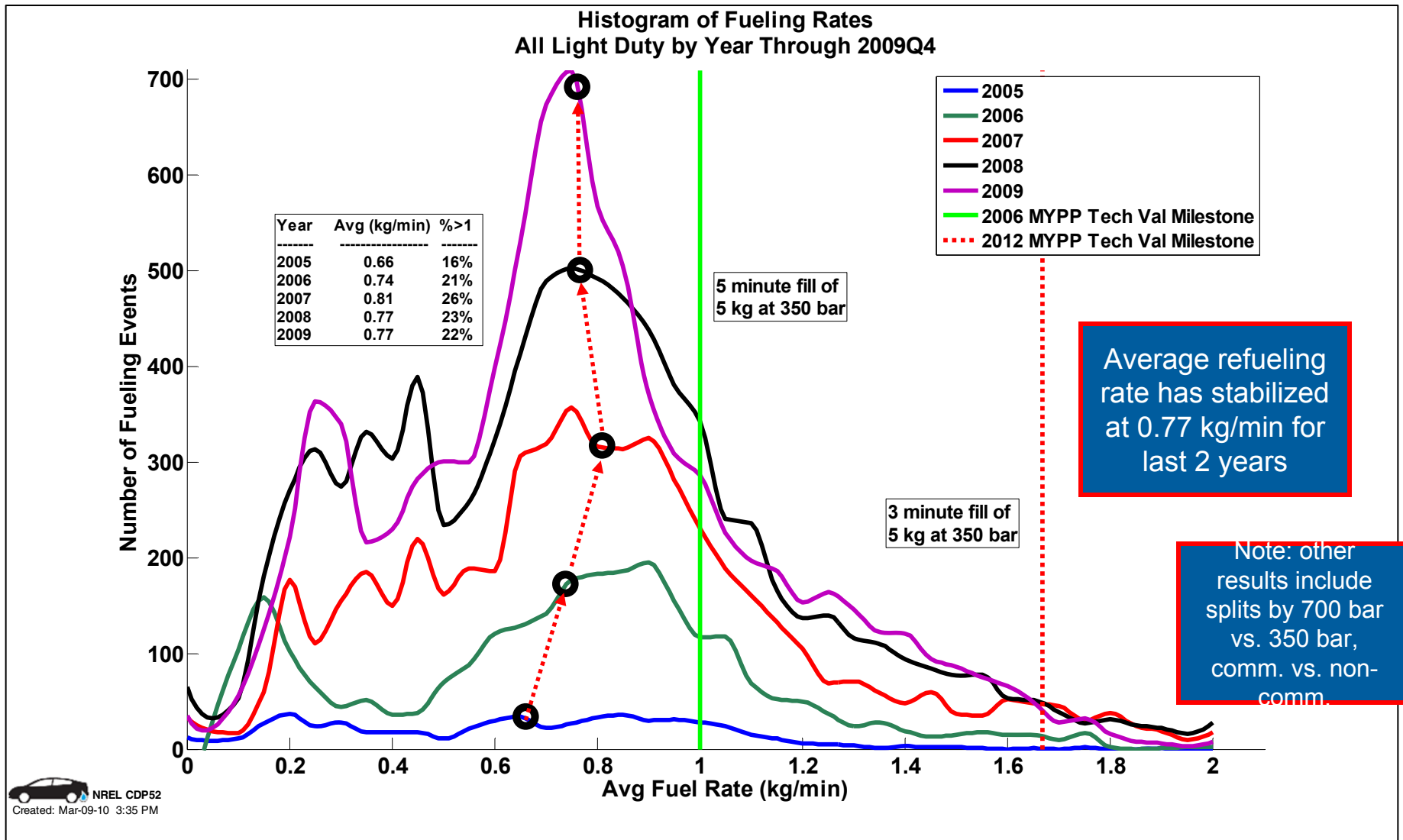
Quantified Gen 2 Fuel Cell System Durability* Improvement from Gen 1



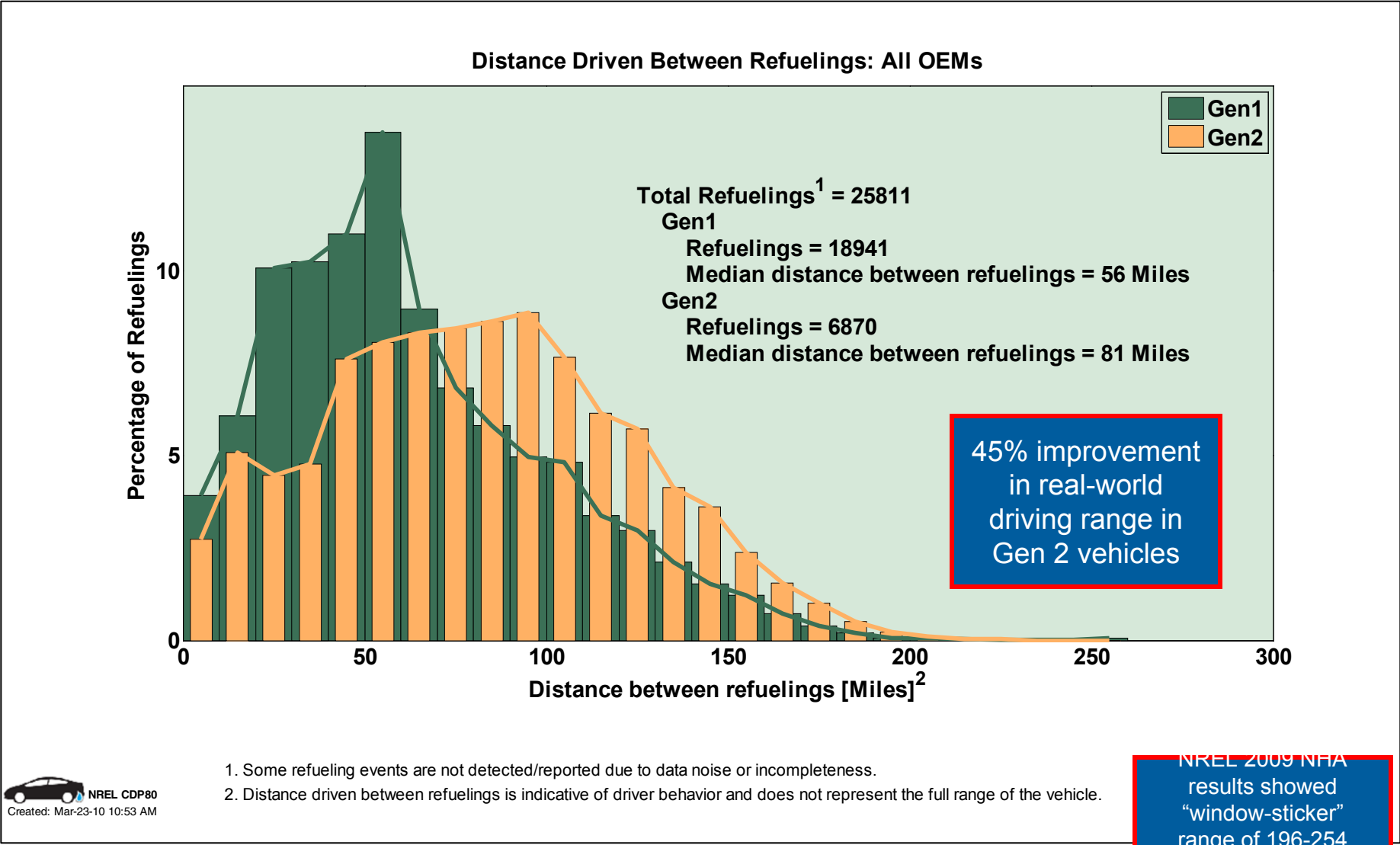
- (1) Range bars created using one data point for each OEM. Some stacks have accumulated hours beyond 10% voltage degradation.
- (2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
- (3) Range (highest and lowest) 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.

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

Tracked Refueling Rates Over 5 Year Period of Project



Range: Quantified Real-World Improvement in Driving Range Between Gen 1 and Gen 2 Vehicles



U.S. FCV Learning Demonstration Performance Summary

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	<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	
Driving Range	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
H₂ Cost at Station (early market)*	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)

American Recovery and Reinvestment Act (ARRA) Fuel Cell Early Market Projects

Project Objective

Deploy ~1,000 fuel cells to **accelerate the commercialization** and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services



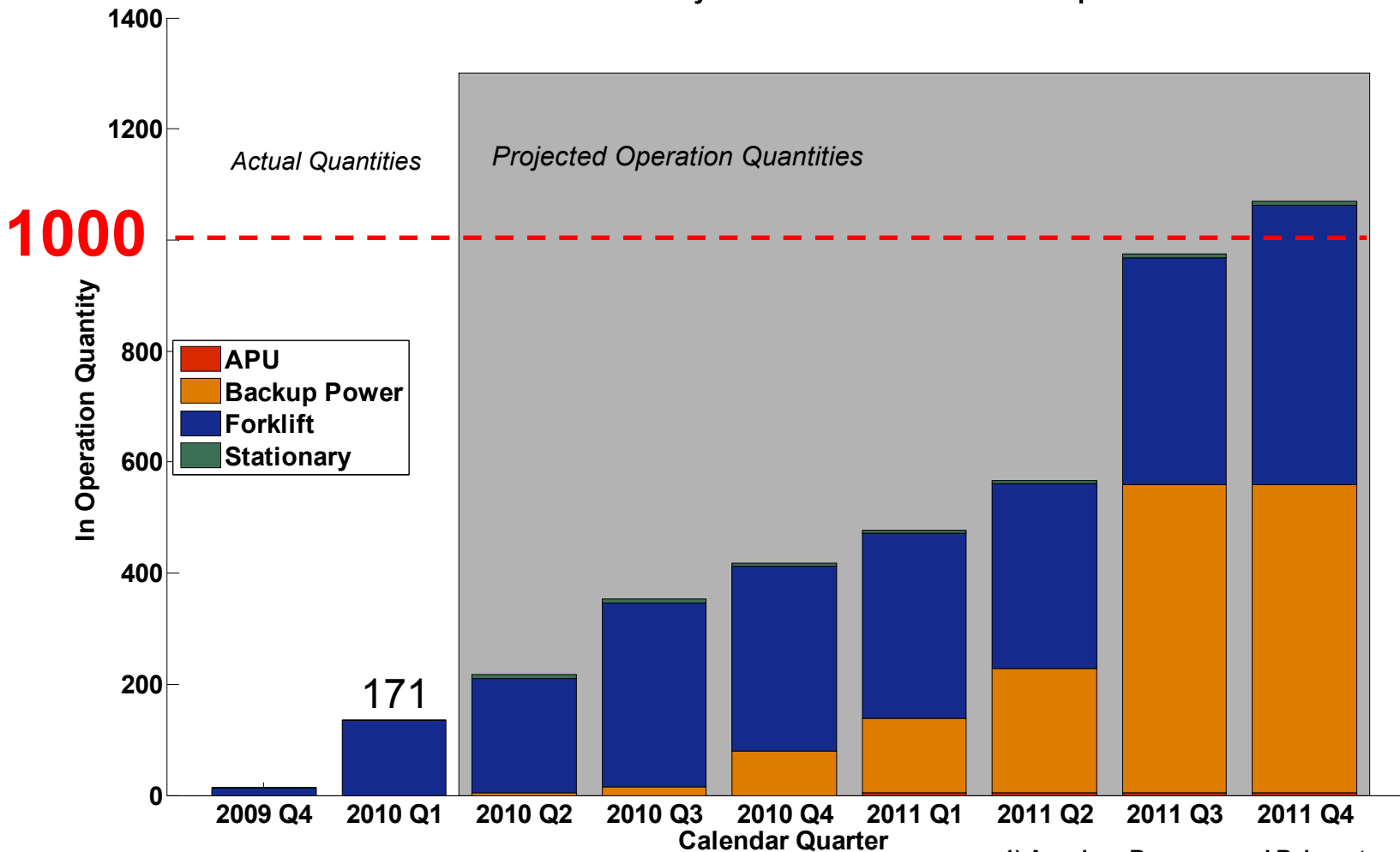
12 awards with >\$40 million ARRA & ~\$53 million cost share

COMPANY	AWARD	APPLICATION
Delphi Automotive	\$2.4 M	Auxiliary Power
FedEx Freight East	\$1.3 M	Specialty Vehicle
GENCO	\$6.1 M	Specialty Vehicle
Jadoo Power	\$2.2 M	Backup Power
MTI MicroFuel Cells	\$3.0 M	Portable
Nuvera Fuel Cells	\$1.1 M	Specialty Vehicle
Plug Power, Inc. (1)	\$3.4 M	CHP
Plug Power, Inc. (2)	\$2.7 M	Backup Power
Univ. of N. Florida	\$2.5 M	Portable
ReliOn Inc.	\$8.5 M	Backup Power
Sprint Comm.	\$7.3 M	Backup Power
Sysco of Houston	\$1.2 M	Specialty Vehicle

U.S. ARRA Fuel Cell Units in Operation

Current and Projected Quantities

DOE ARRA¹ Funded Early Fuel Cell Markets: Units in Operation



Created: Apr-14-10 4:16 PM

1) American Recovery and Reinvestment Act

U.S. Department of Defense

FC Forklift Demonstration Overview

4 Fuel Cell Forklift Demonstration Projects

- DOD's Defense Logistics Agency uses over 3,000 forklifts to accomplish its warehousing operations in DOD's 26 Defense Distribution Centers
- DLA has selected 4 warehouse sites to operate and demonstrate multiple hydrogen generation, dispensing and fuel cell technologies to power materials handling equipment (MHE) 24-month pilot phase
- DDSP is DLA's first fuel cell MHE pilot site
 - Ribbon cutting: February 10, 2009



Locations:

DDSP: 40 forklifts, delivered (cryogenic) hydrogen, indoor dispensing

DDWG: 20 forklifts, hydrogen via onsite natural gas reformation, mobile refueling

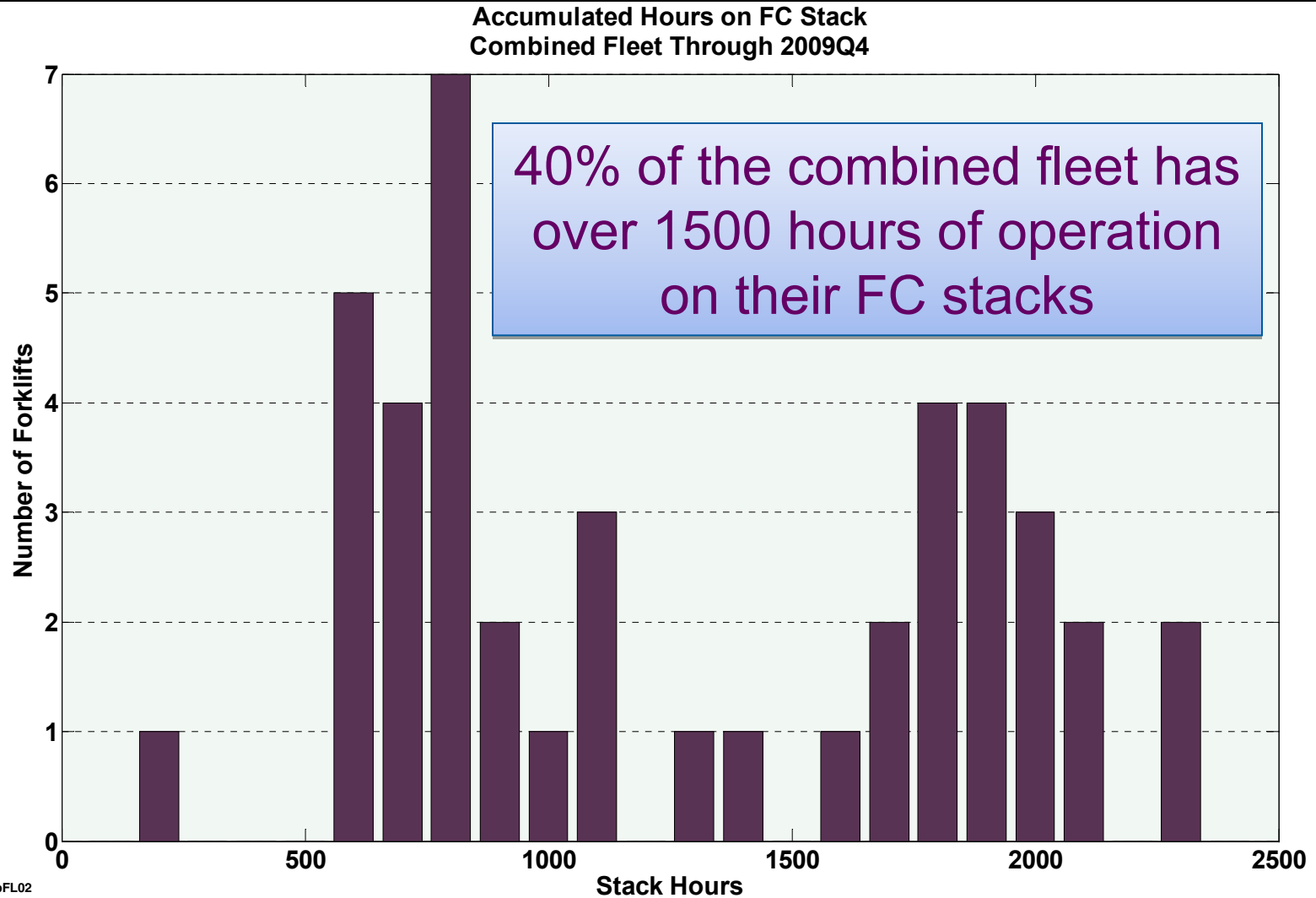
DDJC: 20 forklifts, hydrogen via solar electrolysis

Ft. Lewis: 19 forklifts, 1 bus, wastewater digester gas hydrogen, mobile refueling

Duration: 2 years of operation at each site

Technology Validation: NREL to perform data analysis to validate fuel cell technologies

Fuel Cell Stack Hours are Accumulating Rapidly in the Forklift Applications (~10X faster than cars)



U.S. Fuel Cell Bus Demonstration

Planned FCB Evaluations for DOE and FTA

NREL Hydrogen Bus Evaluations for DOE and FTA																		
Site/Location	State	Eval. Funding	2009				2010				2011				2012			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
AC Transit/ SF Bay Area	CA	DOE Technology Validation									CA ZEB Advanced Demo							
SunLine/ Thousand Palms	CA		FCB															
SunLine/ Thousand Palms	CA										Advanced FCB Project							
CTTRANSIT/ Hartford	CT		FCB Demo															
City of Burbank/ Burbank	CA										Burbank FCB							
AC Transit/ Oakland	CA	FTA National Fuel Cell Bus Program	Accel. Test															
SunLine/ Thousand Palms	CA										American FCB Demo							
CTTRANSIT/ Hartford	CT										Nutmeg Hybrid FCB Demo							
USC, CMRTA/ Columbia UT/ Austin	SC, TX						Hybrid FCB											
Logan Airport / Boston	MA										MA H2 FCB Demo							
Albany / NY	NY										Light-wt FCB							
TBD / NY	NY										NYPA H2 Powered FCB							
SFMTA / San Francisco	CA										FC APU Hybrid							

Demonstration sites color coded by geographic area:

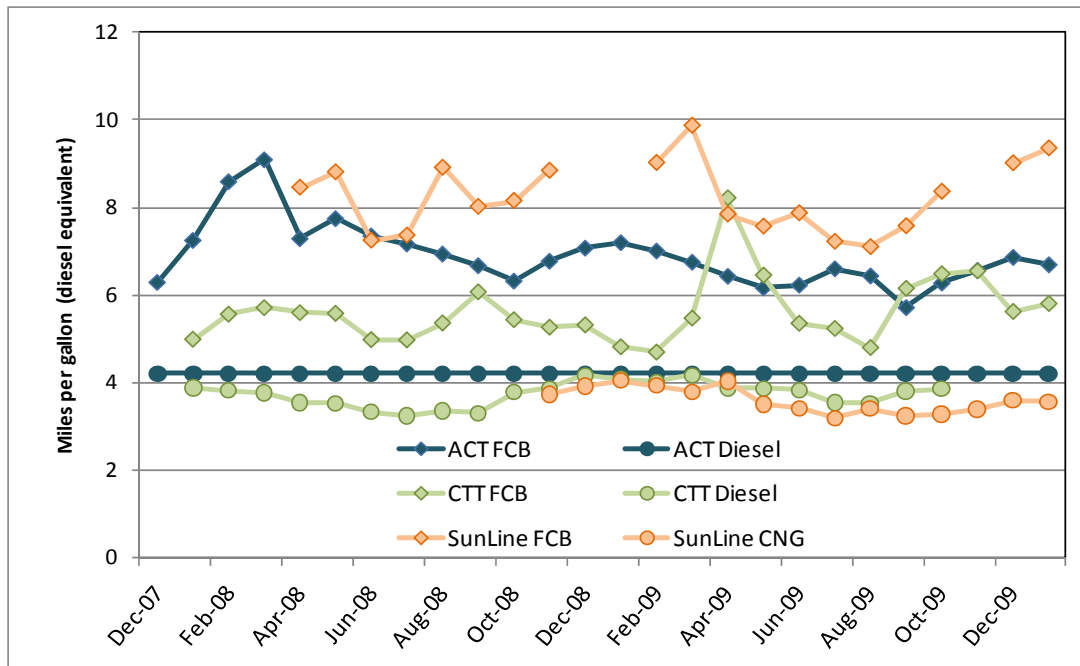
- Northern California
- New England
- Southeast
- Southern California
- New York
- South

U.S. Fuel Cell Bus Demonstration

Significant Fuel Consumption Reduction Quantified

Progress

- Continued data collection & analysis of five FCBs in real-world service at three transit agencies
- Documented fuel economy improvement over conventional technology as high as 2 times (depending on duty cycle)
- Manufacturer has modified FC based on early results to increase durability and reliability. New version installed in all 5 buses beginning in late 2007.



Monthly Fuel Economy

- Two new FC systems have surpassed 5,000 hours without any repairs (routine maintenance only)

Session TA.5: Early Morning Schedule

Sessionplan

TA.5 - Demonstration Projects, Costs and Market Introduction

date: 19 May 2010 - room: Deutschland

Session Chair:

Time	Lastname	Firstname	Degree	Country	Institution	Title
08:30	Wipke	Keith		US	National Renewable Energy Laboratory	Review Presentation on Demonstration Projects, Costs and Market Introduction
	Barbir	Frano	Dr.	HR	University of Split	Co-Chair

Speakers:

Time	Lastname	Firstname	Degree	Country	Institution	Title
09:00	Kimmel	Terry		CA	Canadian Hydrogen and Fuel Cell Association	Hydrogen and Fuel Cell Demonstration Programs leading to commercialization
09:30	Simonsen	Björn		NO	Lillestrøm Centre of Expertise	HyNor - the Norwegian hydrogen highway
10:00	Schnell	Patrick		D	TOTAL Deutschland GmbH	The Clean Energy Partnership: Strength of big companies, innovation from small and medium sized enterprises
10:30	Coffee Break					

Session TA.5: Late Morning Schedule

11:00	Walter	Stephan		CH	Paul Scherrer Institut	Assessing consumer preferences for hydrogen driven road-sweepers
11:30	Bünger	Ulrich	Dr.	D	LBST Ludwig-Bölkow-Systemtechnik GmbH	H2moves Scandinavia - Status of the first European Lighthouse Project to demonstrate hydrogen fuel cell cars in Scandinavia
12:00	de Miranda	Paulo Emilio V.	Prof.	BR	Universidade Federal do Rio de Janeiro	Brazilian Hybrid Electric Fuel Cell Bus
12:30	Stolzenburg	Klaus		D	PLANET GbR	Lessons Learned from Hydrogen Infrastructure Operation in the HyFLEET:CUTE Project
13:00	Lunch Break					

Session TA.5: After Lunch and Posters

13:00	Lunch Break					
14:30	Kolbusch	Thomas		D	COATEMA Coating Machinery GmbH	Manufacturing Processes for Gas-Diffusion-Electrodes for Polymer Electrolyte Fuel Cells
15:00	Flanz	Sabine		D	Ford Research Center Aachen	Experiences from 5 Years of Fuel Cell Vehicle Fleet Operation
15:30	Barbir	Frano	Dr.	HR	University of Split	Demonstration of a fuel cell powered boat
16:00	Coffee Break					
16:30	Leites	Keno		D	TKMS Blohm + Voss Nordseewerke GmbH	Fuel Cells in High Seas
17:00	Kolke	Reinhard		D	ADAC e.V	Consumers Perspective on Hydrogen in Transportation - Experience from world's third largest automobile club with hydrogen use in road petrol

Postertime: 18 May 2010, 13:00-14:30 17:30-19:00

Time	Lastname	Firstname	Degree	Country	Institution	Title
	Aso Aguarta	Ismael		ES	Fha Parque Tecnológico Walqa	Poster: Formula Zero: Development and Kart's Competition Driven by PEM Fuel Cell
	Cook	Shawn		CA	Canadian Hydrogen and Fuel Cell Association	Poster: Summary of Results and Learning Experiences from the Vancouver Fuel Cell Vehicle Program

Questions and Discussion



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

All public U.S. Technology Validation papers and presentations are available online at http://www.nrel.gov/hydrogen/proj_tech_validation.html