



# Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Spring 2009

Composite Data Products  
Final Version March 13, 2009

Keith Wipke, Sam Sprik, Jennifer Kurtz, and Todd Ramsden

*Technical Report*  
NREL/TP-560-45451  
March 2009

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC

Contract No. DE-AC36-08-GO28308





### **Disclaimer and Government License**

This work has been authored by Midwest Research Institute (MRI) under Contract No. DE-AC36-99GO10337 with the U.S. Department of Energy (the "DOE"). The United States Government (the "Government") retains and the publisher, by accepting the work for publication, acknowledges that the Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for Government purposes.

Neither MRI, the DOE, the Government, nor any other agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the Government or any agency thereof. The views and opinions of the authors and/or presenters expressed herein do not necessarily state or reflect those of MRI, the DOE, the Government, or any agency thereof.

# Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project



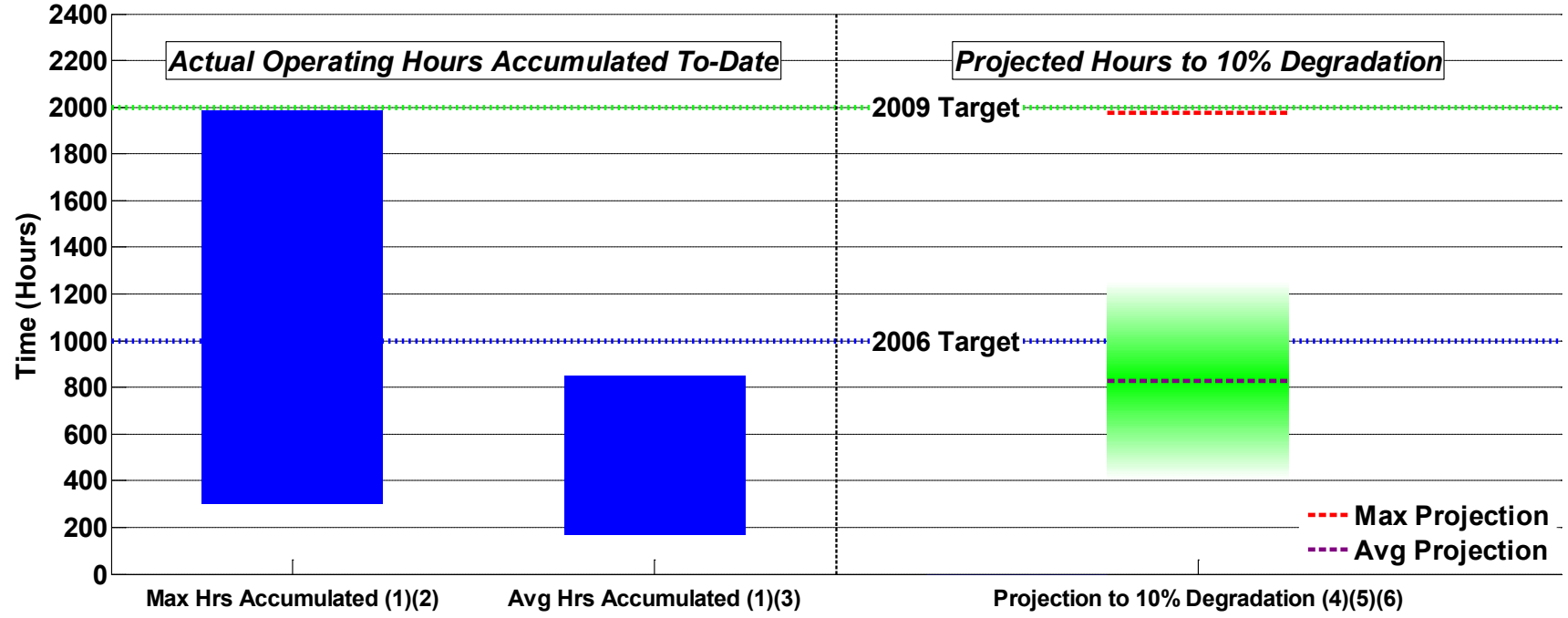
**Spring 2009  
Composite Data  
Products**

**March 13, 2009**

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

# CDP#1: Hours Accumulated and Projected Hours to 10% Stack Voltage Degradation

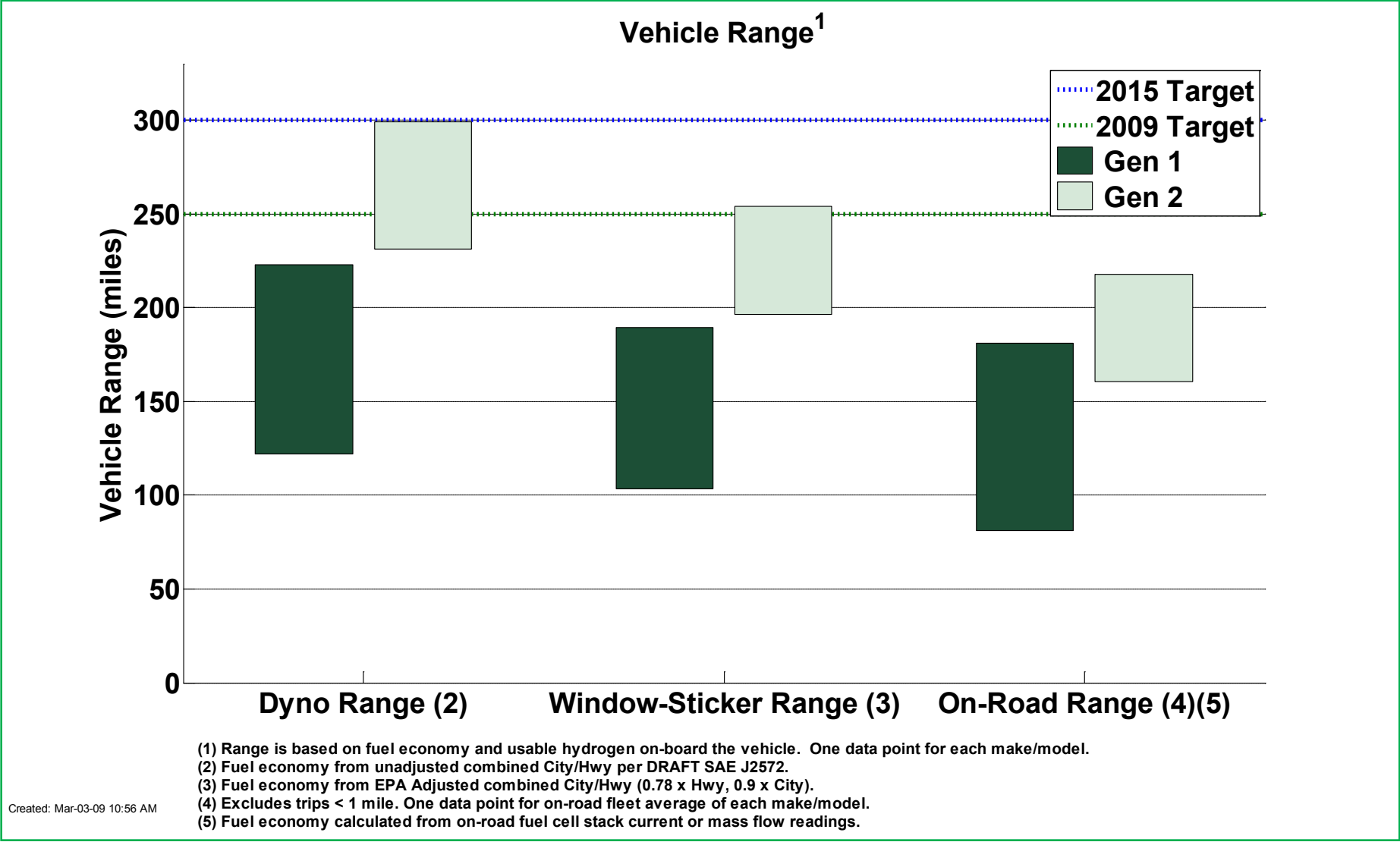
DOE Learning Demonstration Fuel Cell Stack Durability:  
Based on Data Through 2008 Q4



- (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 green bar 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 2008 Q2 data.

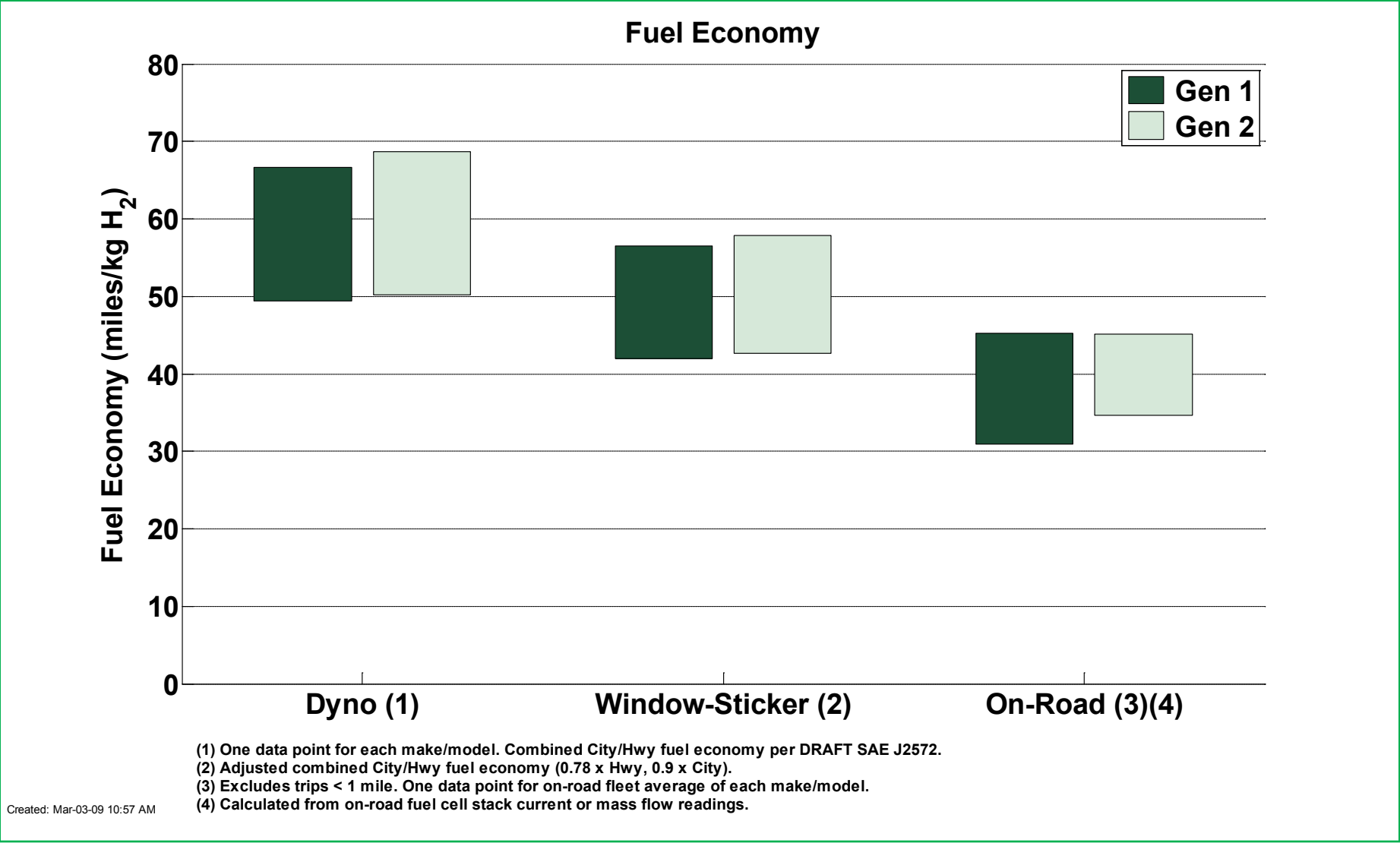
Created: Feb-24-09 1:21 PM

# CDP#2: Vehicle Range

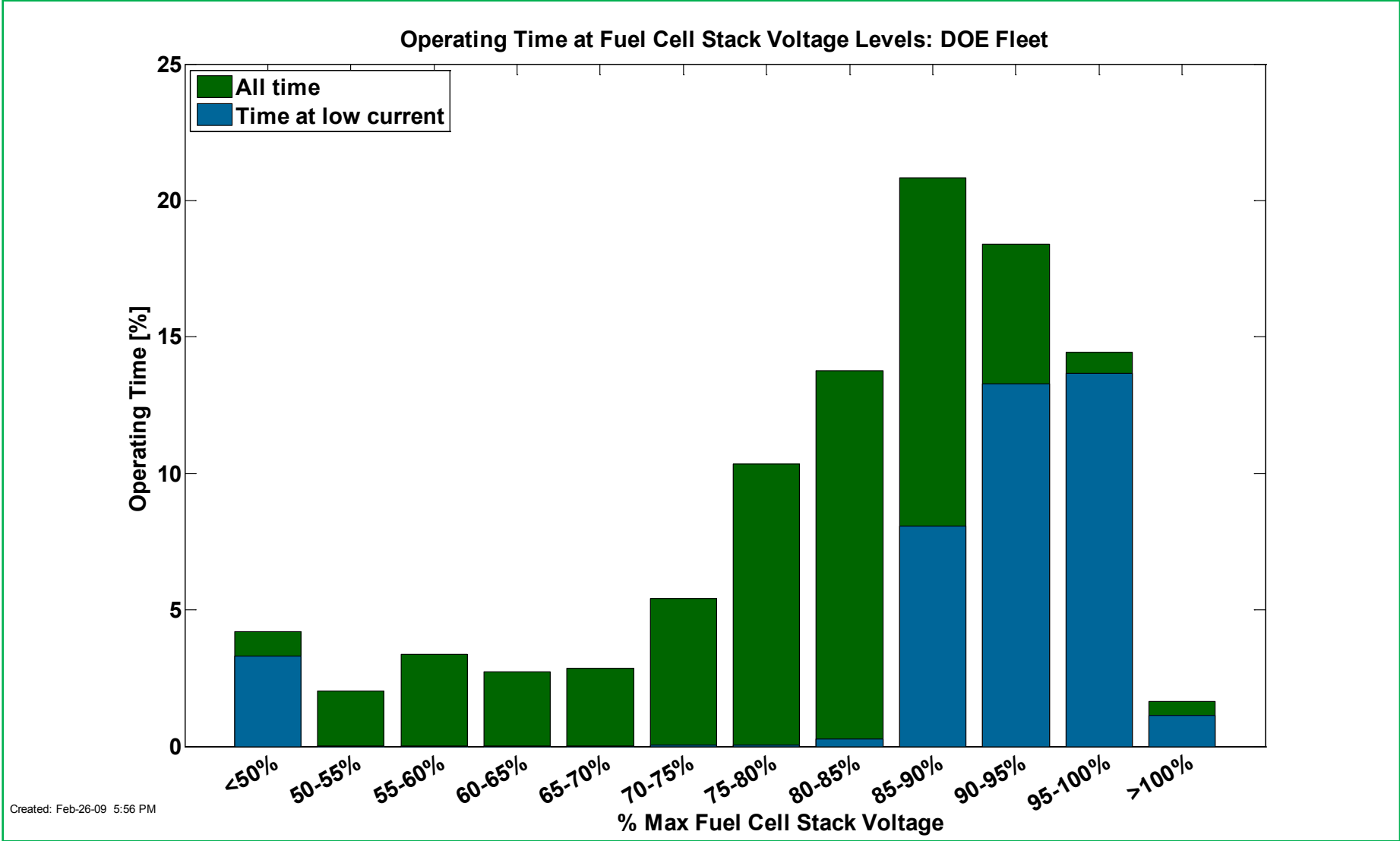


Created: Mar-03-09 10:56 AM

# CDP#6: Fuel Economy

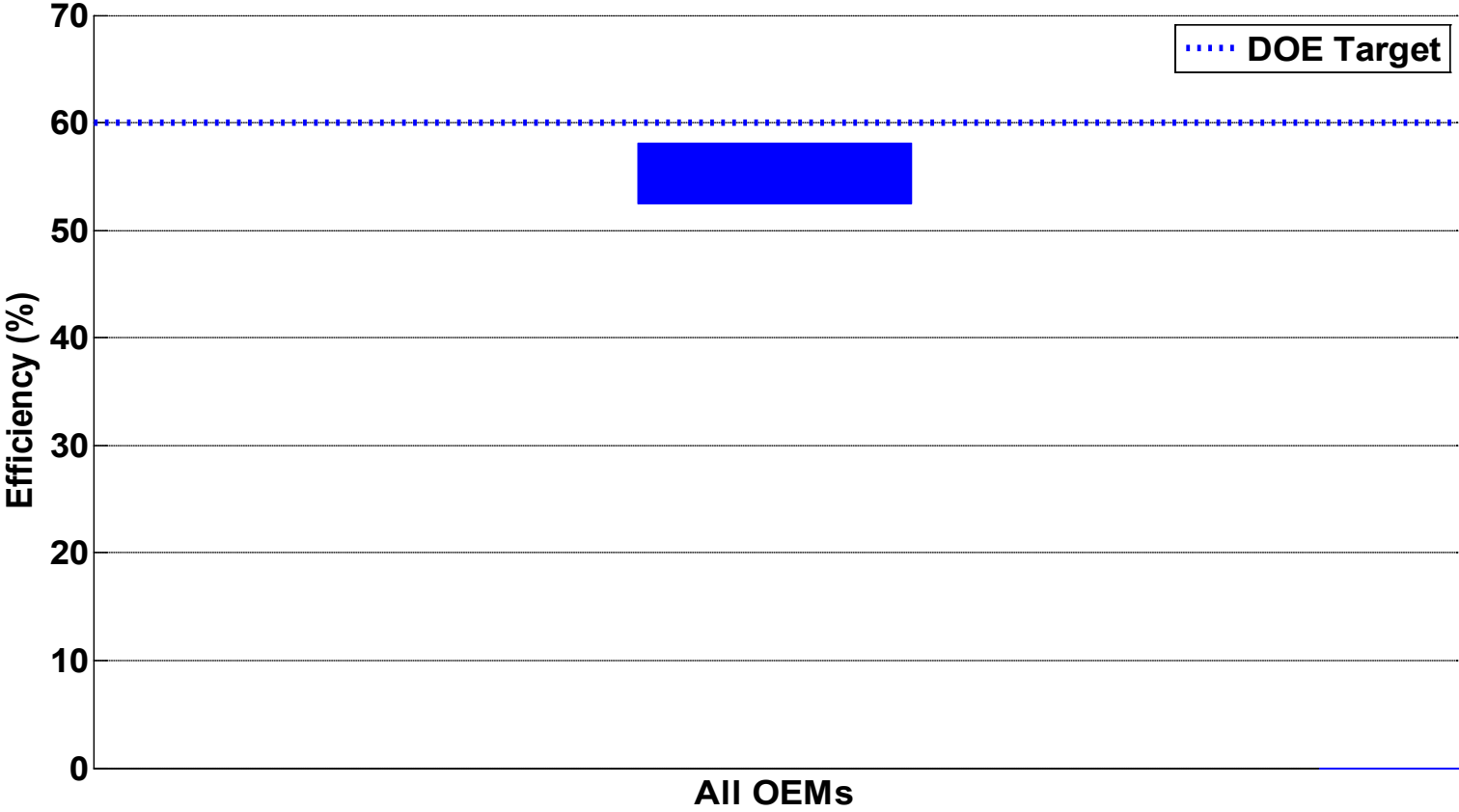


# CDP#7: Fuel Cell Voltage



# CDP#8: FC System Efficiency

Fuel Cell System<sup>1</sup> Efficiency<sup>2</sup> at ~25% Net Power.

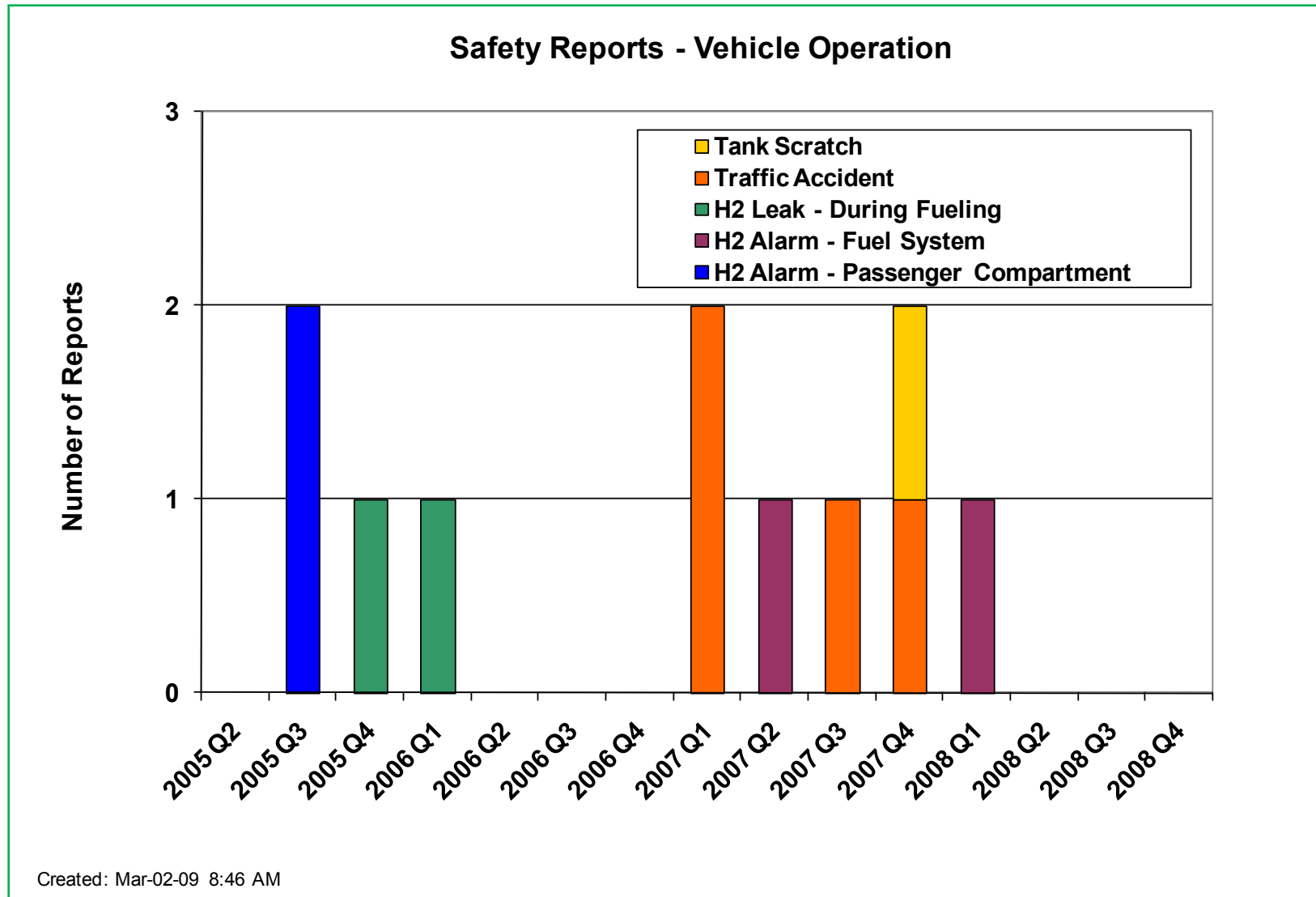


<sup>1</sup> Gross stack power minus fuel cell system auxiliaries, per DRAFT SAEJ2615.

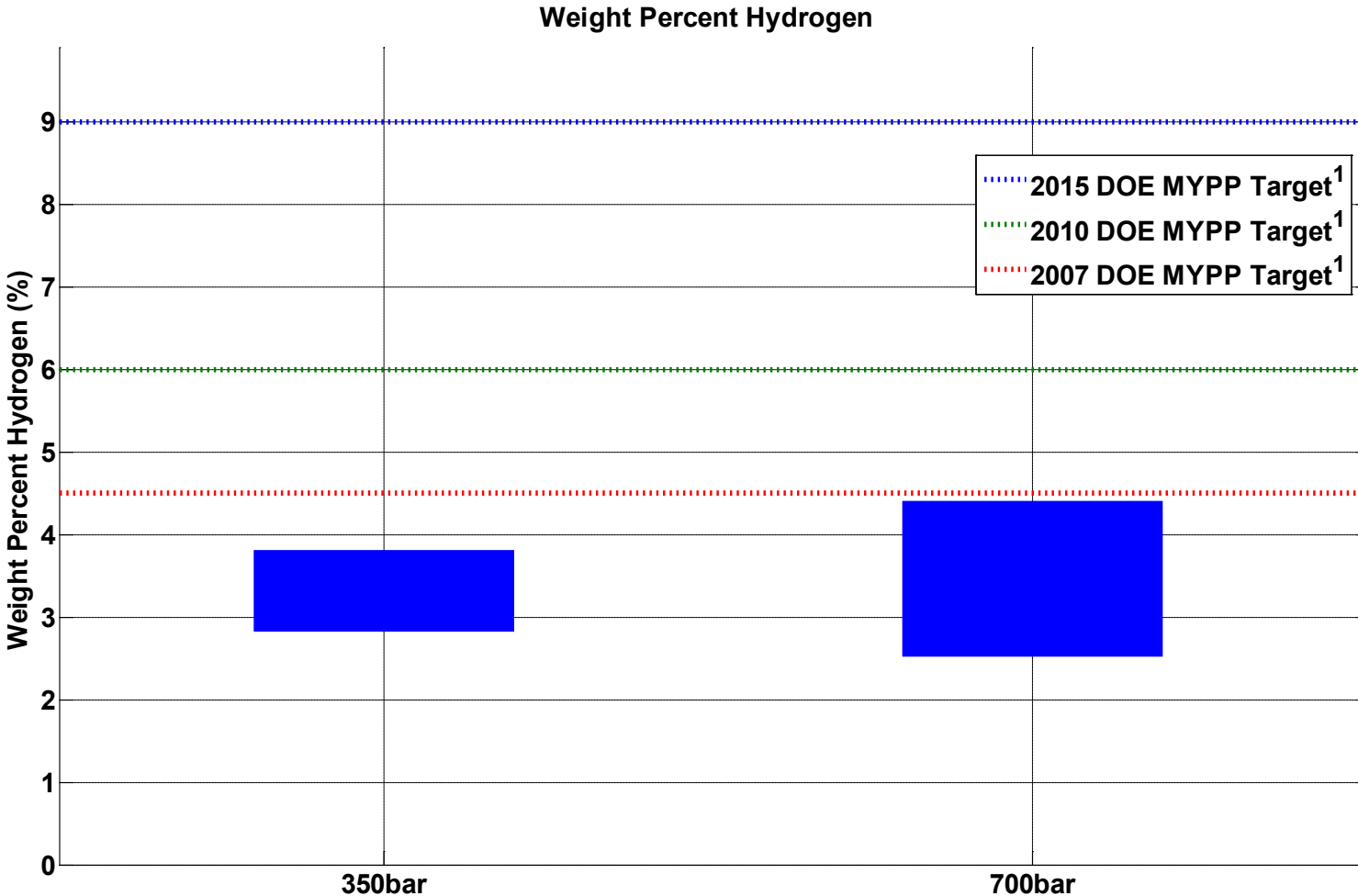
<sup>2</sup> Ratio of DC output energy to the lower heating value of the input fuel (hydrogen). Excludes power electronics and electric drive.



# CDP#9: Safety Reports – Vehicles



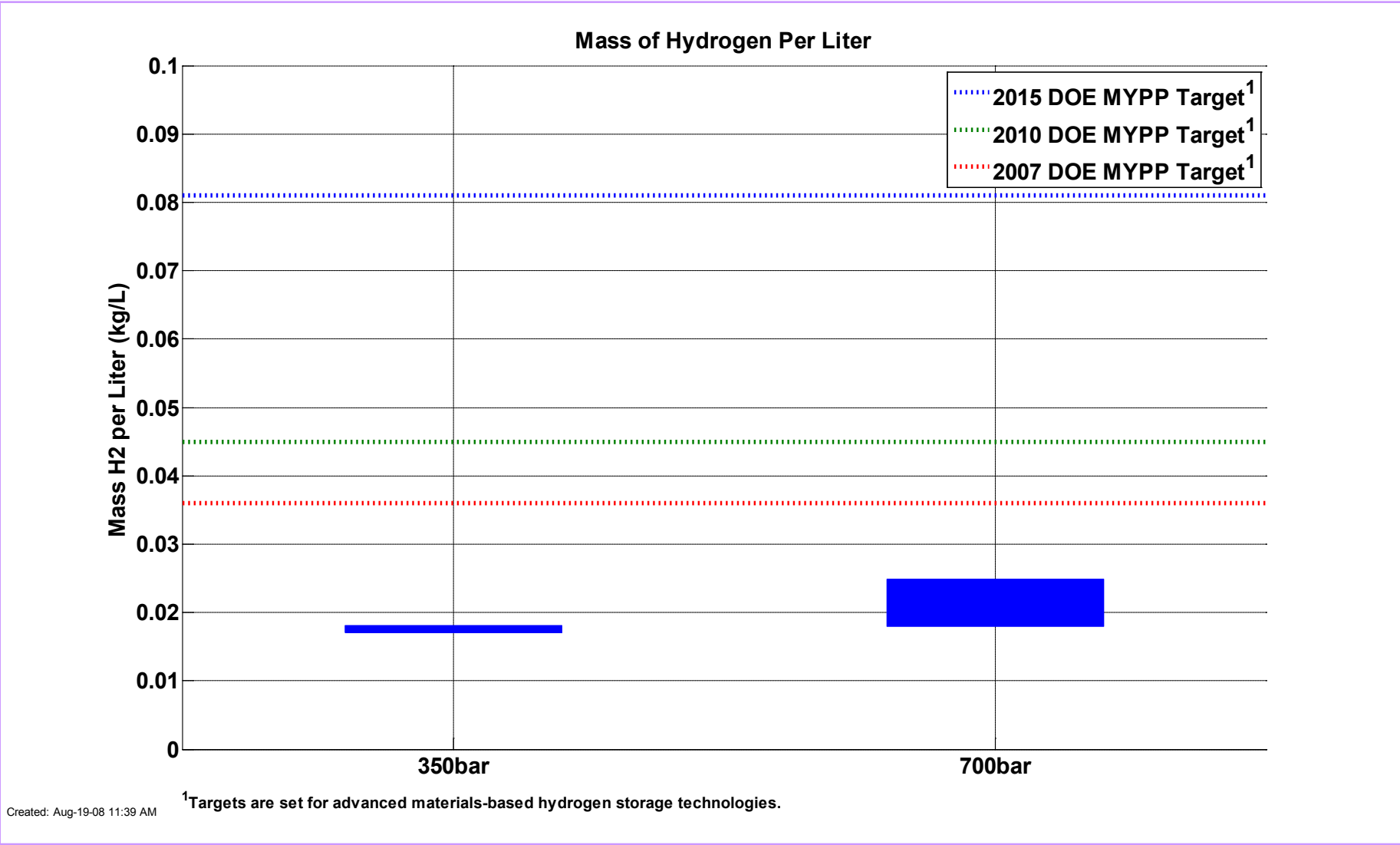
# CDP#10: Storage Weight % Hydrogen



<sup>1</sup>Targets are set for advanced materials-based hydrogen storage technologies.

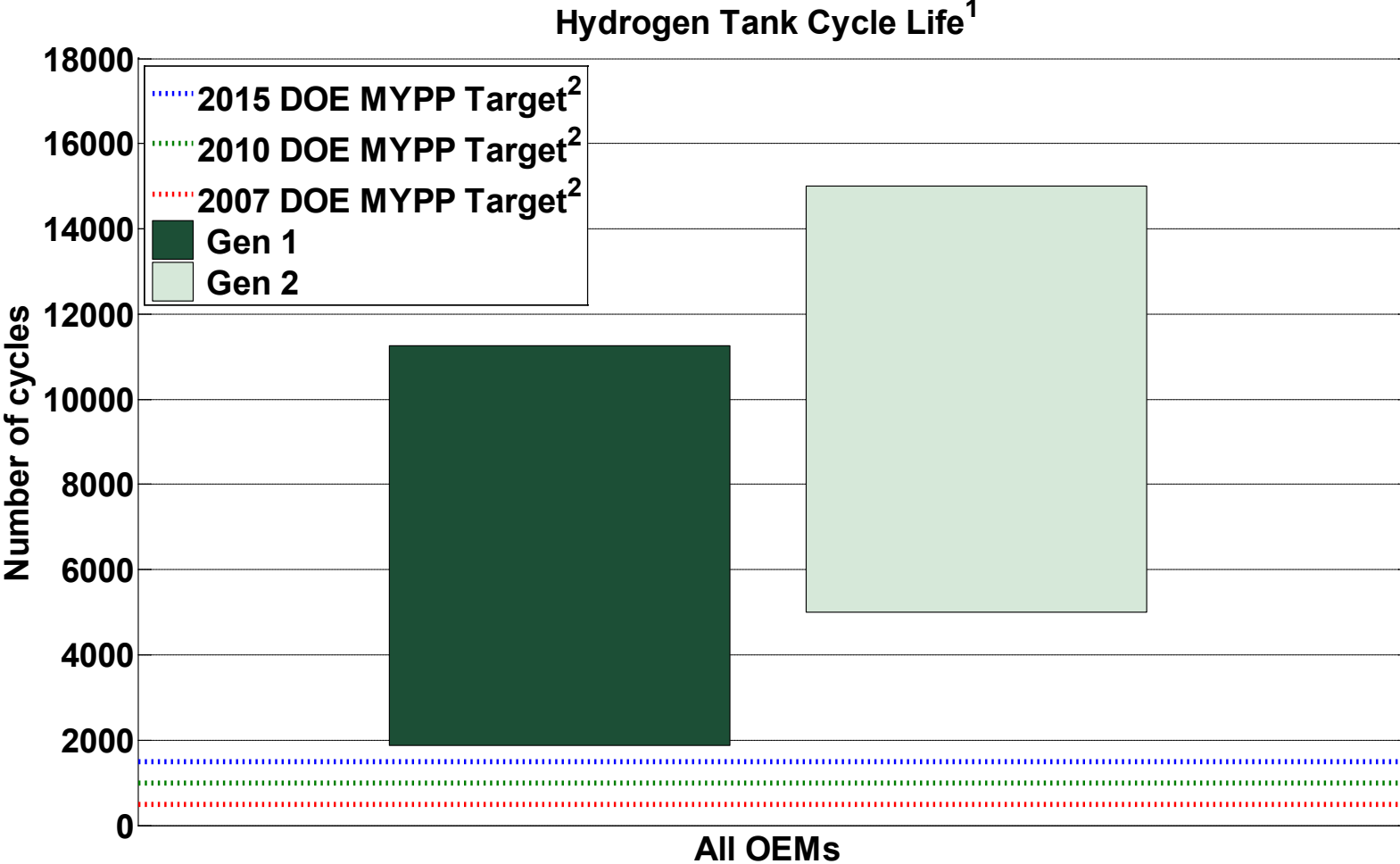
Created: Aug-19-08 11:39 AM

# CDP#11: Volumetric Capacity of H2 Storage



Created: Aug-19-08 11:39 AM

# CDP#12: Vehicle Hydrogen Tank Cycle Life

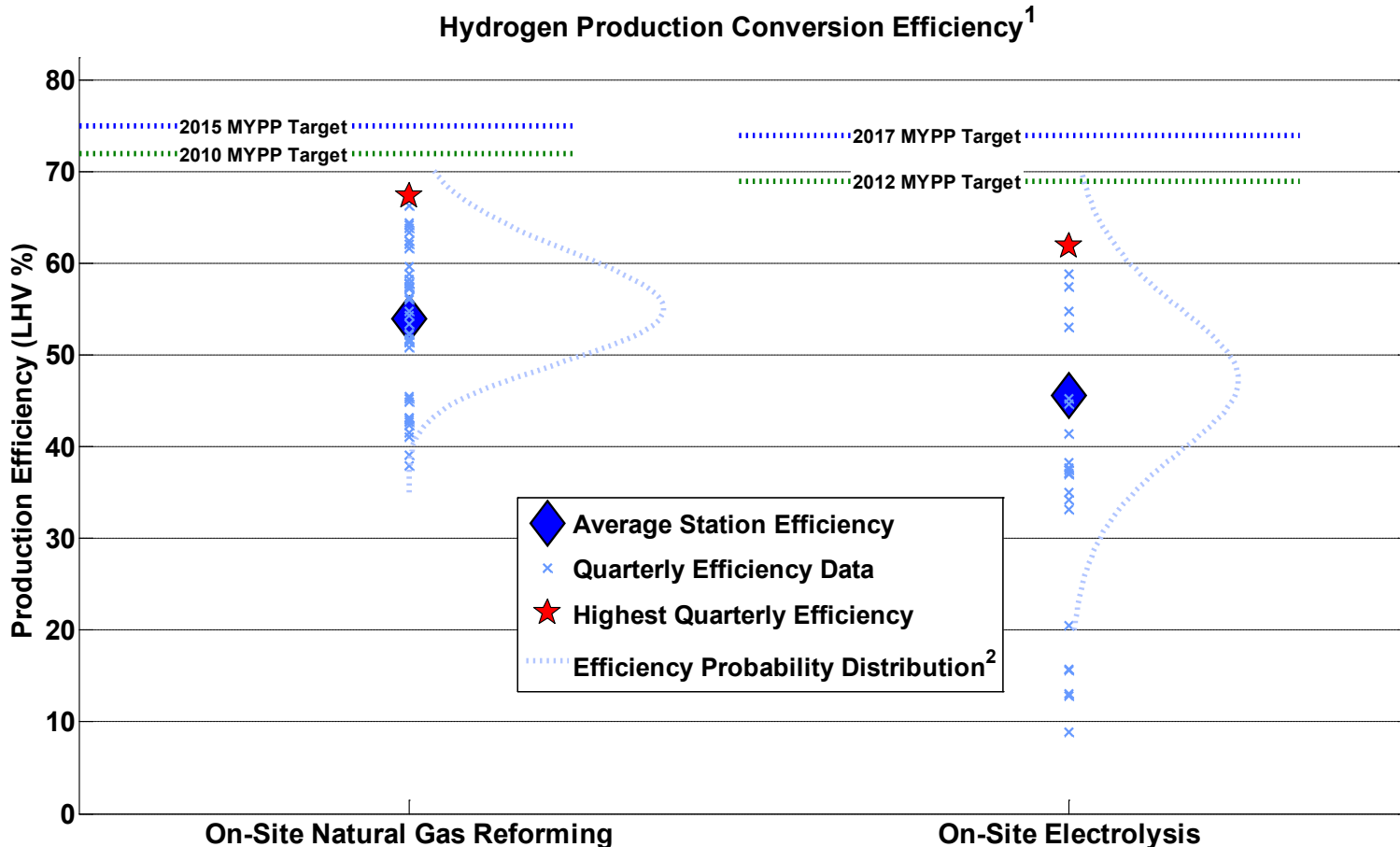


<sup>1</sup>Data reported reference NGV2, HGV2, or EIHP standards.

<sup>2</sup>Some near-term targets have been achieved with compressed and liquid tanks. Emphasis is on advanced materials-based technologies.

Created: Sep-17-08 10:29 AM

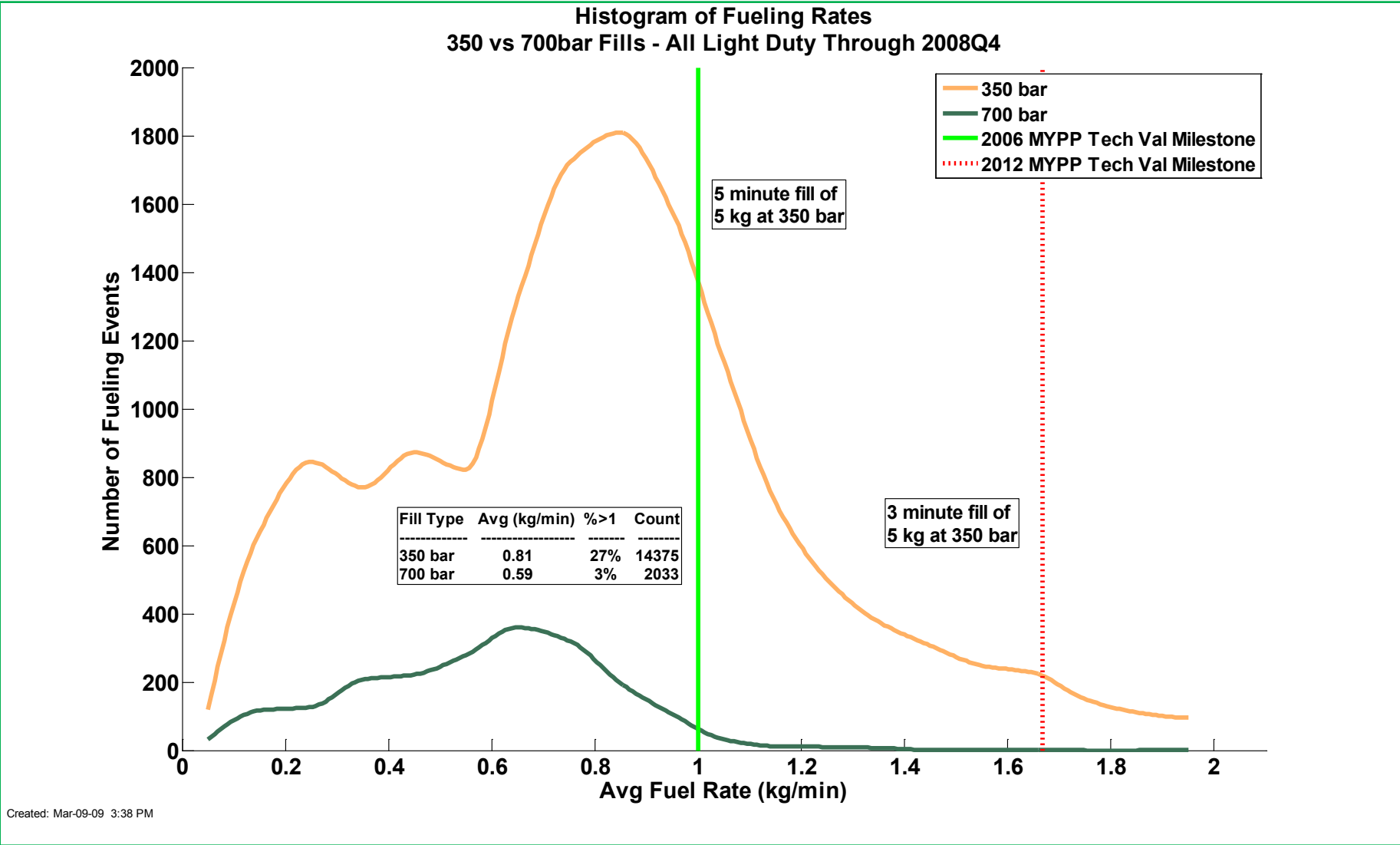
# CDP#13: On-Site Hydrogen Production Efficiency



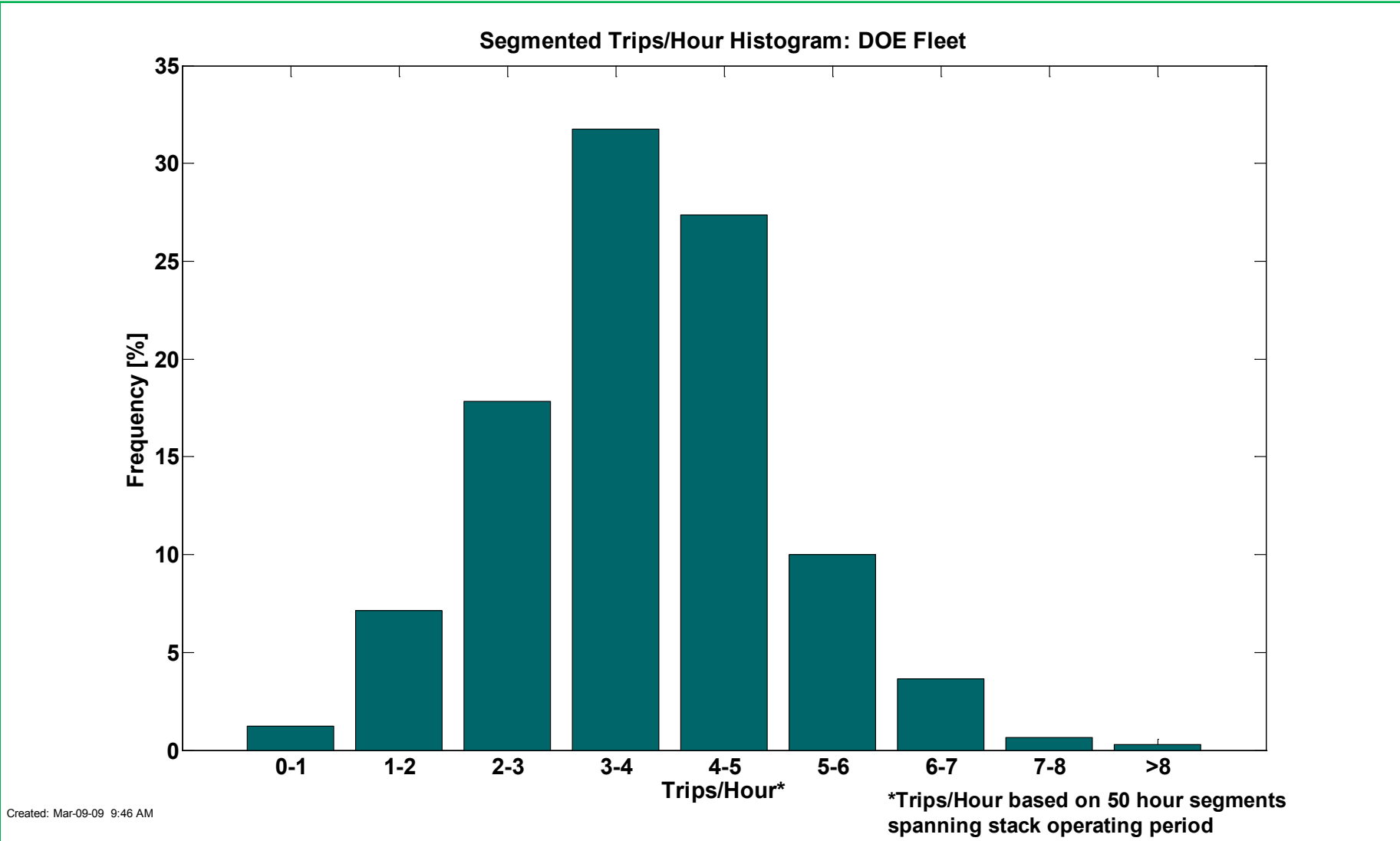
<sup>1</sup>Production conversion efficiency is defined as the energy of the hydrogen out of the process (on an LHV basis) divided by the sum of the energy into the production process from the feedstock and all other energy as needed. Conversion efficiency does not include energy used for compression, storage, and dispensing.  
<sup>2</sup>The efficiency probability distribution represents the range and likelihood of hydrogen production conversion efficiency based on monthly conversion efficiency data from the Learning Demonstration.

Created: Feb-26-09 2:26 PM

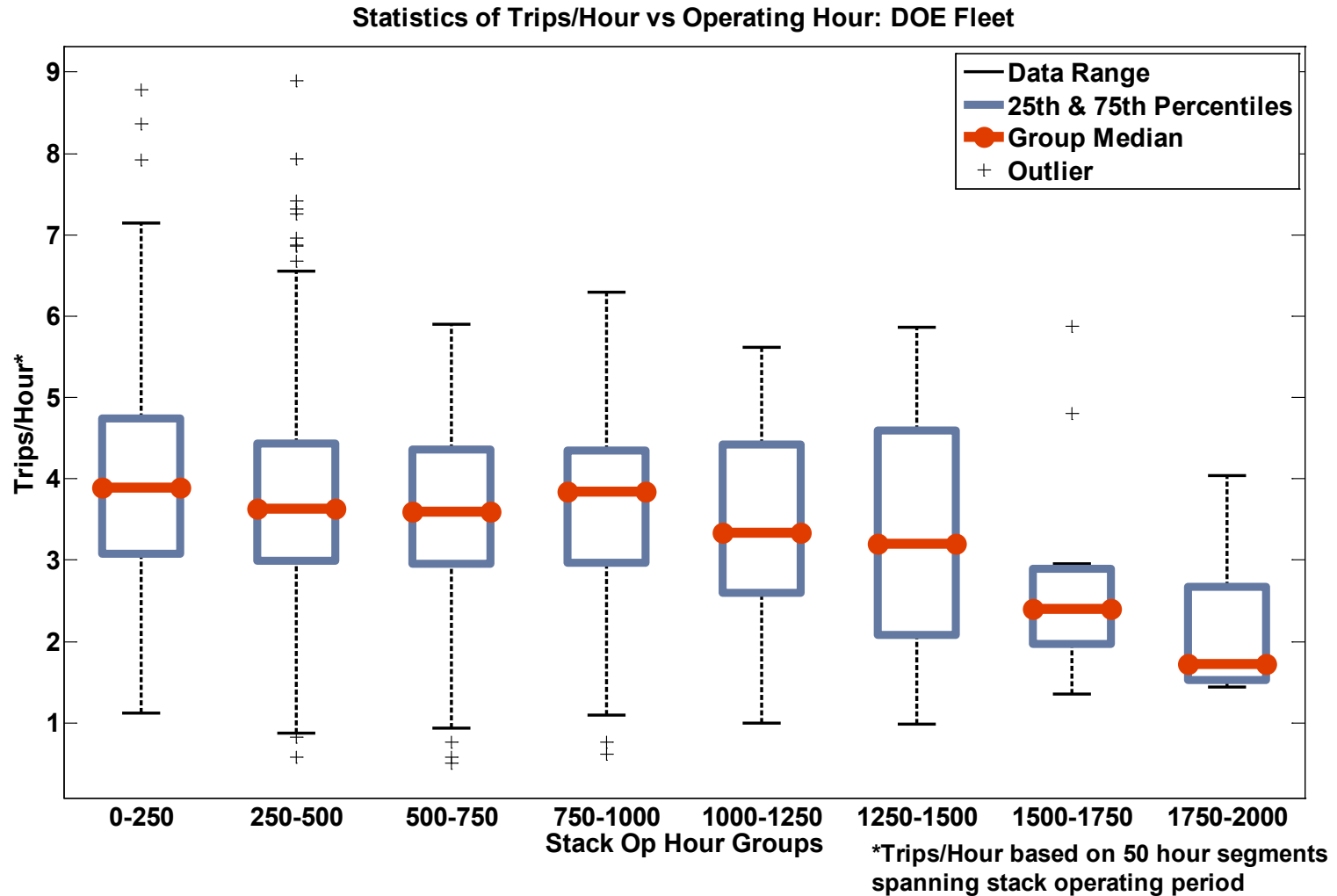
# CDP#14: Fueling Rates – 350 and 700 bar



# CDP#16: Fuel Cell Stack Trips Per Hour Histogram



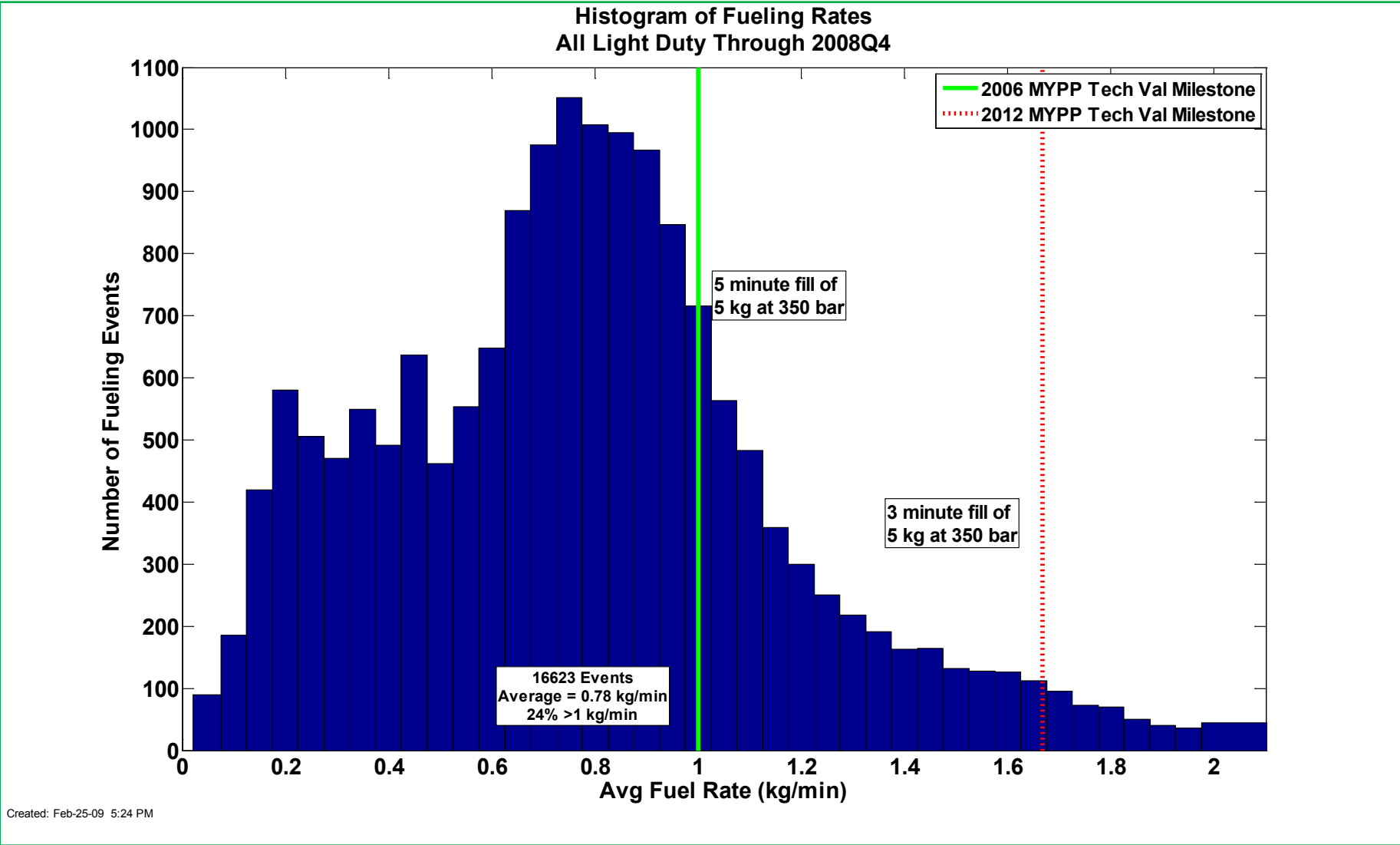
# CDP#17: Statistics of Trips/Hour vs. Operating Hour



Created: Mar-09-09 9:46 AM

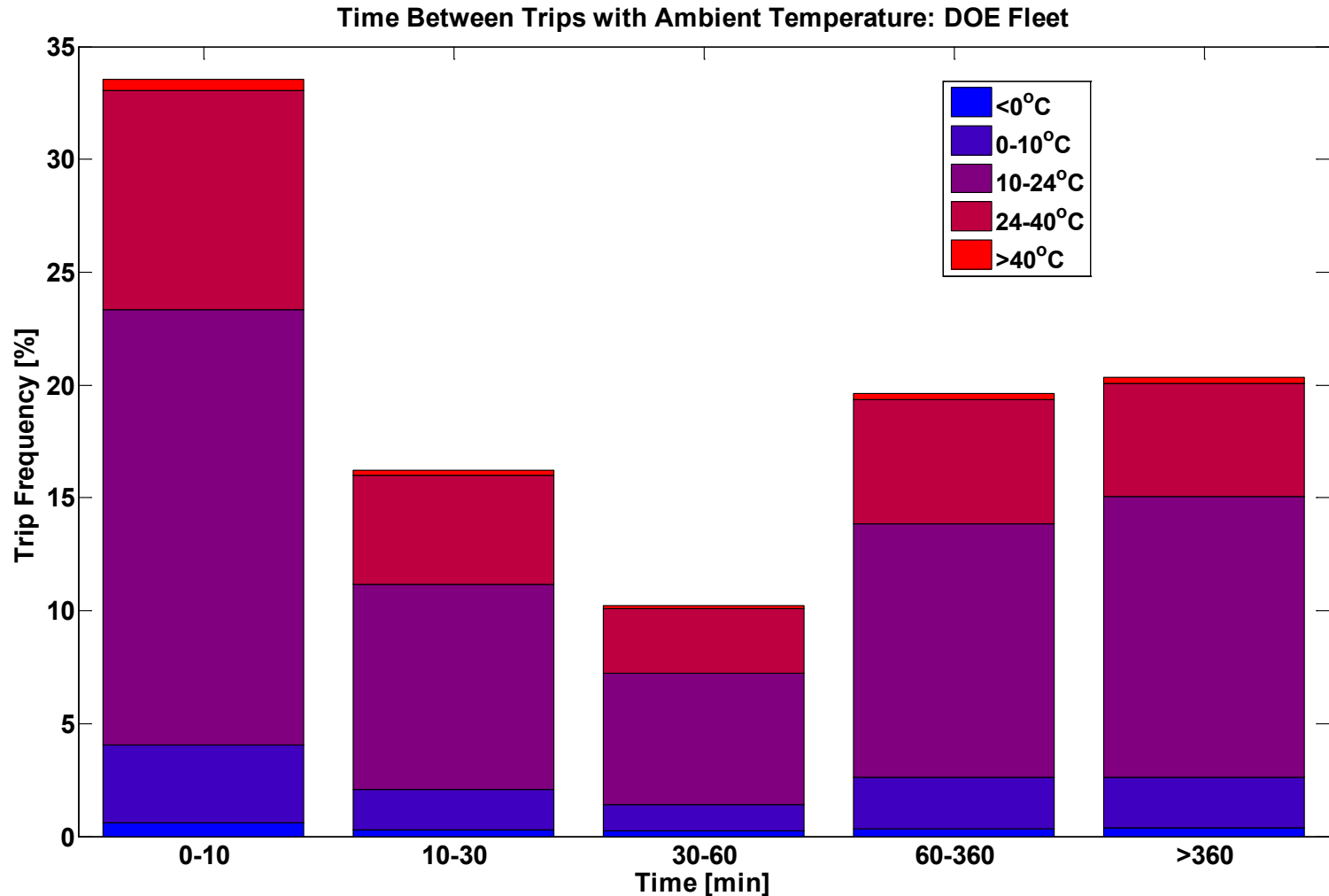


# CDP#18: Refueling Rates



Created: Feb-25-09 5:24 PM

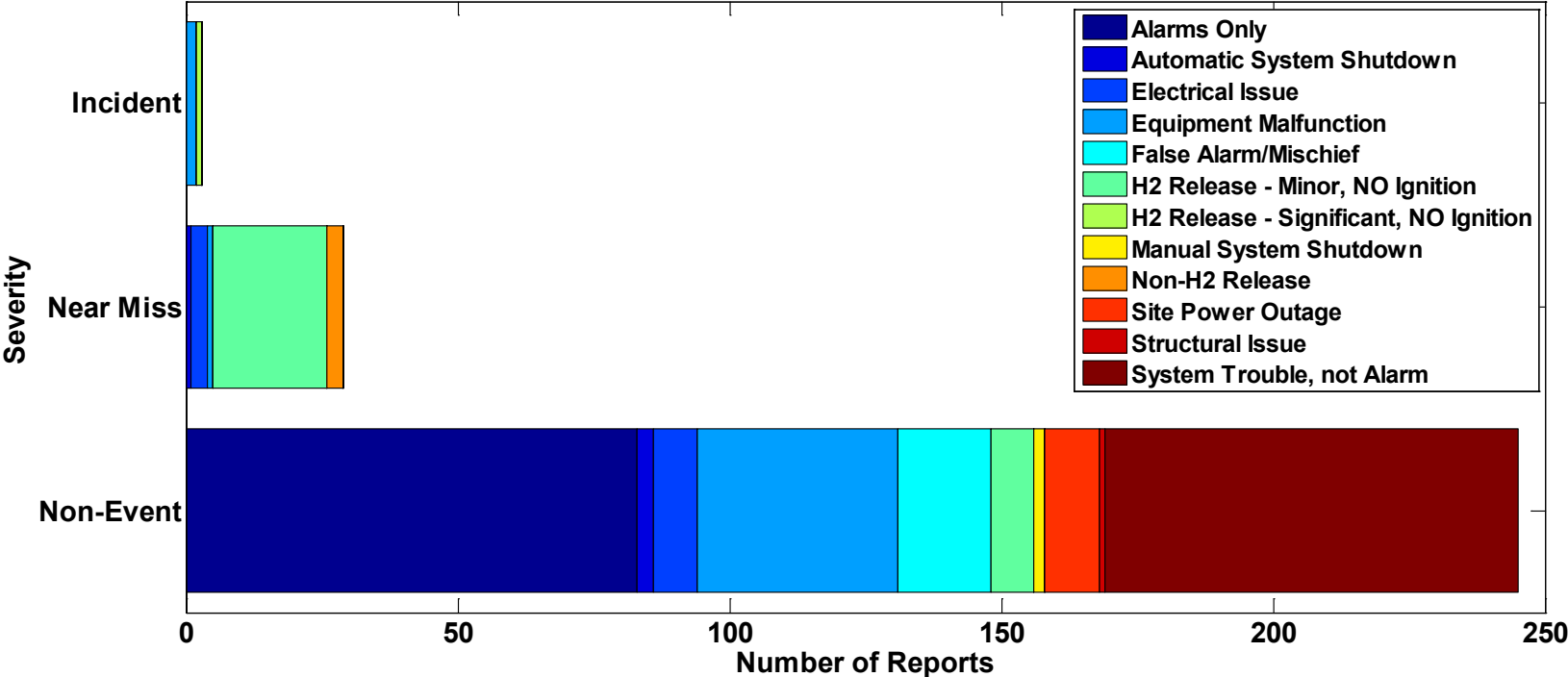
# CDP#19: Time Between Trips & Ambient Temperature



Created: Feb-26-09 5:56 PM

# CDP#20: Safety Reports – Infrastructure

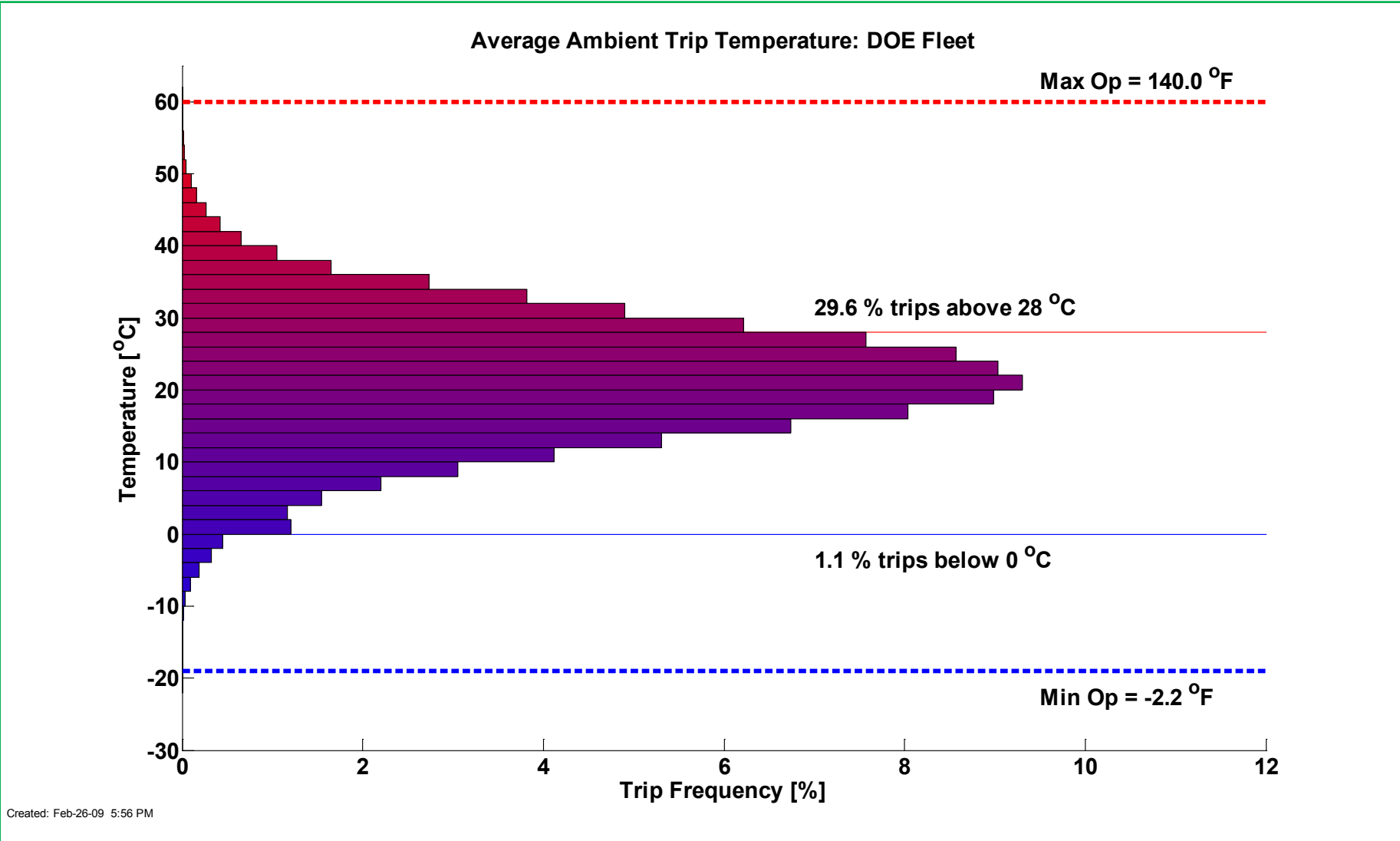
Total Infrastructure Safety Reports by Severity and Report Type Through 2008 Q4



- An INCIDENT is an event that results in:
- a lost time accident and/or injury to personnel
  - damage/unplanned downtime for project equipment, facilities or property
  - impact to the public or environment
  - any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
  - release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)
- A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
  - unplanned H2 release insufficient to sustain a flame

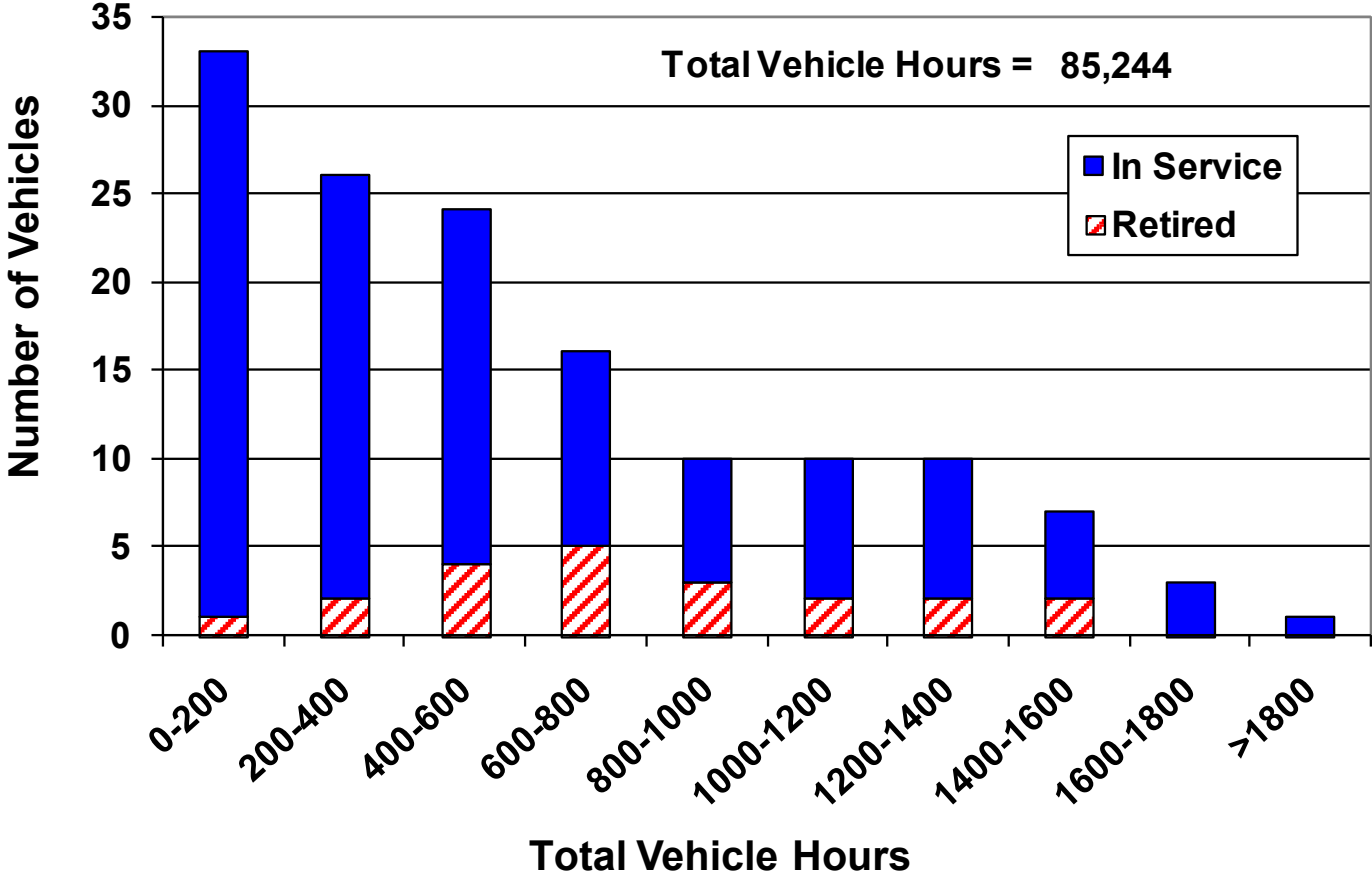
Created: Feb-27-09 8:16 AM

# CDP#21: Range of Ambient Temperature During Vehicle Operation



# CDP#22: Vehicle Operating Hours

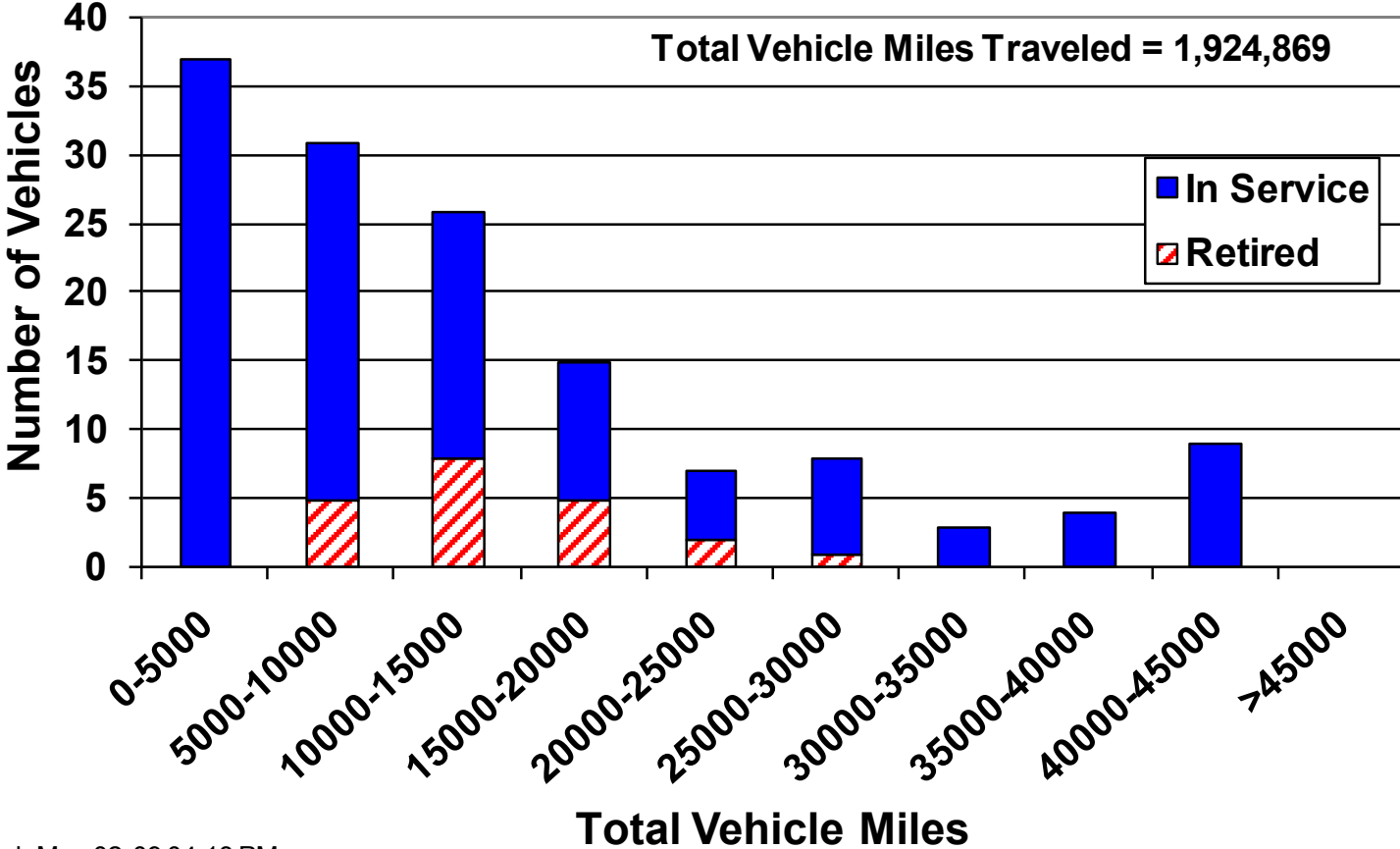
Vehicle Hours: All OEMs, Gen 1 and Gen 2  
Through 2008 Q4



Created: Mar-02-09 04:13 PM

# CDP#23: Vehicles vs. Miles Traveled

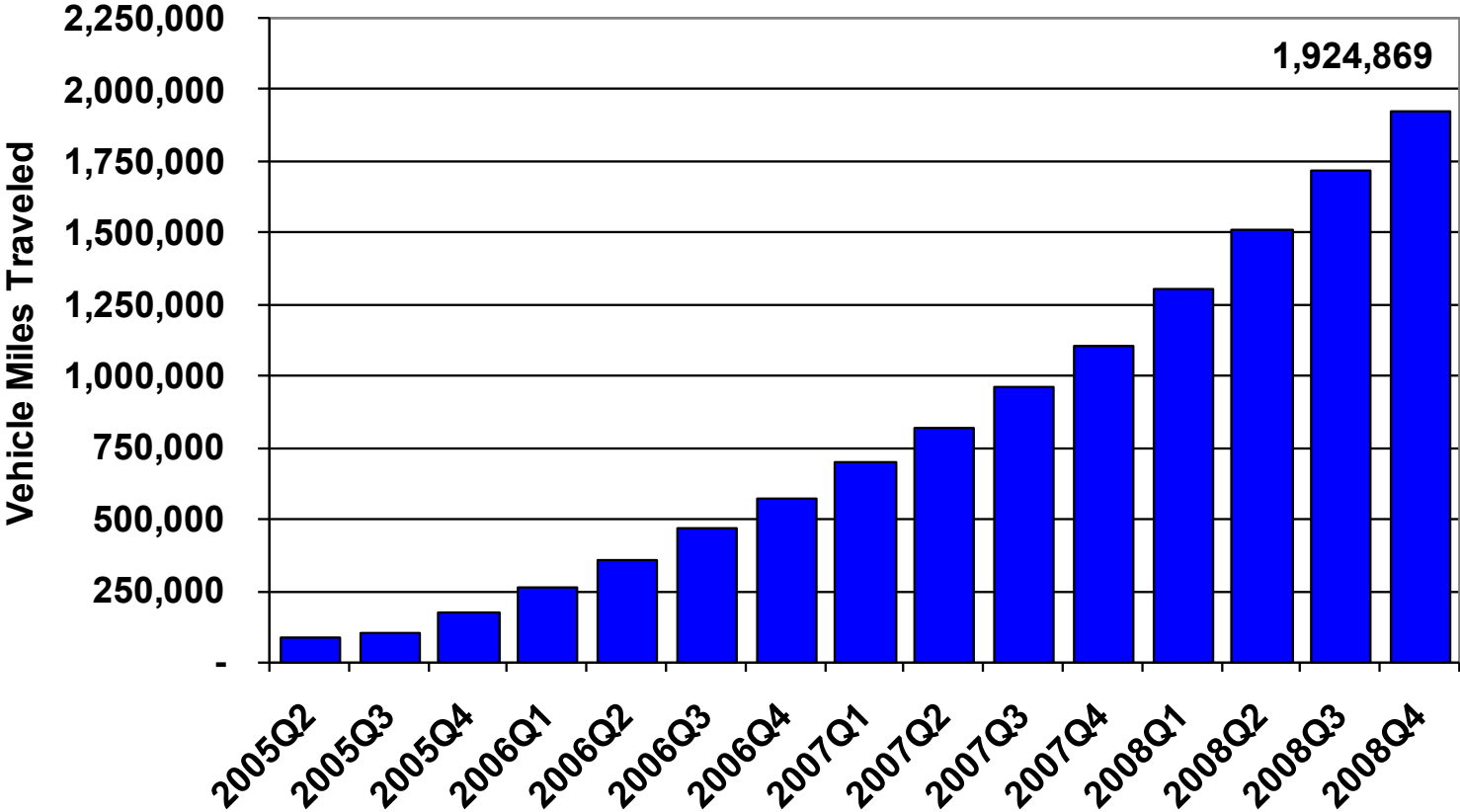
Vehicle Miles: All OEMs Combined, Gen 1 and 2  
Through 2008 Q4



Created: Mar-02-09 04:13 PM

# CDP#24: Cumulative Vehicle Miles Traveled

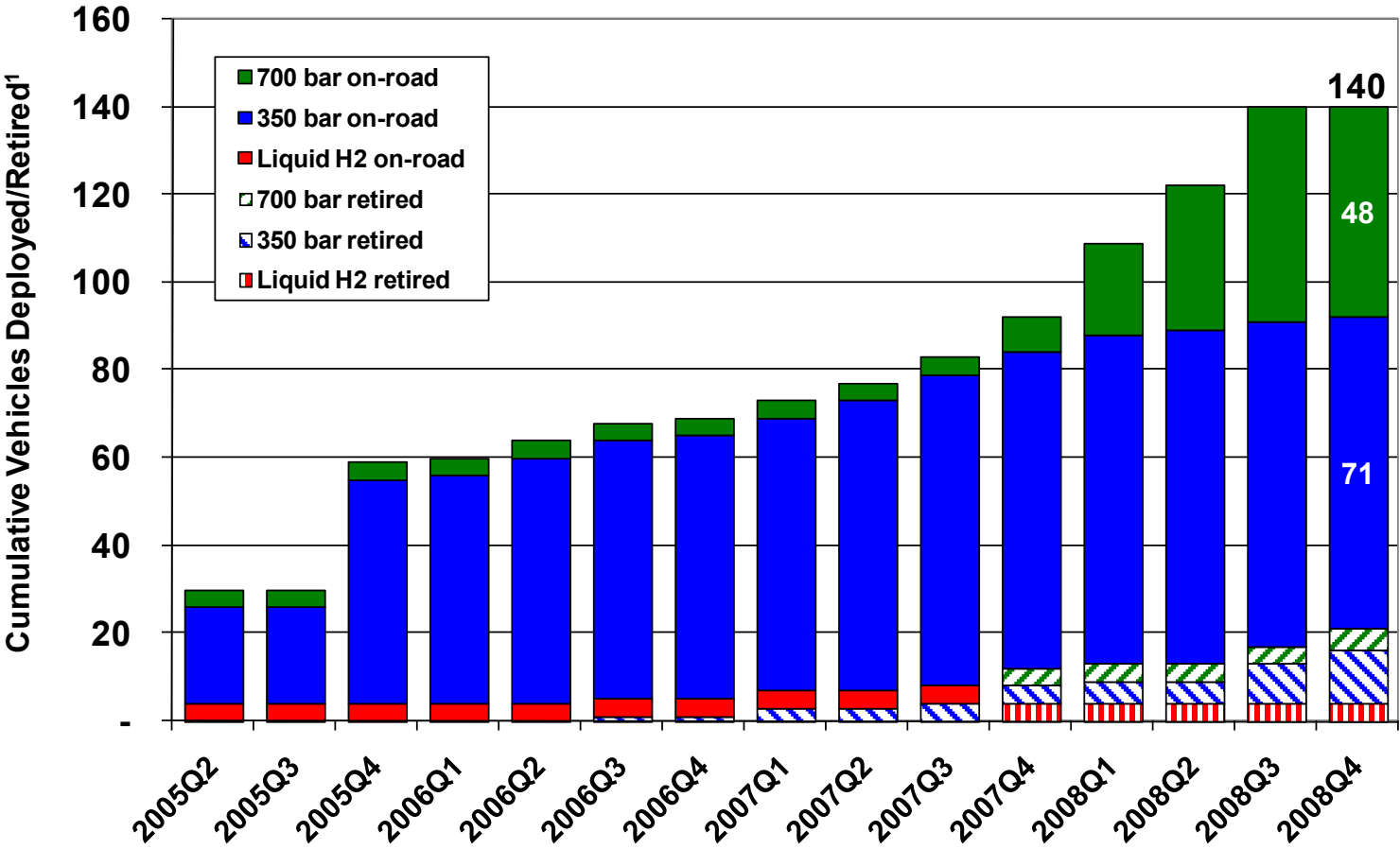
Cumulative Vehicle Miles: All OEMs, Gen 1 and Gen 2  
Through 2008 Q4



Created: Mar-02-09 04:03 PM

# CDP#25: Vehicle H2 Storage Technologies

Vehicle Deployment by On-Board Hydrogen Storage Type

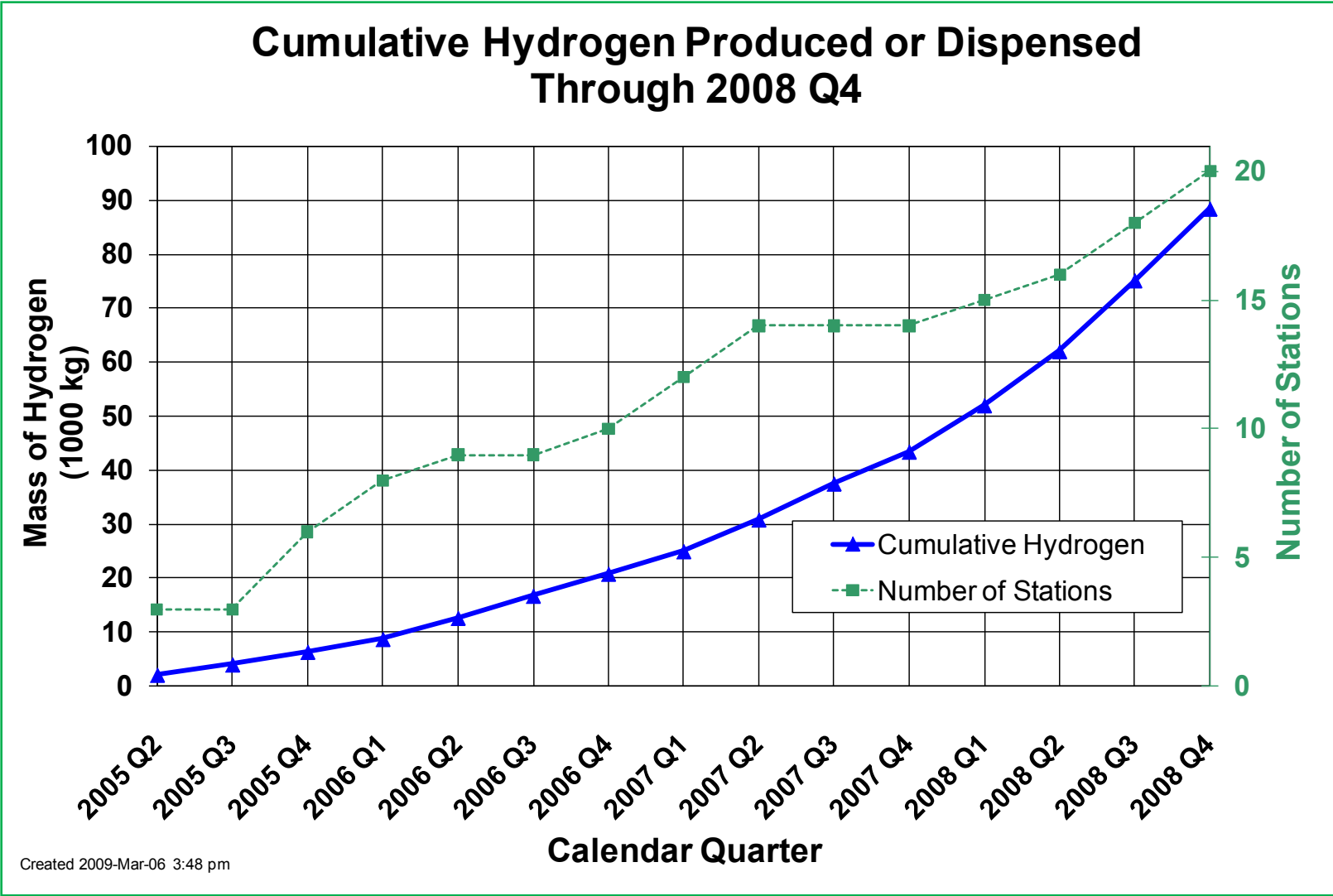


Created Feb-27-2009 9:10 AM

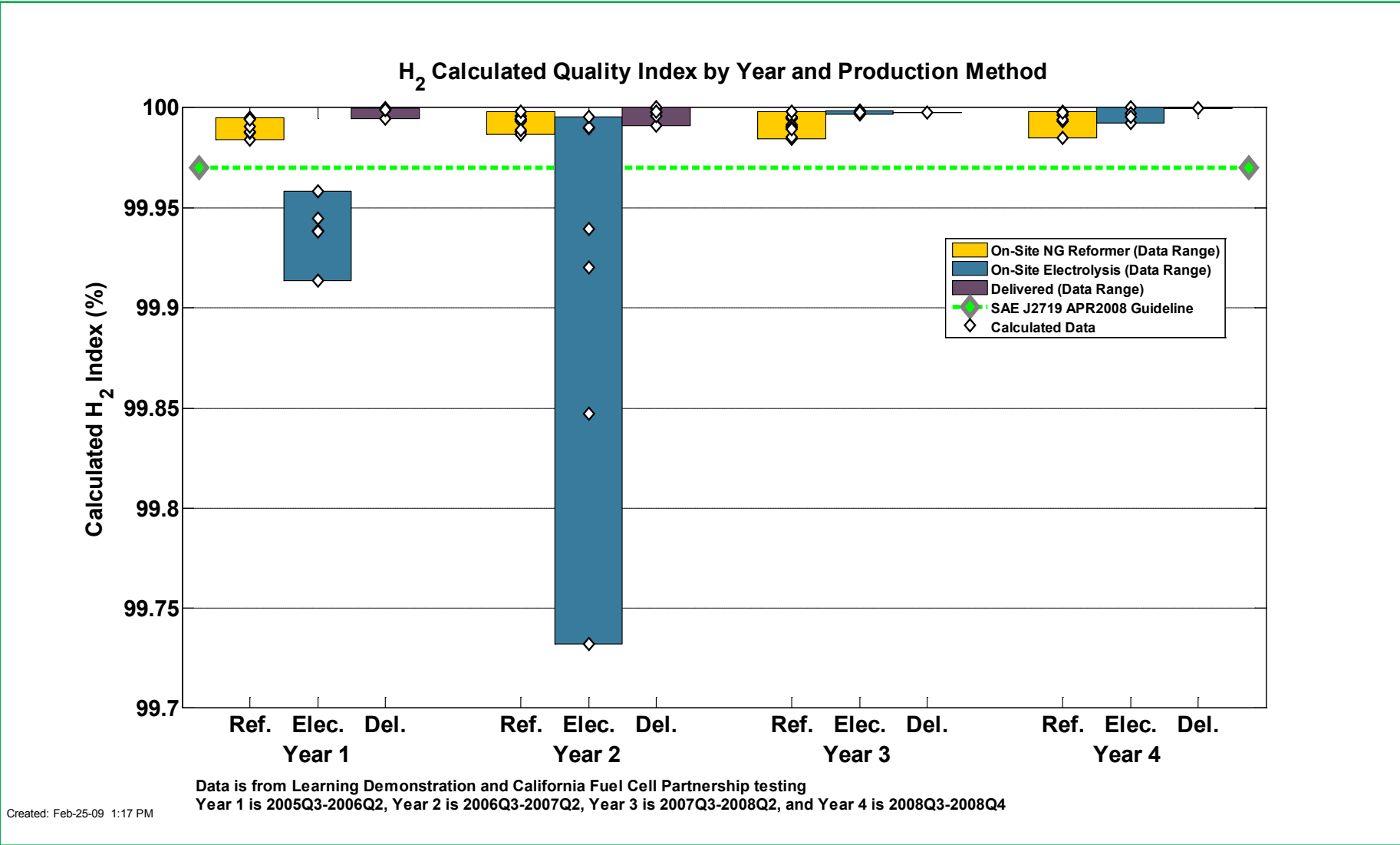
(1) Retired vehicles have left DOE fleet and are no longer providing data to NREL



# CDP#26: Cumulative H2 Produced or Dispensed

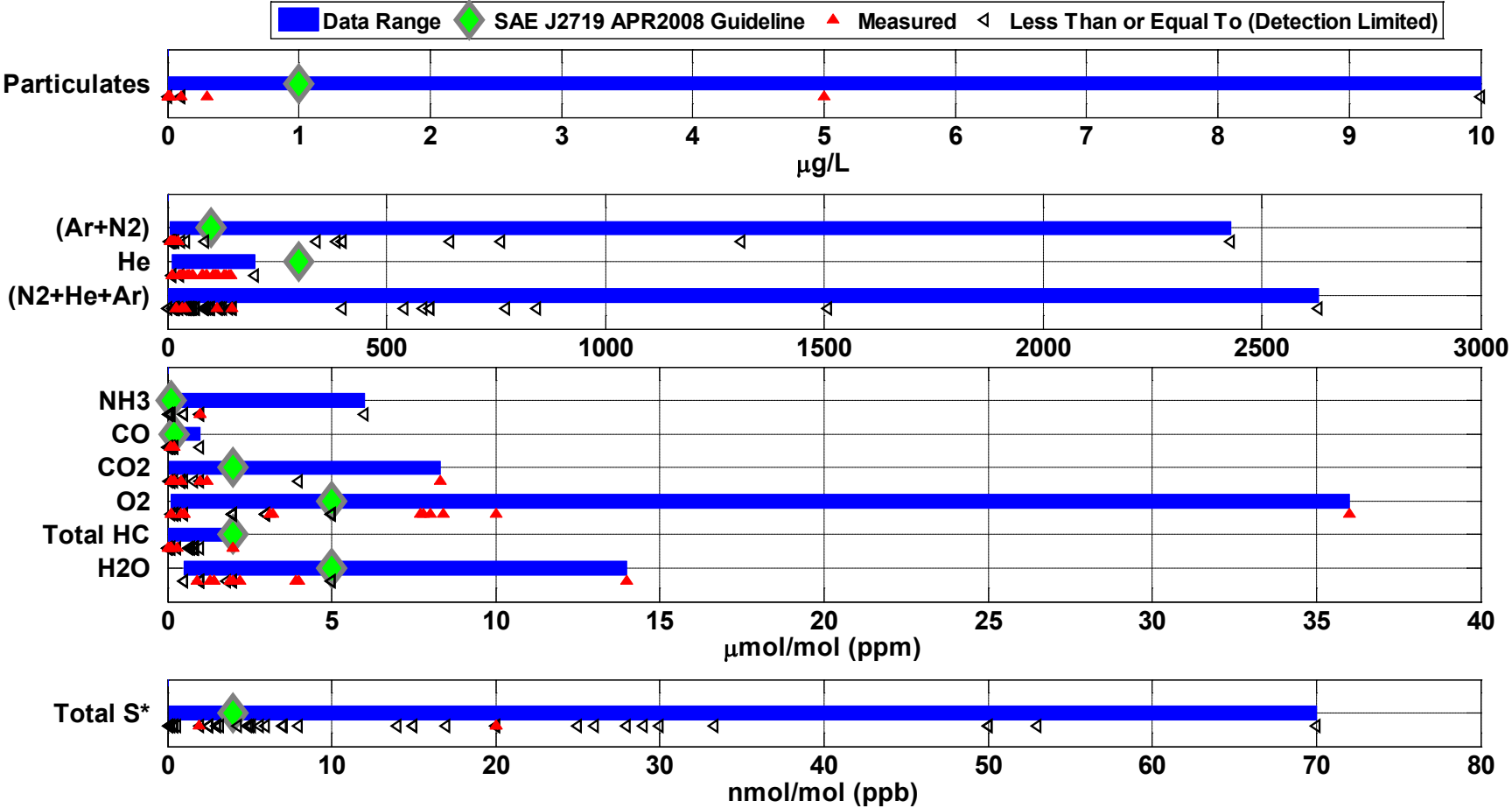


# CDP#27: Hydrogen Quality Index



# CDP#28: Hydrogen Fuel Constituents

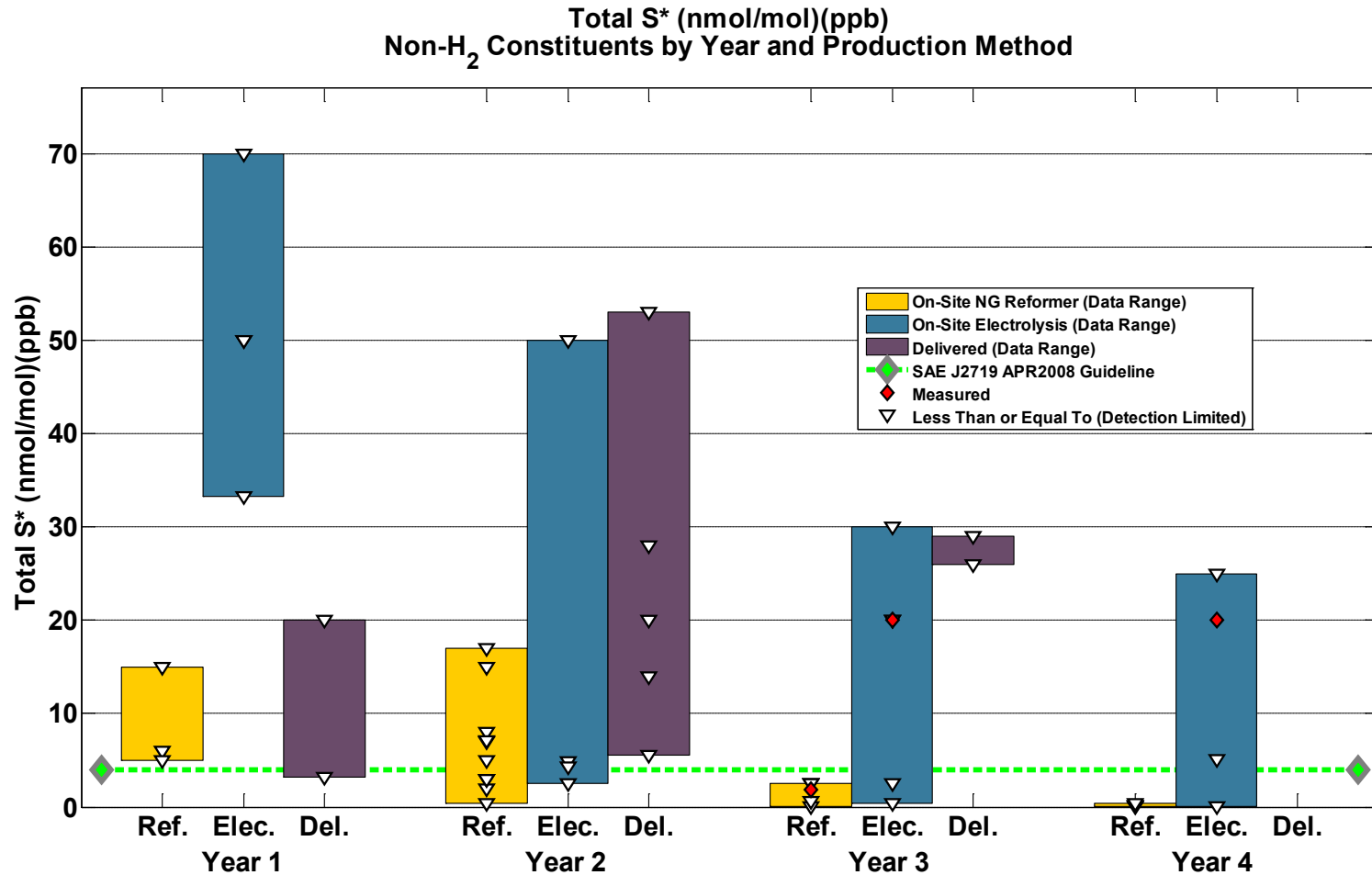
H<sub>2</sub> Fuel Constituents



Created: Feb-25-09 1:23 PM

Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 \*Total S calculated from SO<sub>2</sub>, COS, H<sub>2</sub>S, CS<sub>2</sub>, and Methyl Mercaptan (CH<sub>3</sub>SH).

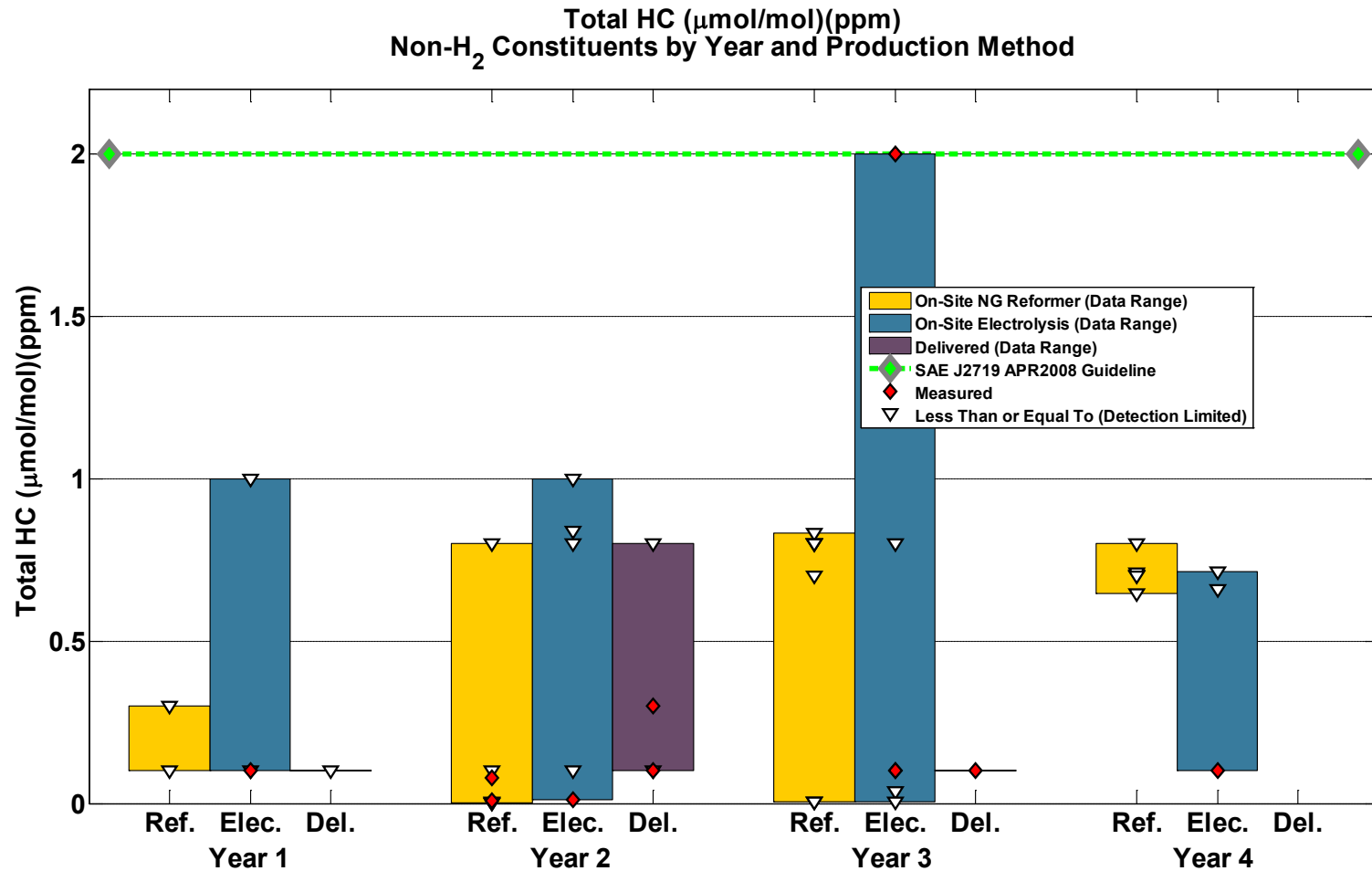
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4  
 \*Total S calculated from SO<sub>2</sub>, COS, H<sub>2</sub>S, CS<sub>2</sub>, and Methyl Mercaptan (CH<sub>3</sub>SH).

Created: Feb-25-09 1:18 PM

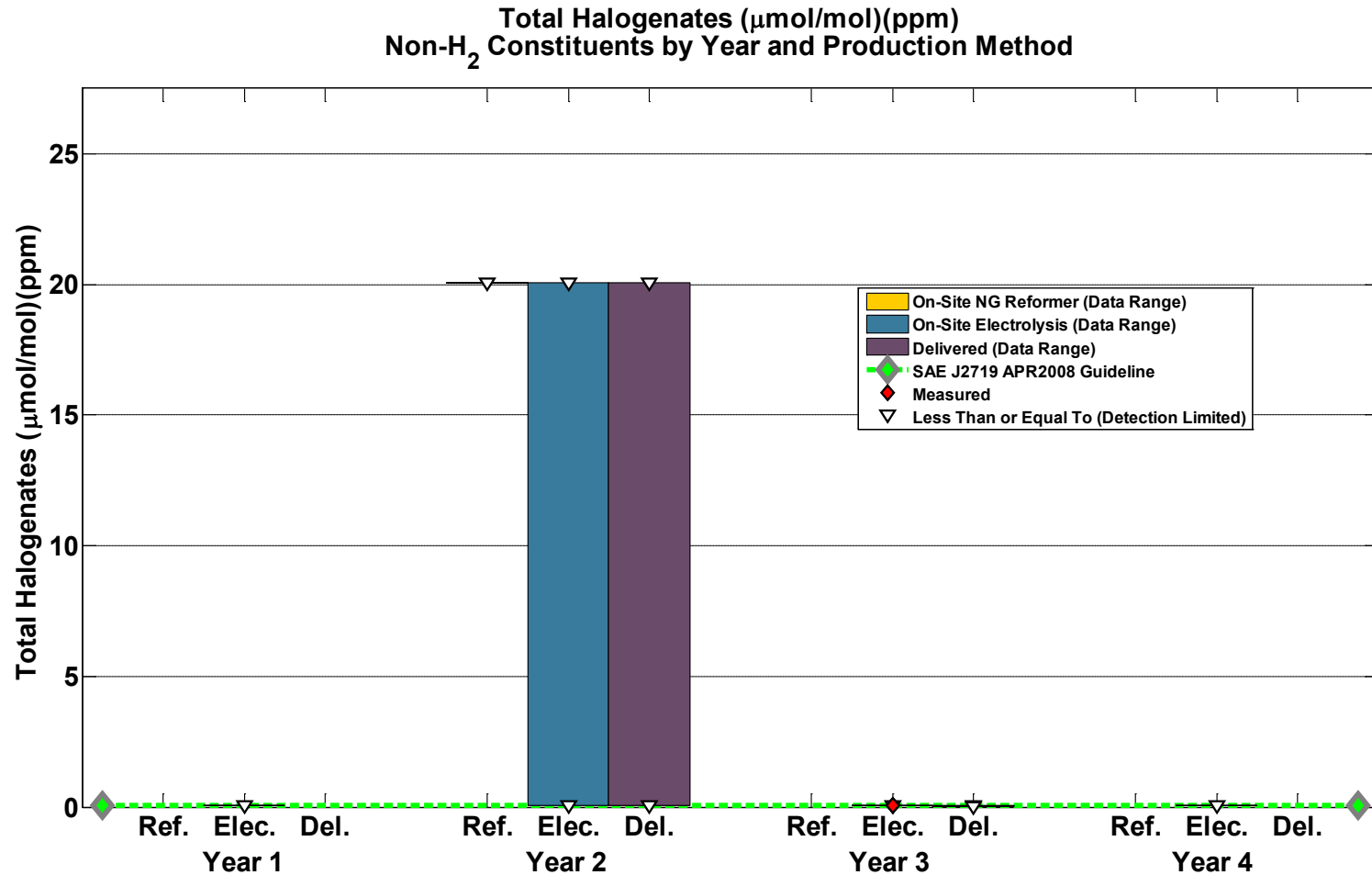
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

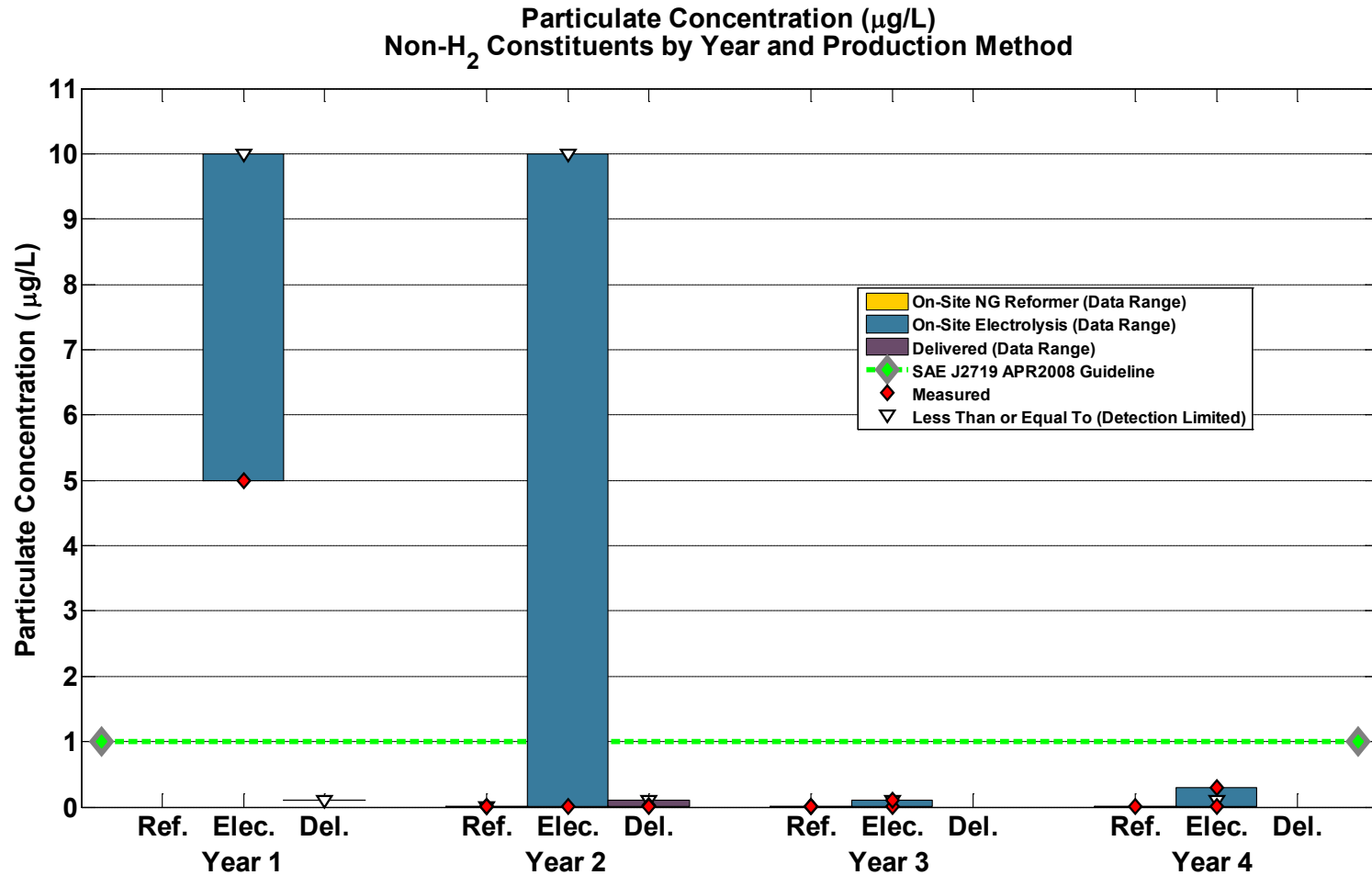
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

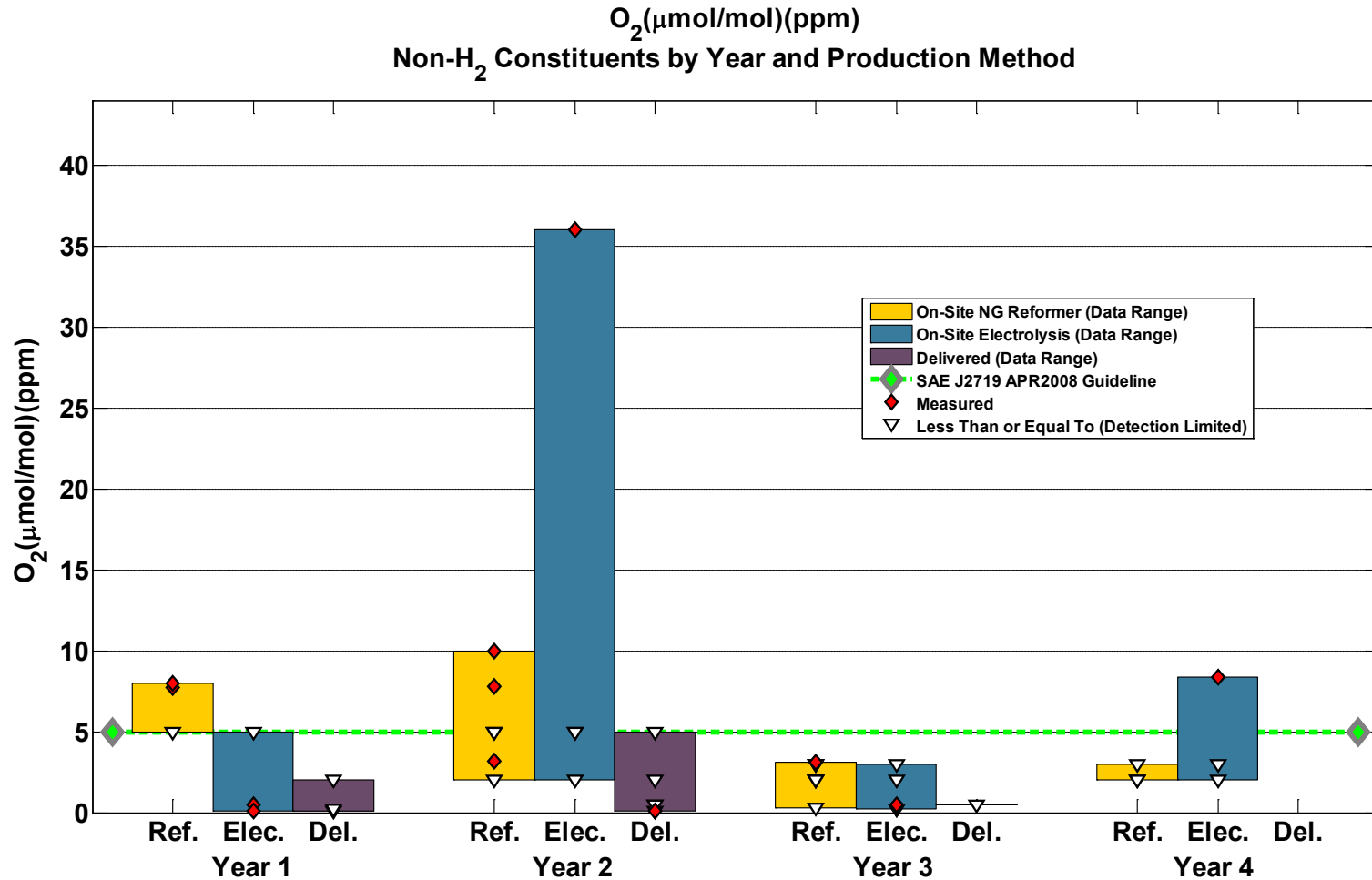
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method

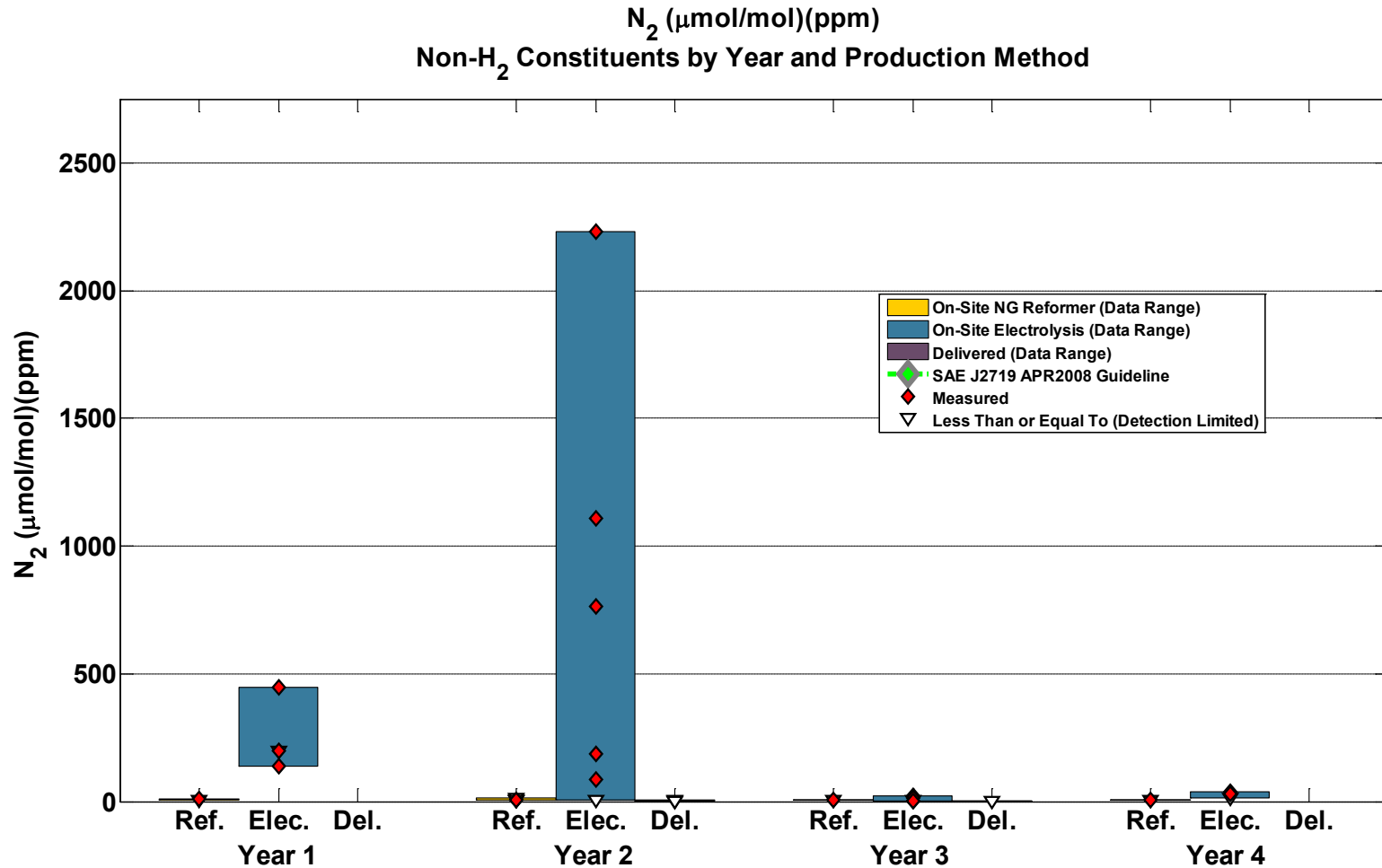


Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM



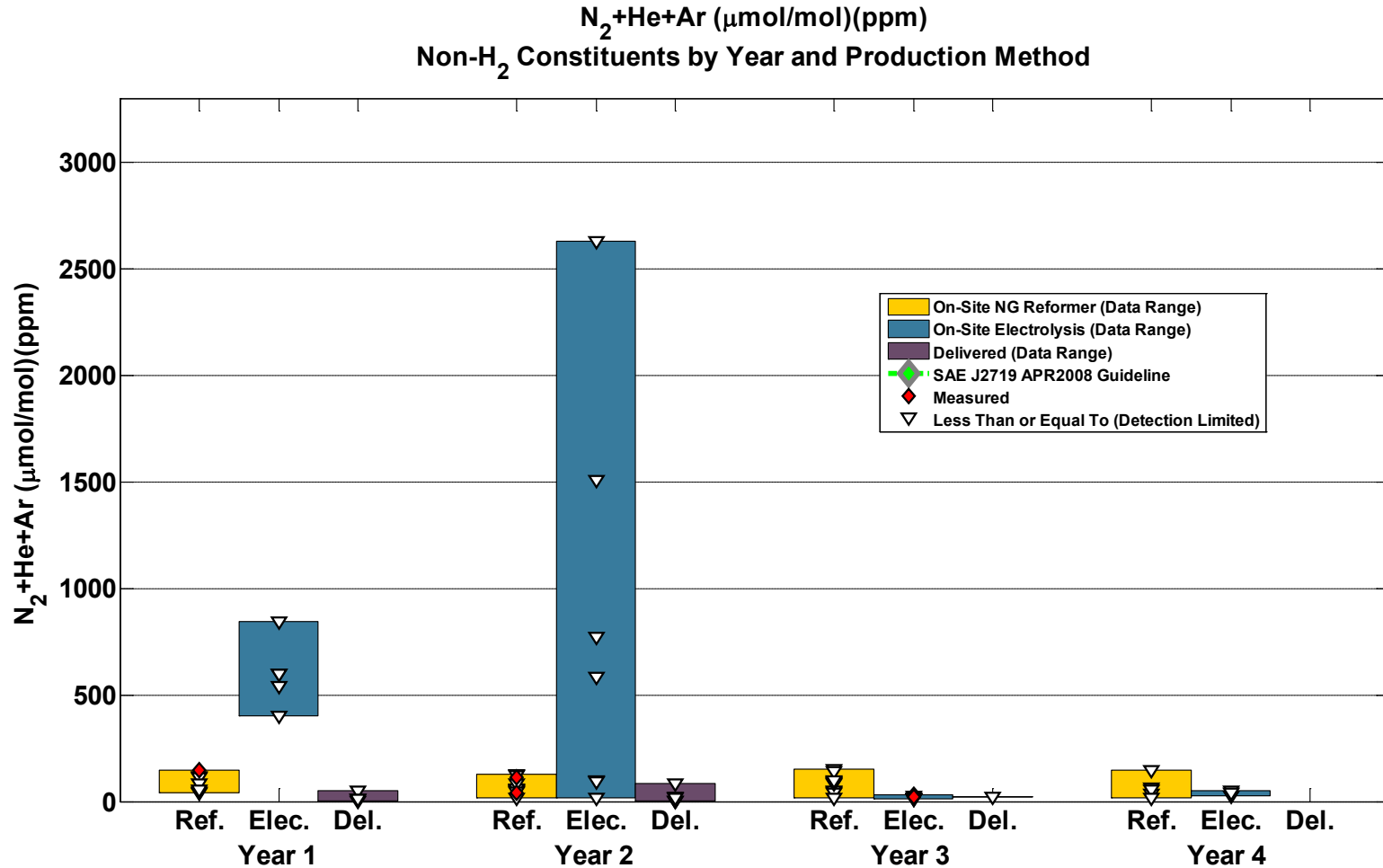
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

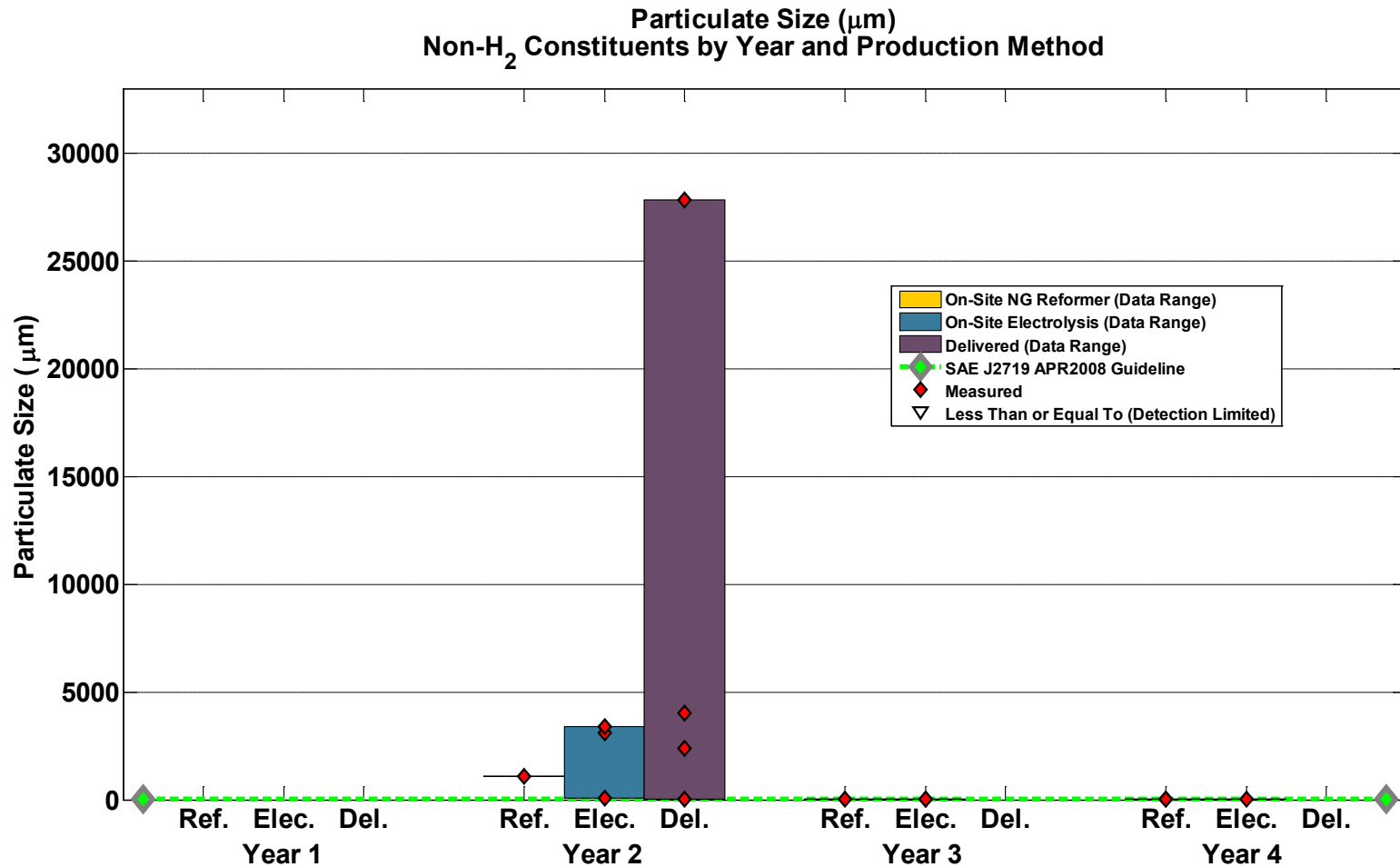
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

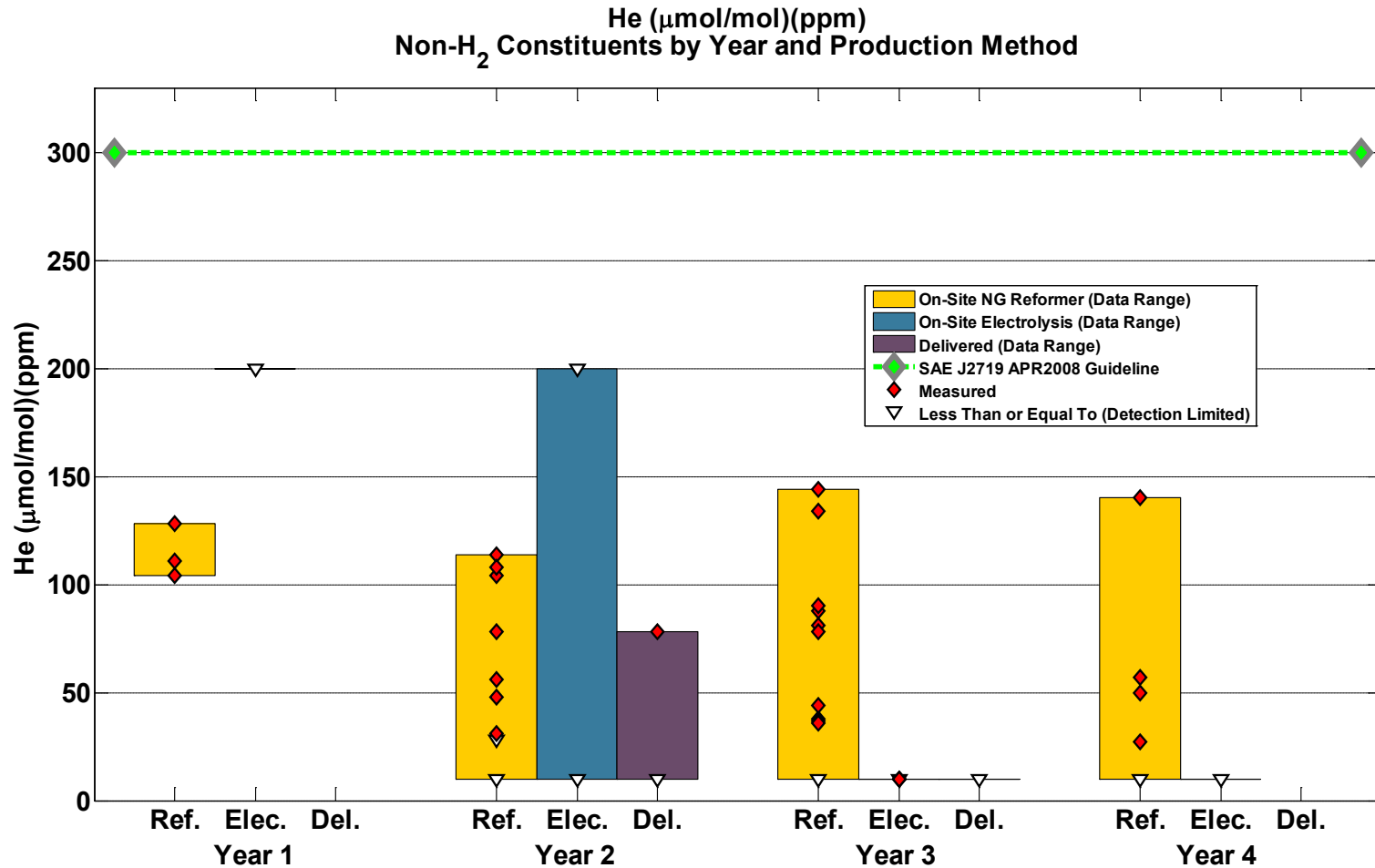
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

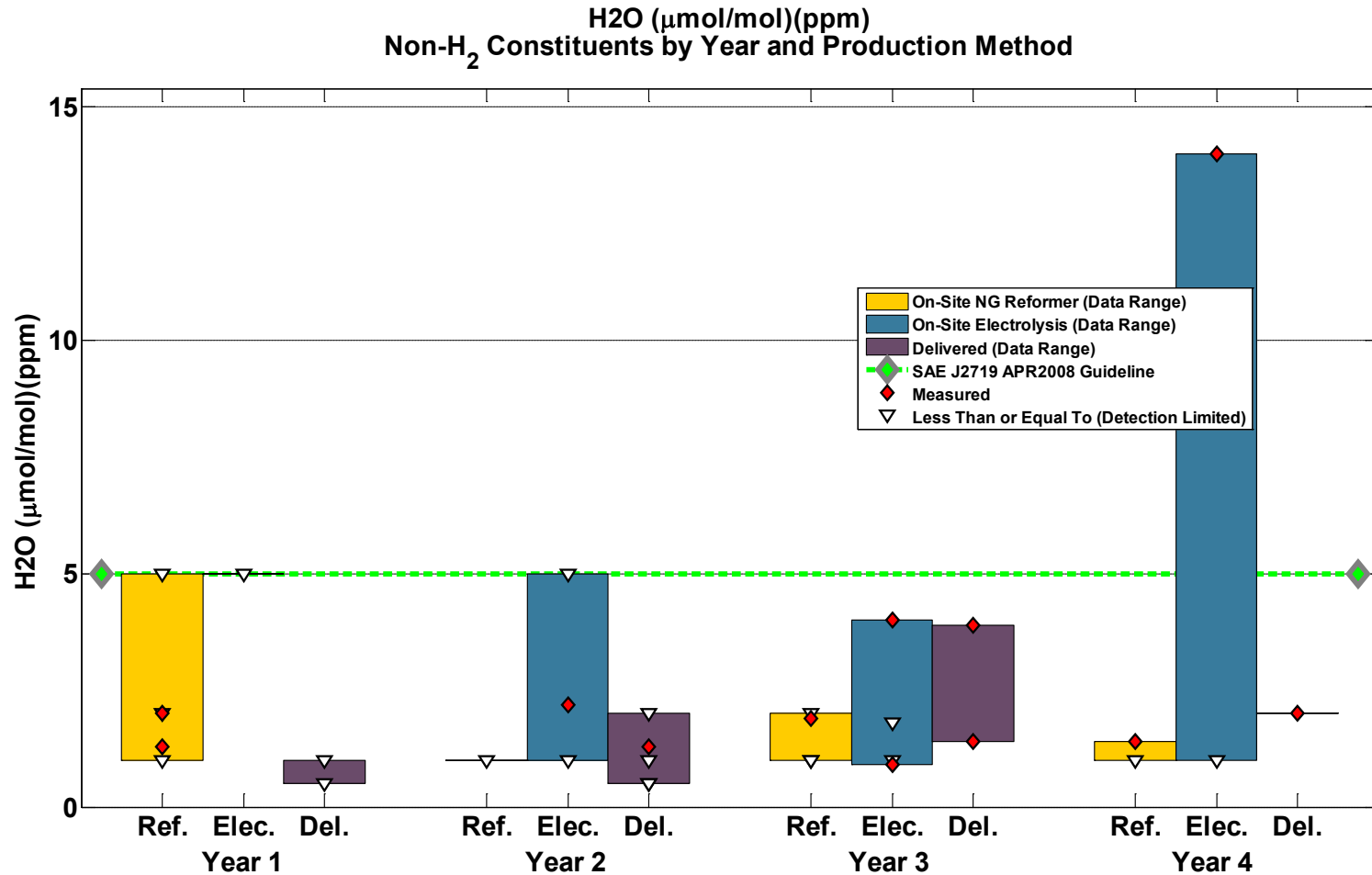
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

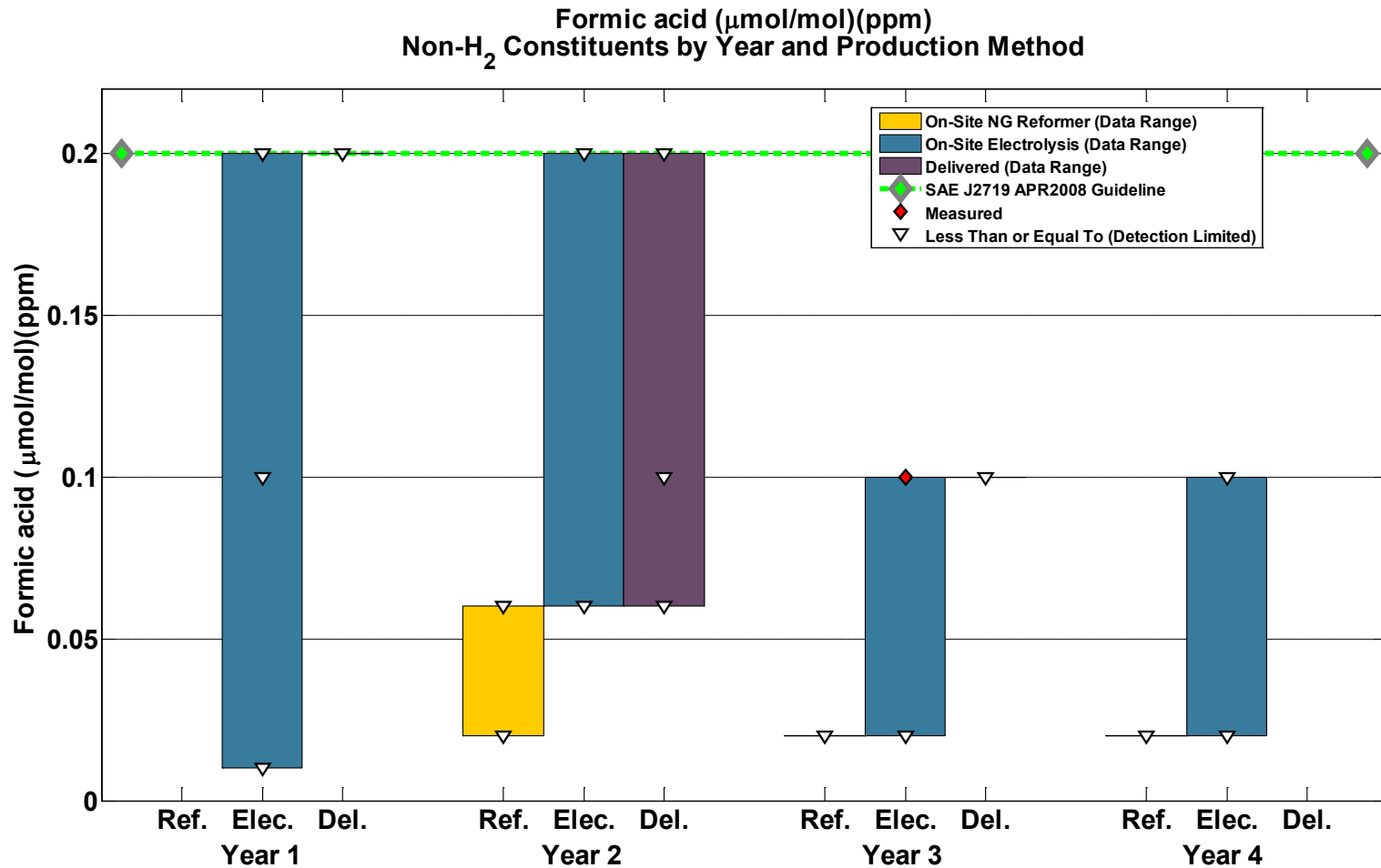
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:17 PM

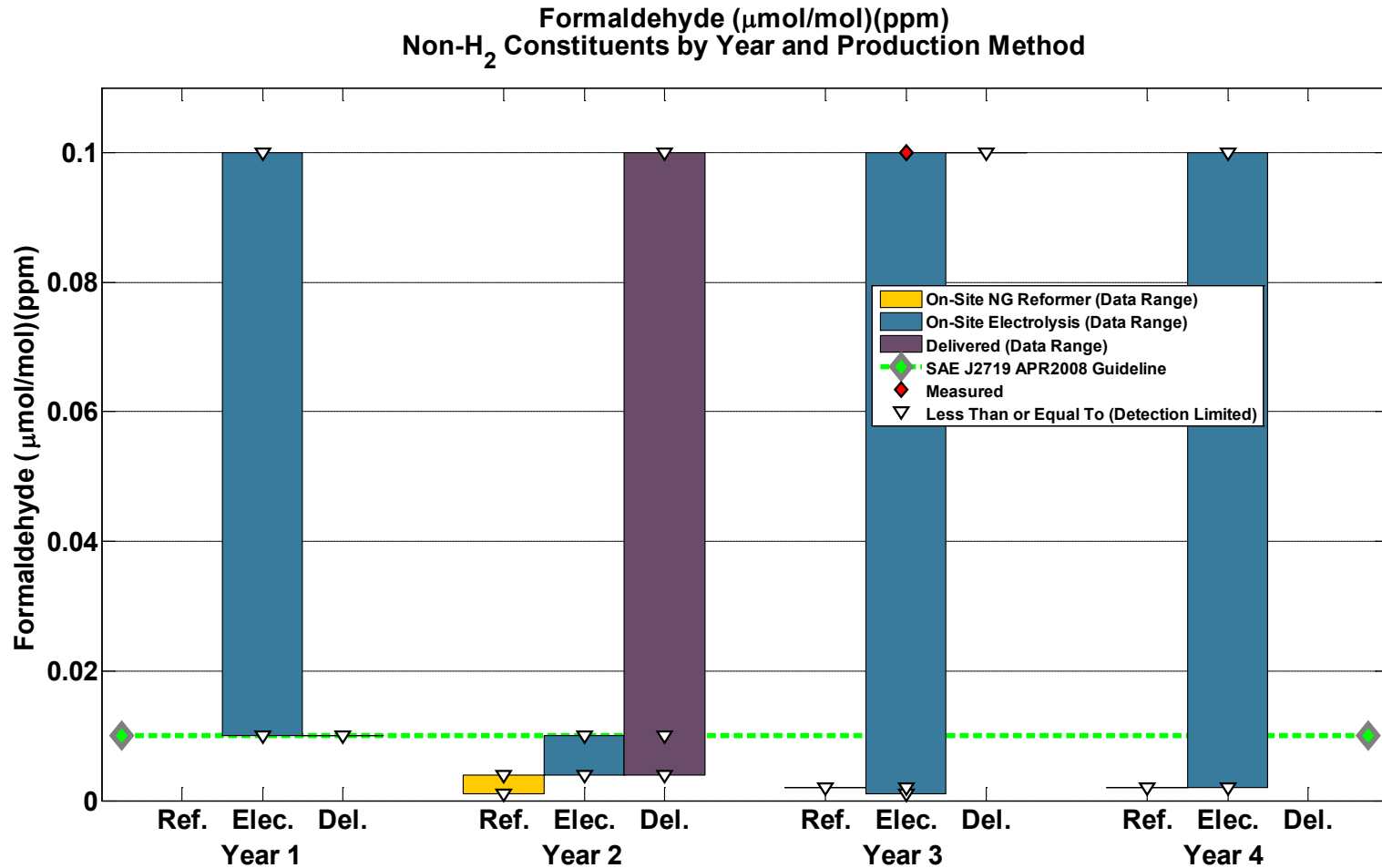
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

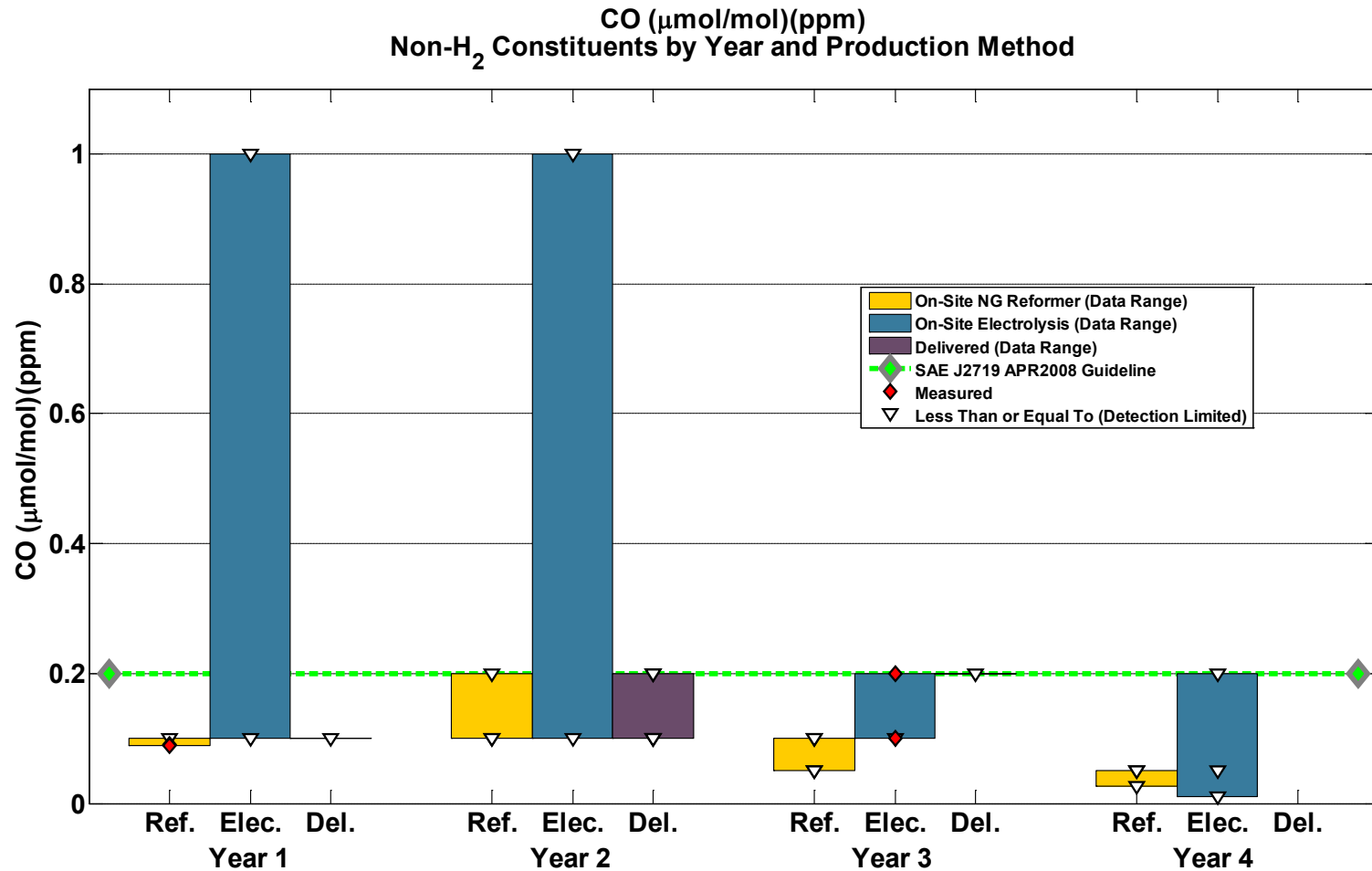
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method

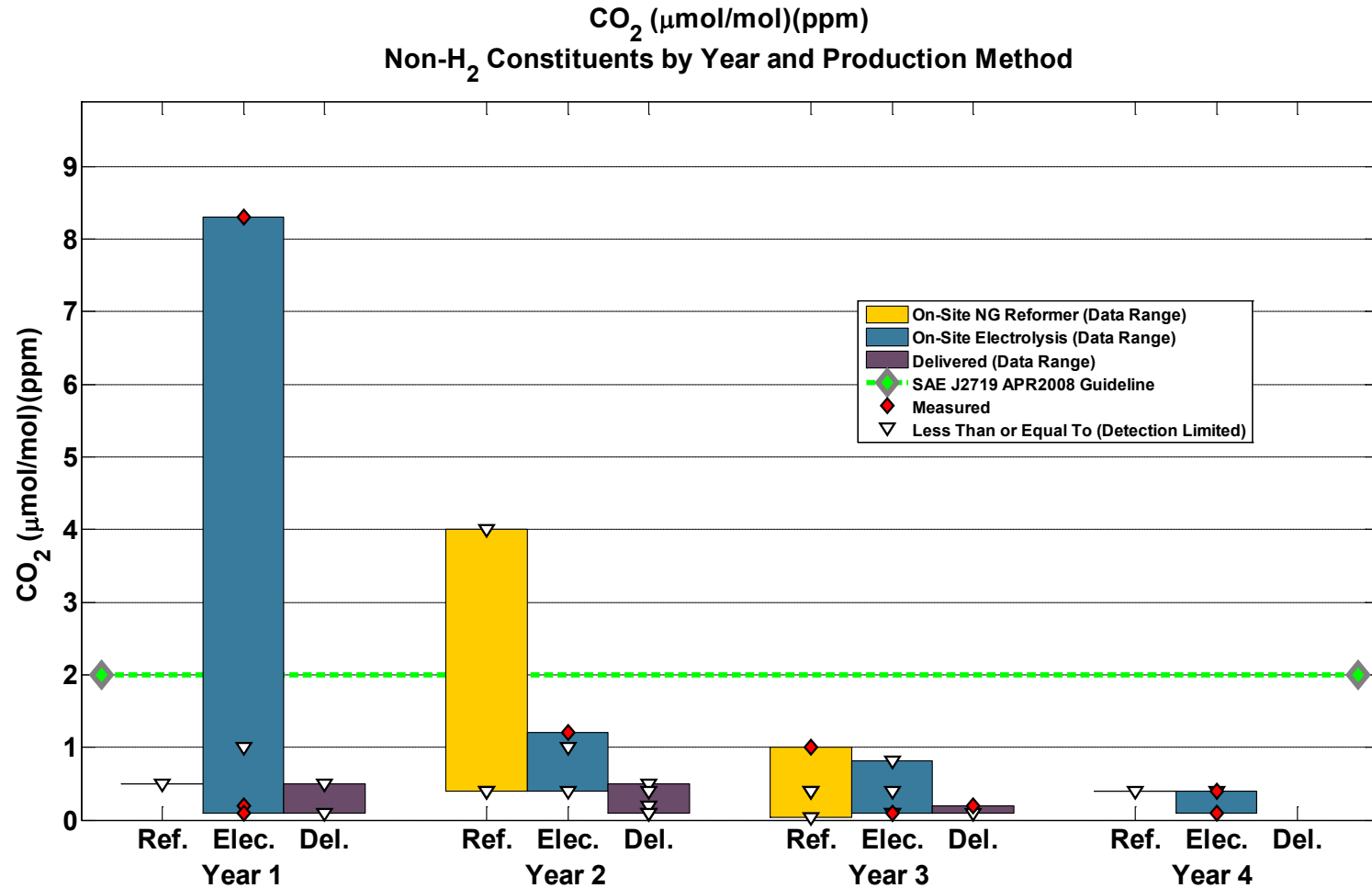


Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM



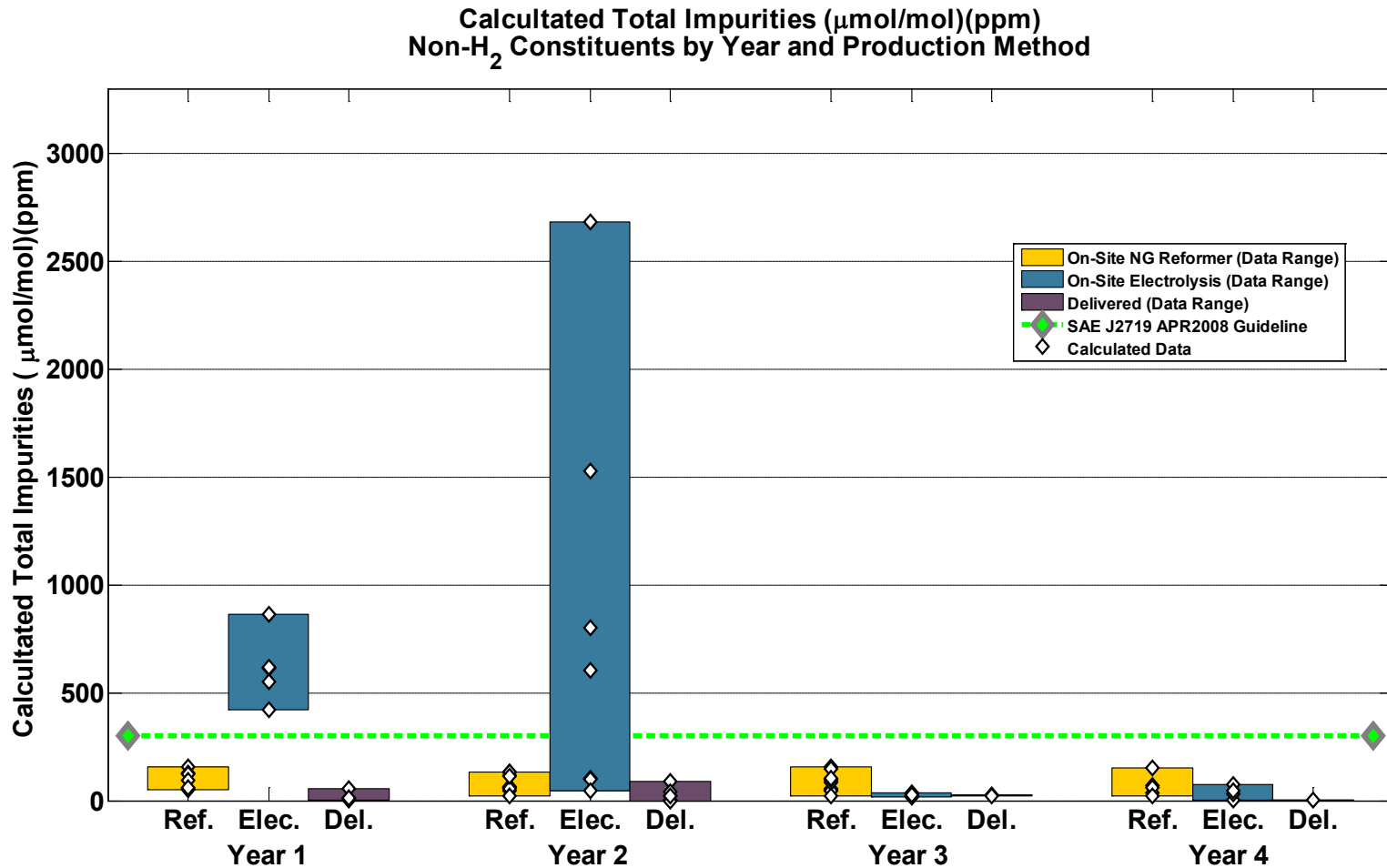
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

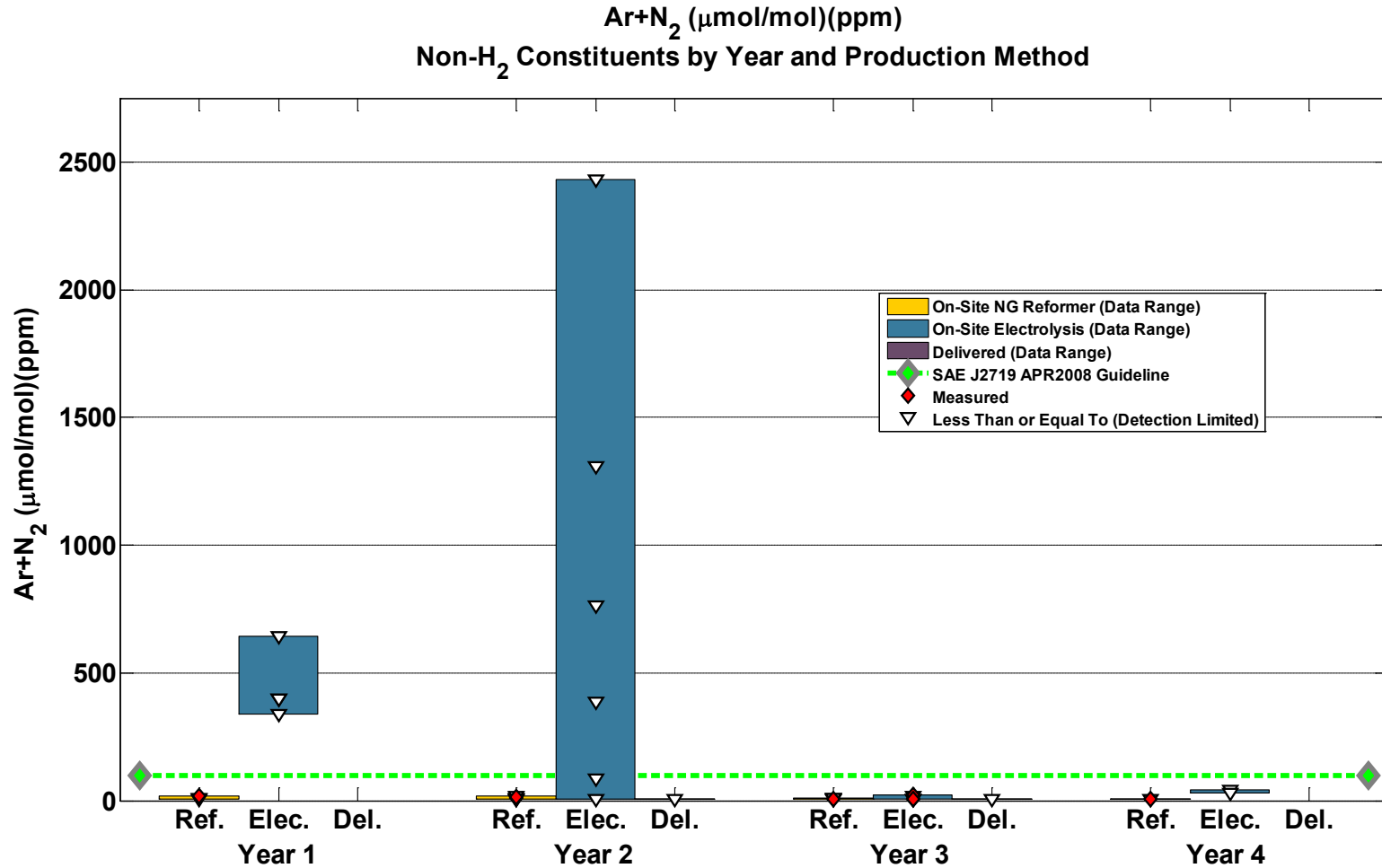
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:17 PM

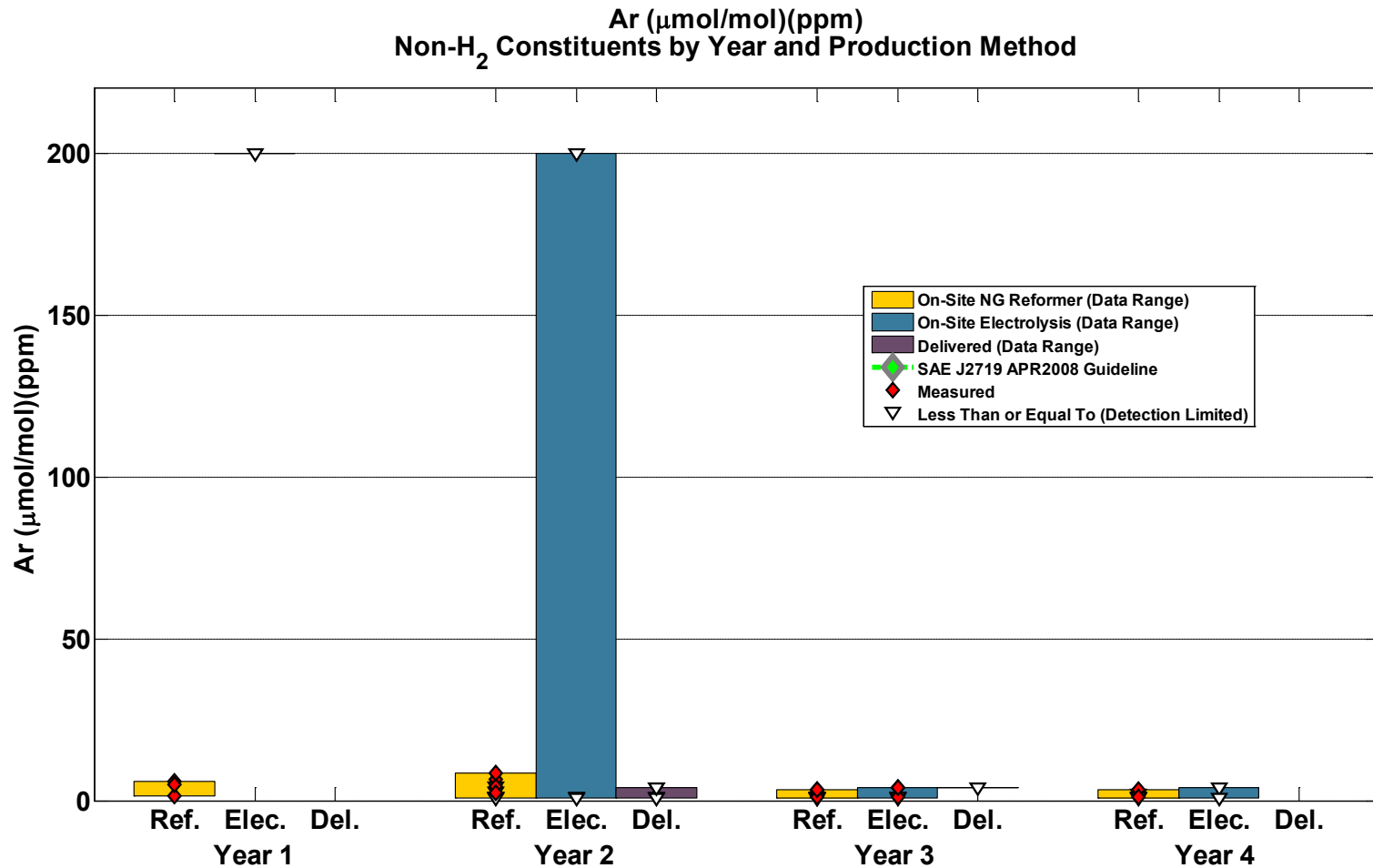
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

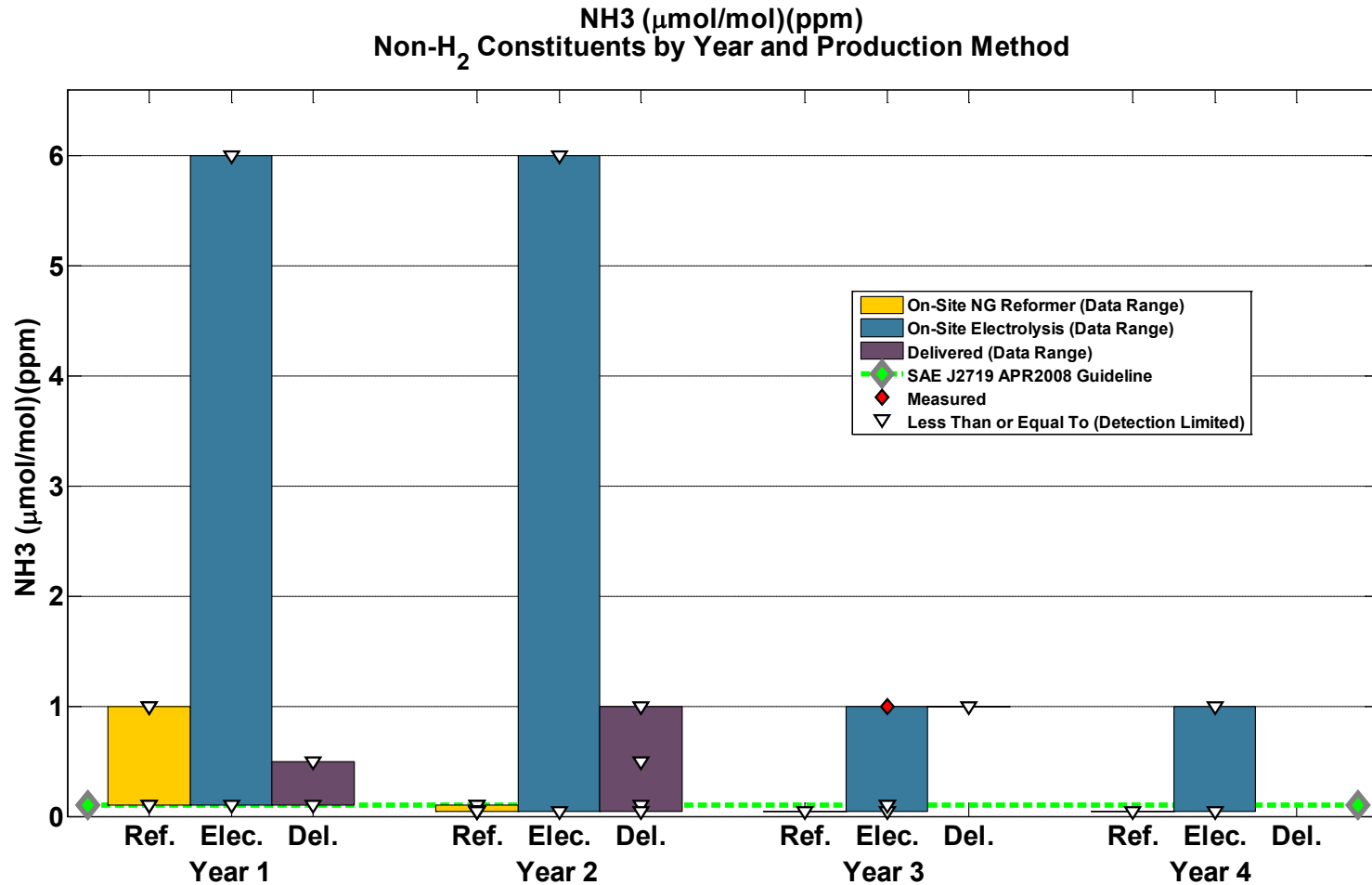
# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method



Data is from Learning Demonstration and California Fuel Cell Partnership testing  
 Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

# CDP#28 Supplemental: Hydrogen Constituents by Year and Production Method

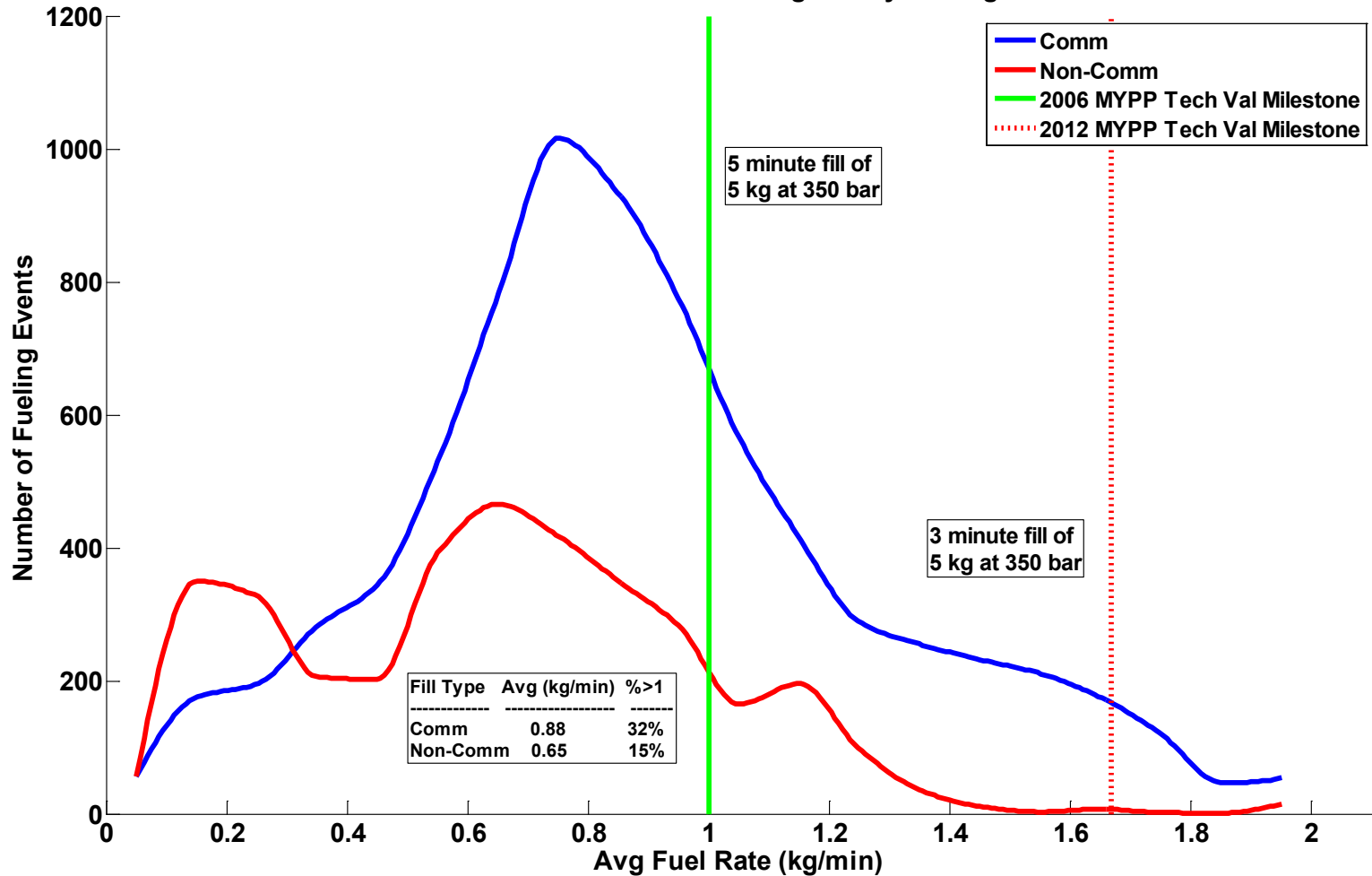


Data is from Learning Demonstration and California Fuel Cell Partnership testing  
Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, Year 3 is 2007Q3-2008Q2, and Year 4 is 2008Q3-2008Q4

Created: Feb-25-09 1:18 PM

# CDP#29: Fueling Rates Communication and Non-Communication Fills

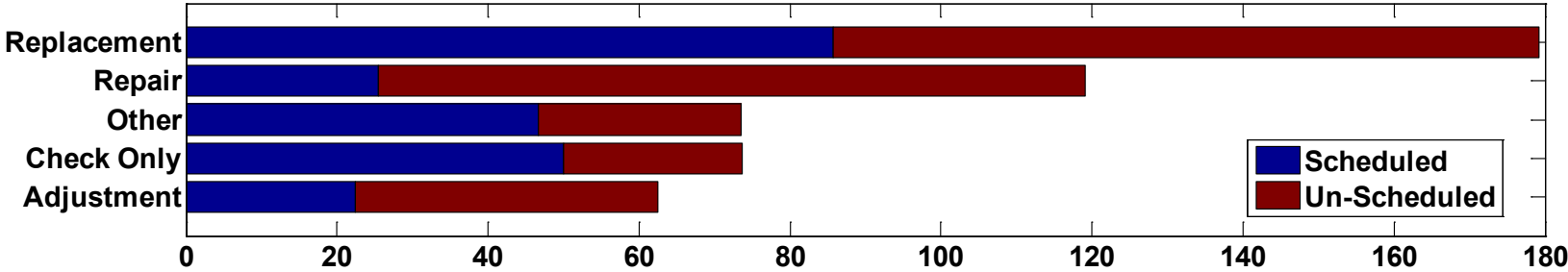
Histogram of Fueling Rates  
Comm vs Non-Comm Fills - All Light Duty Through 2008Q4



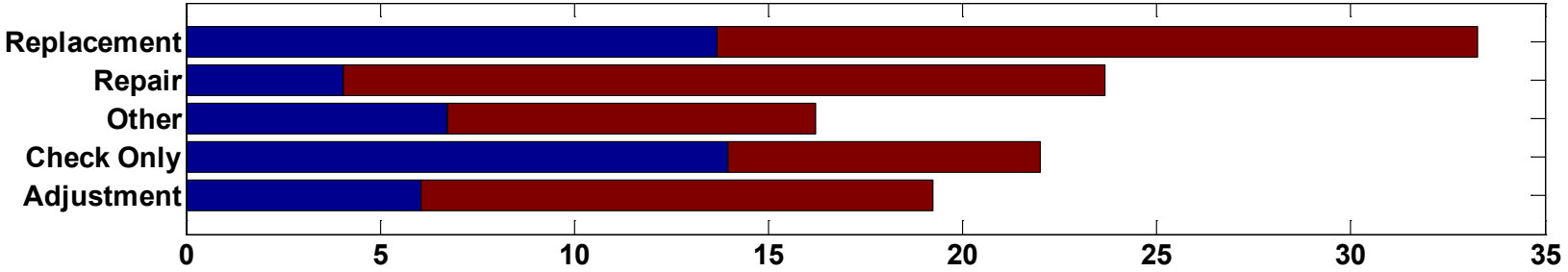
Created: Feb-25-09 4:26 PM

# CDP#30: Infrastructure Maintenance

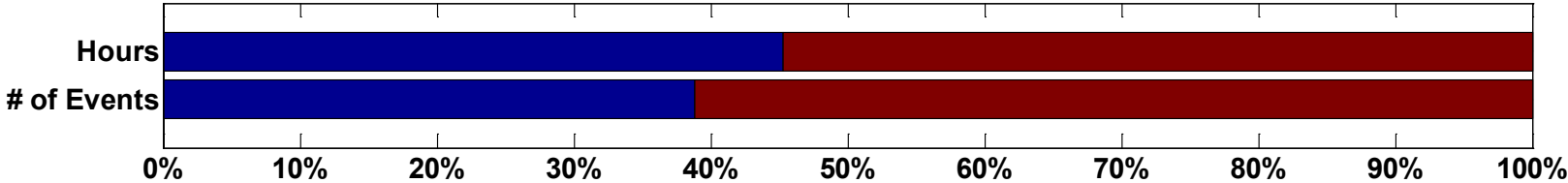
Maintenance: Average Labor Hours Per Station Since Inception Through 2008 Q4



Maintenance: Average Number of Events Per Station Since Inception

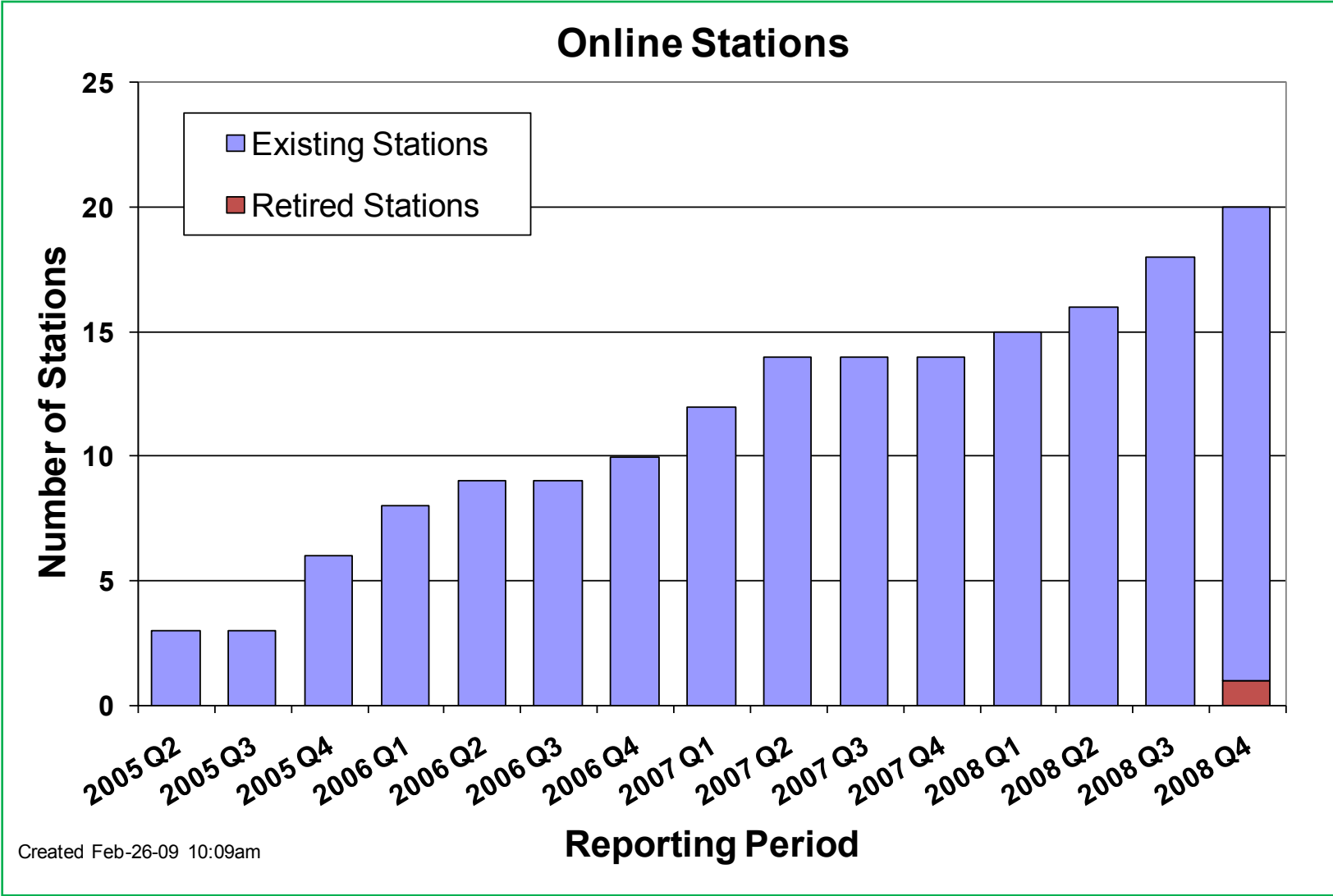


Comparison of Scheduled/Un-Scheduled Maintenance



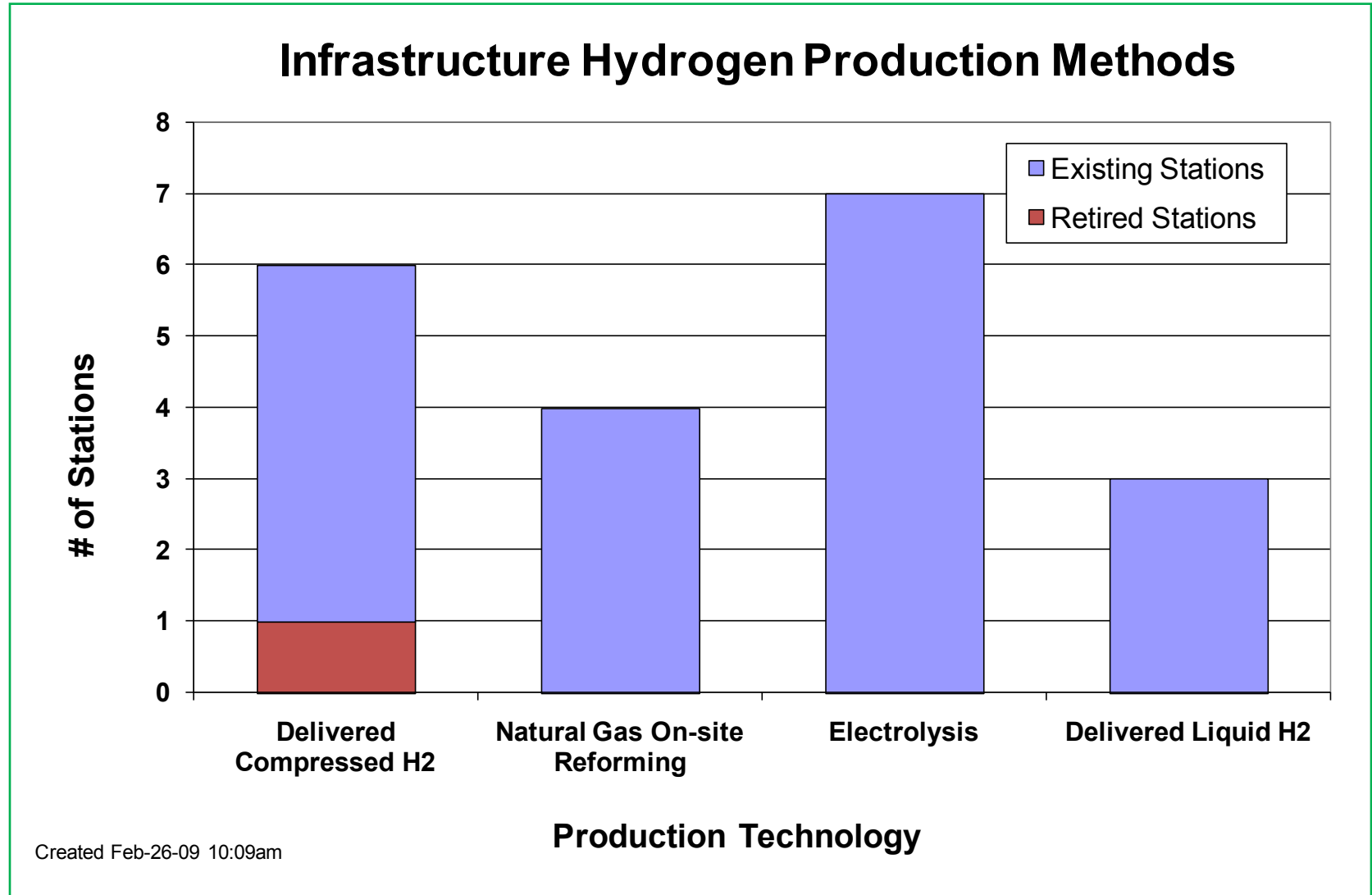
Created: Feb-25-09 7:45 AM

# CDP#31: Number of Online Stations

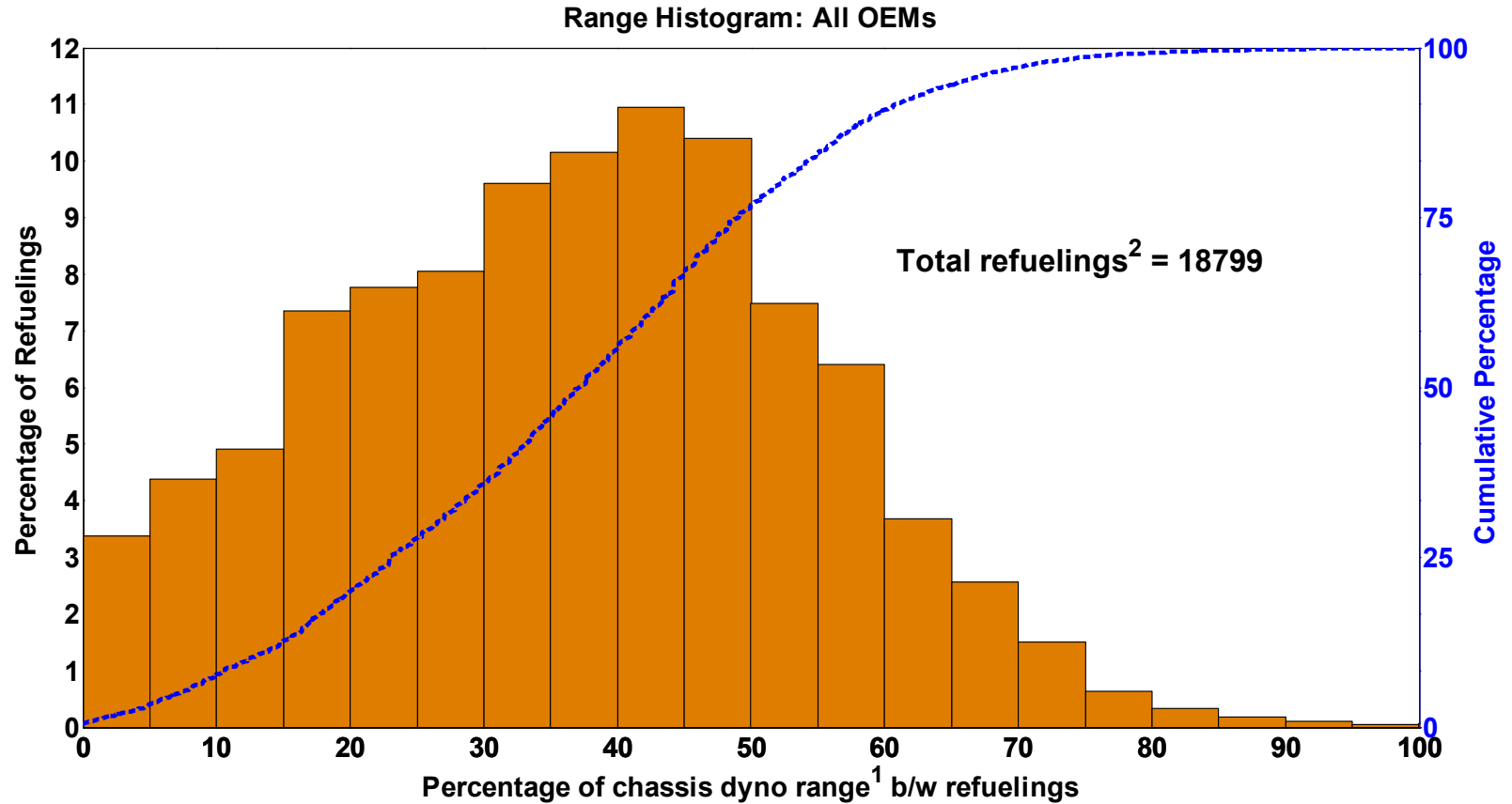




# CDP#32: Infrastructure Hydrogen Production Methods



# CDP#33: Percentage of Theoretical Range Traveled Between Refuelings

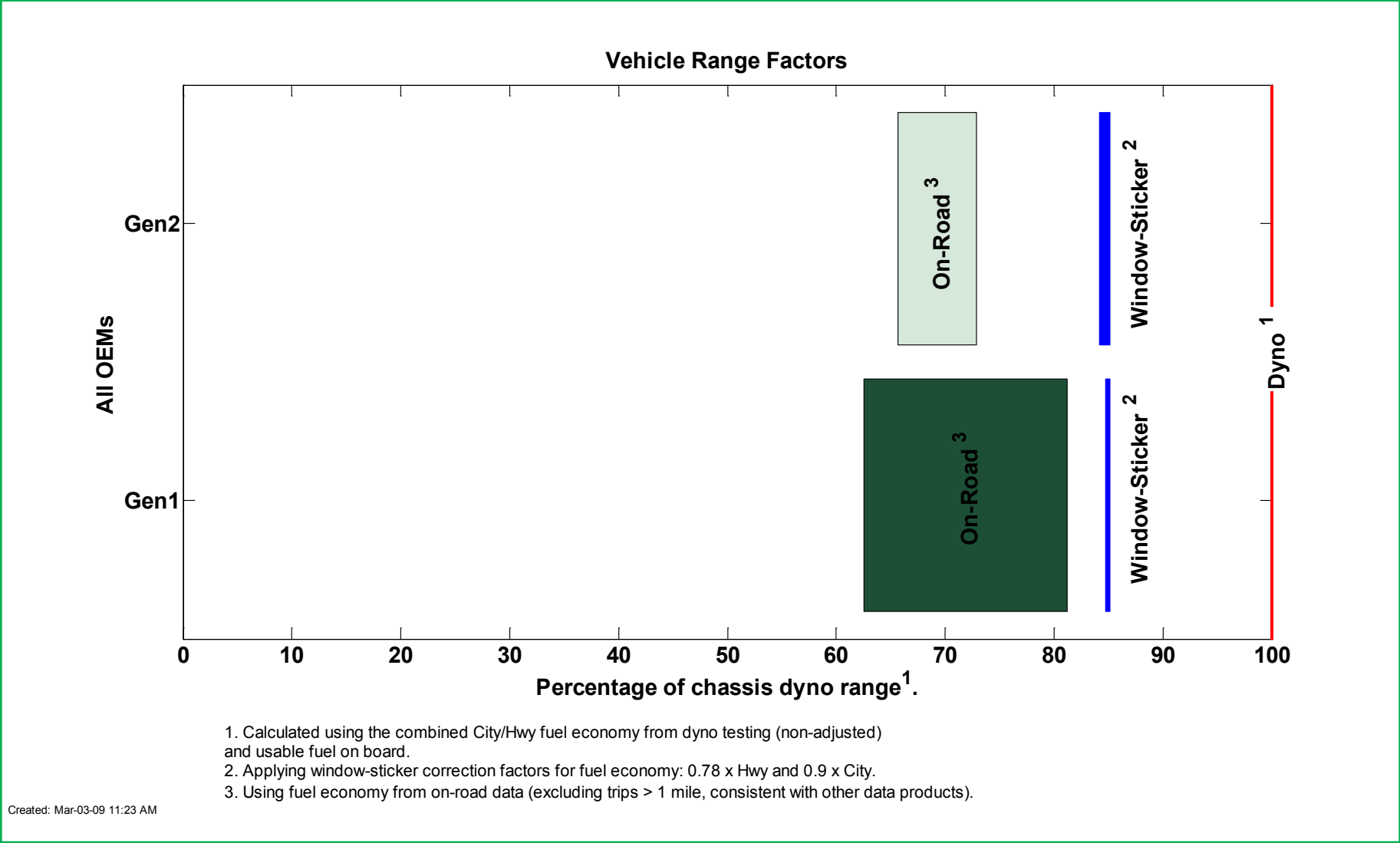


1. Range calculated using the combined City/Hwy fuel economy from dyno testing (not EPA adjusted) and usable fuel on board.

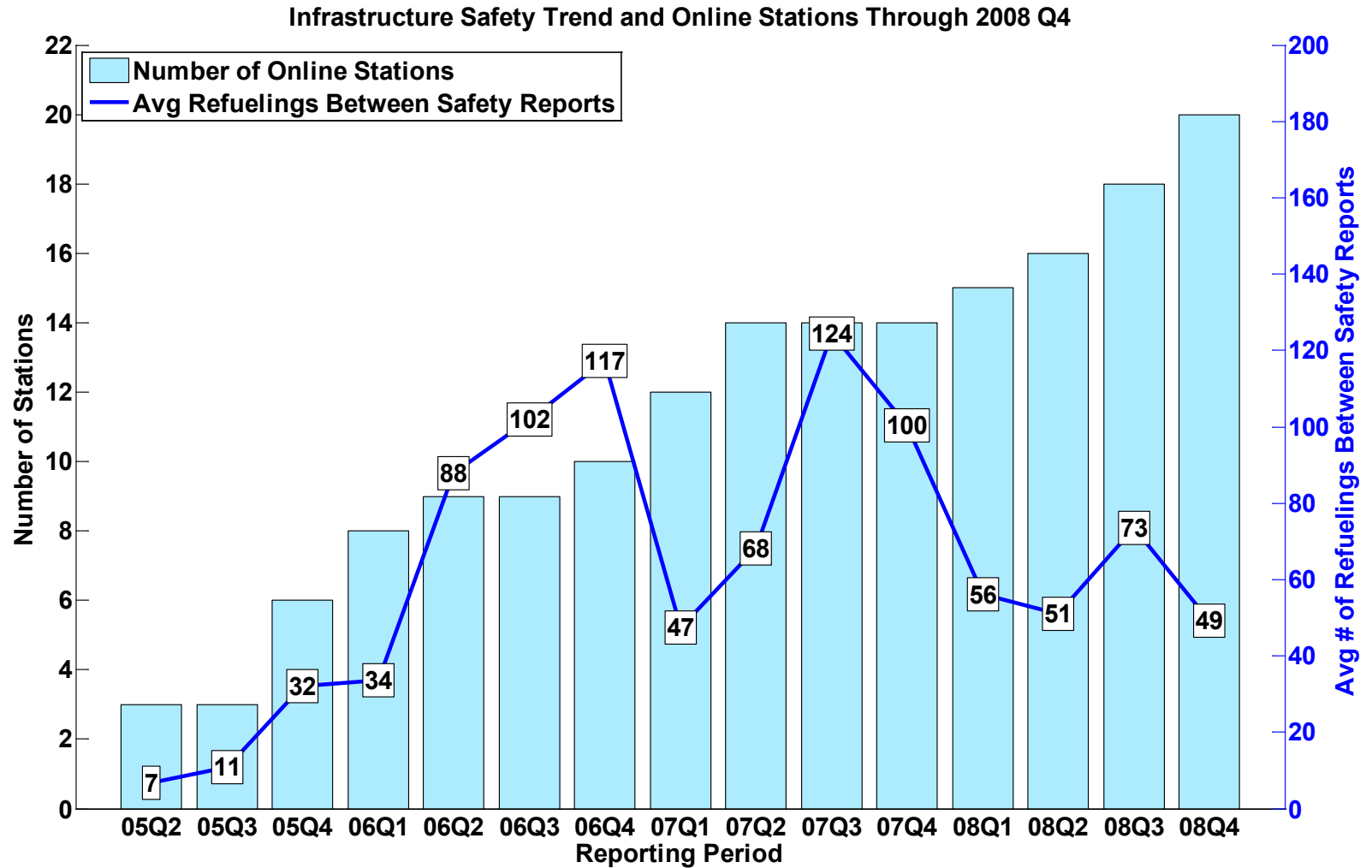
2. Some refueling events are not detected/reported due to data noise or incompleteness.

Created: Feb-20-09 12:25 PM

# CDP#34: Effective Vehicle Range

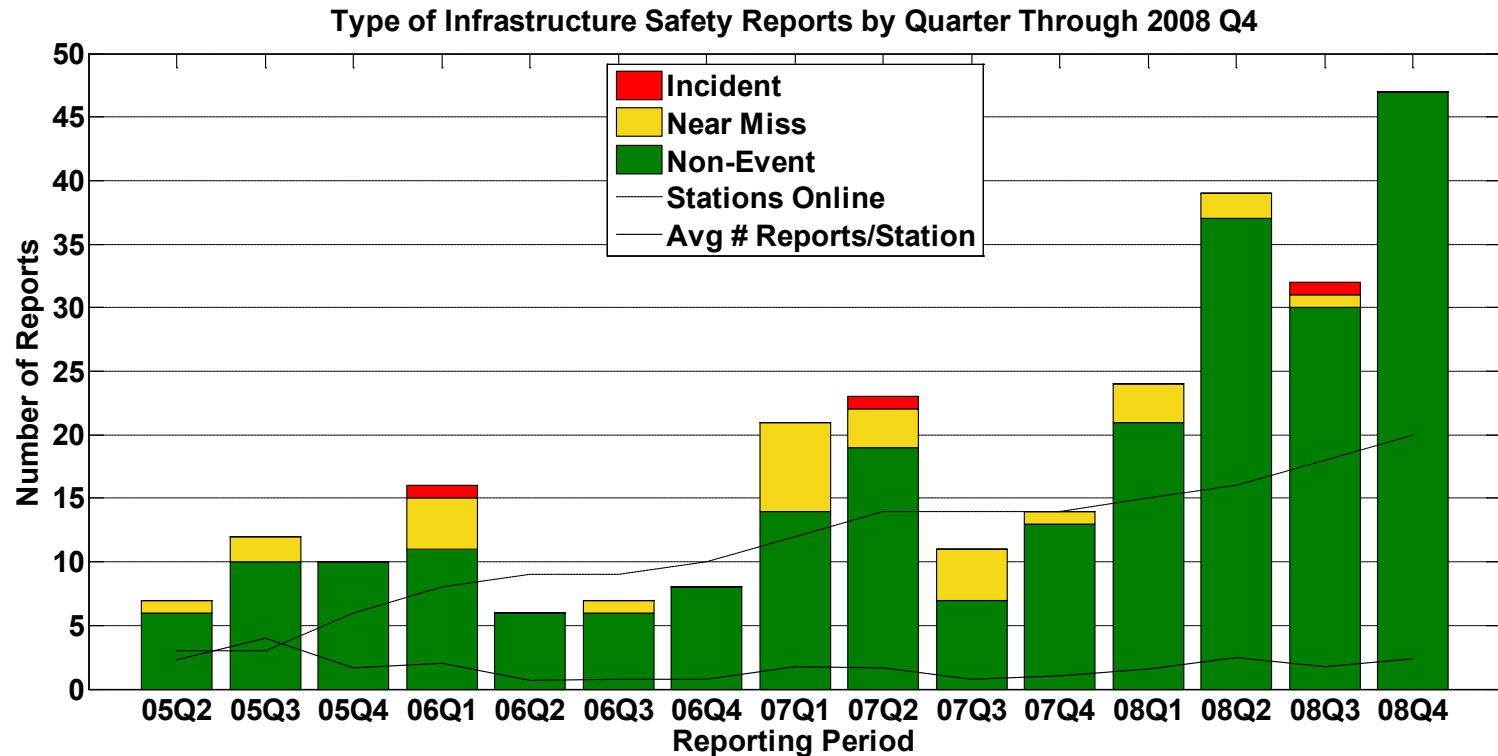


# CDP#35: Average Refuelings Between Infrastructure Safety Reports



Created: Feb-27-09 8:18 AM

# CDP#36: Type of Infrastructure Safety Report By Quarter



An INCIDENT is an event that results in:

- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

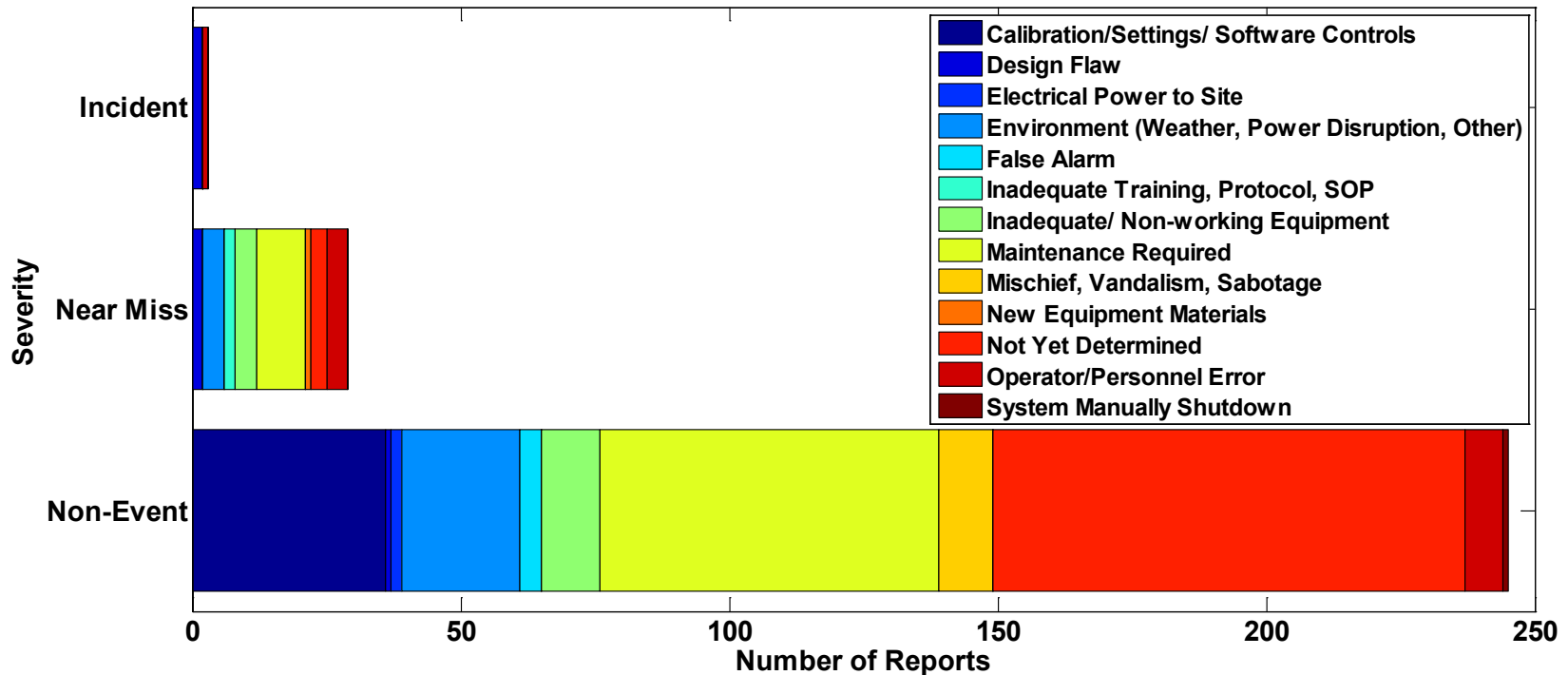
A NEAR-MISS is:

- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

Created: Feb-27-09 8:18 AM

# CDP#37: Primary Factors of Infrastructure Safety Reports

Primary Factors of Infrastructure Safety Reports  
Through 2008 Q4



An INCIDENT is an event that results in:

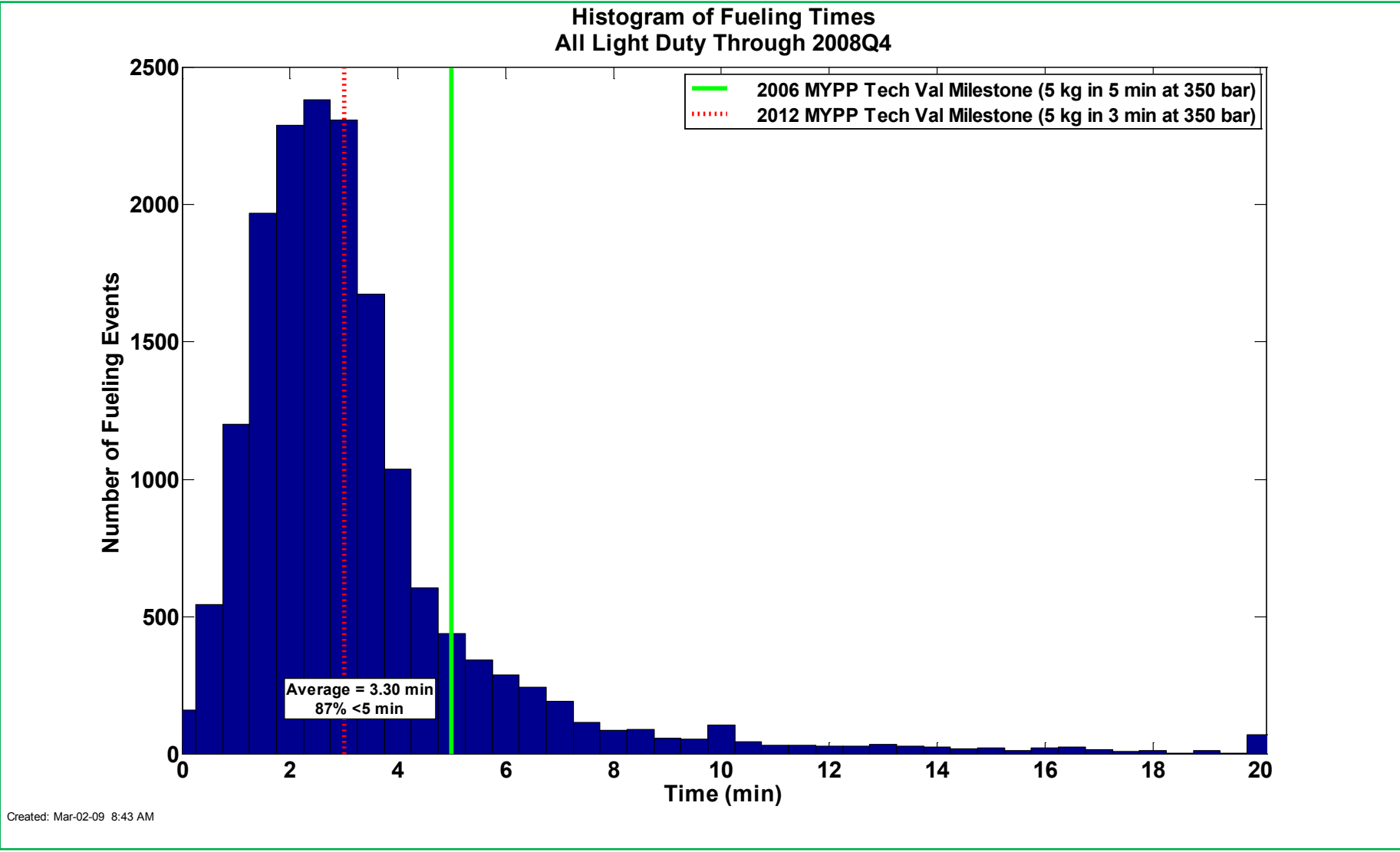
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing compound (other than the hydrocarbons used as common fuels)

A NEAR-MISS is:

- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

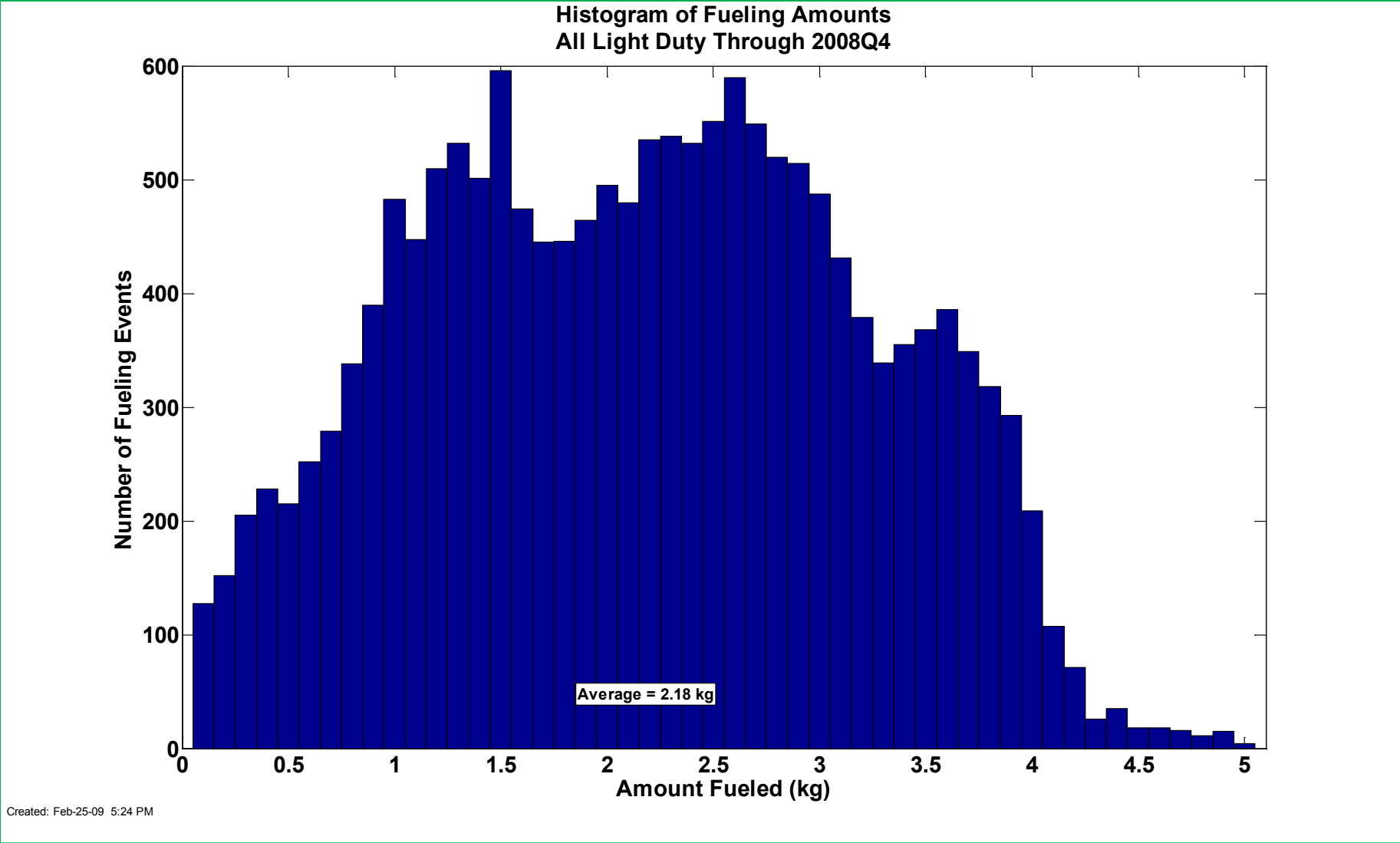
Created: Feb-27-09 8:16 AM

# CDP#38: Refueling Times



Created: Mar-02-09 8:43 AM

# CDP#39: Refueling Amounts



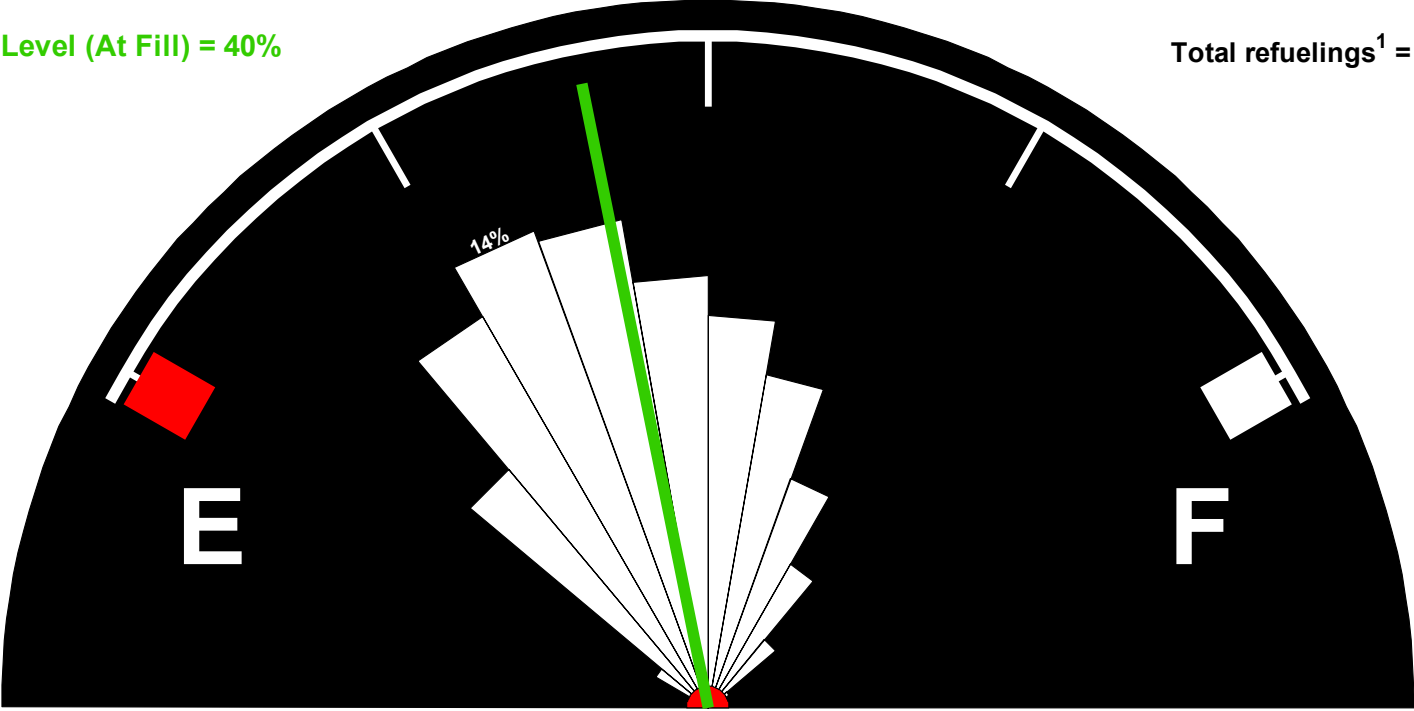


# CDP#40: H2 Tank Level at Refueling

Tank Levels: DOE Fleet

Median Tank Level (At Fill) = 40%

Total refuelings<sup>1</sup> = 20639



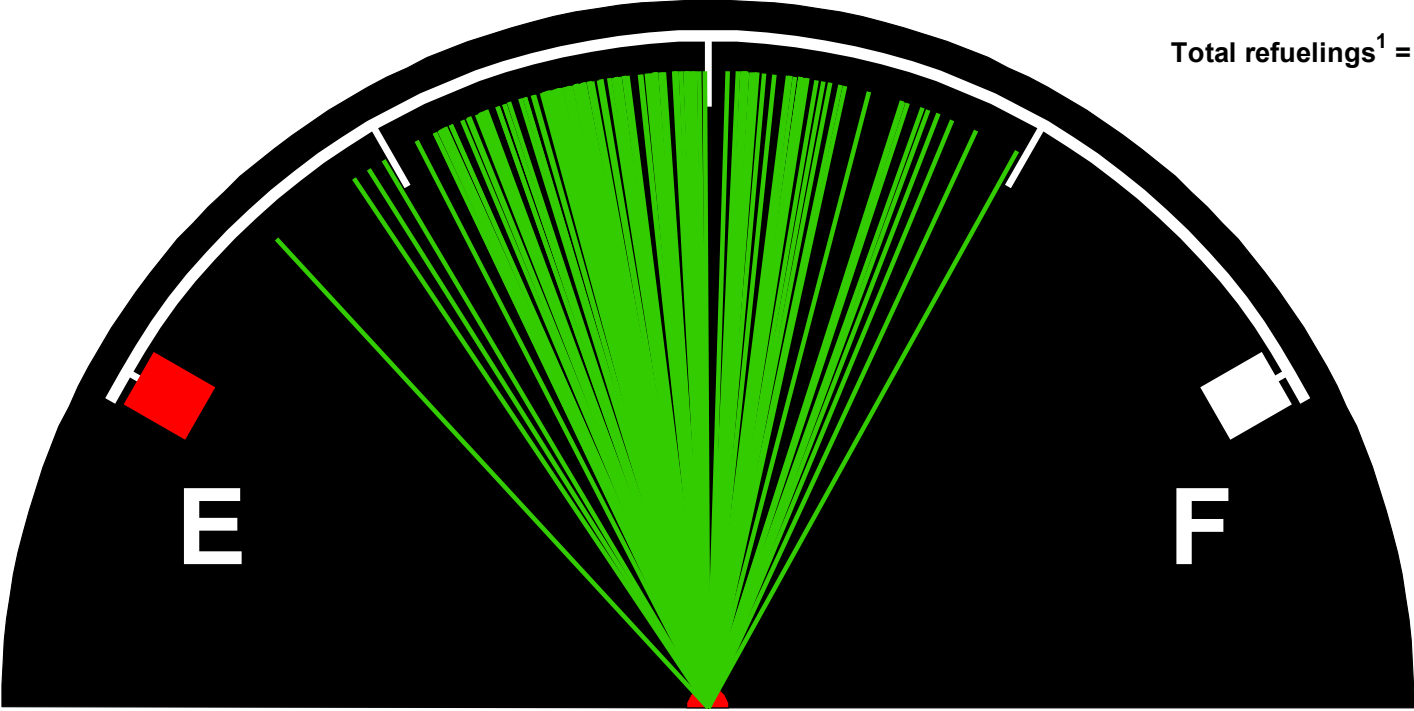
1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 20% total refuelings.
3. If tank level at fill was not available, a complete fill up was assumed.

Created: Feb-20-09 12:37 PM

# CDP#41: Refueling Tank Levels - Medians

Tank Level Medians (At Fill): DOE Fleet, All Vehicles

Total refuelings<sup>1</sup> = 20639



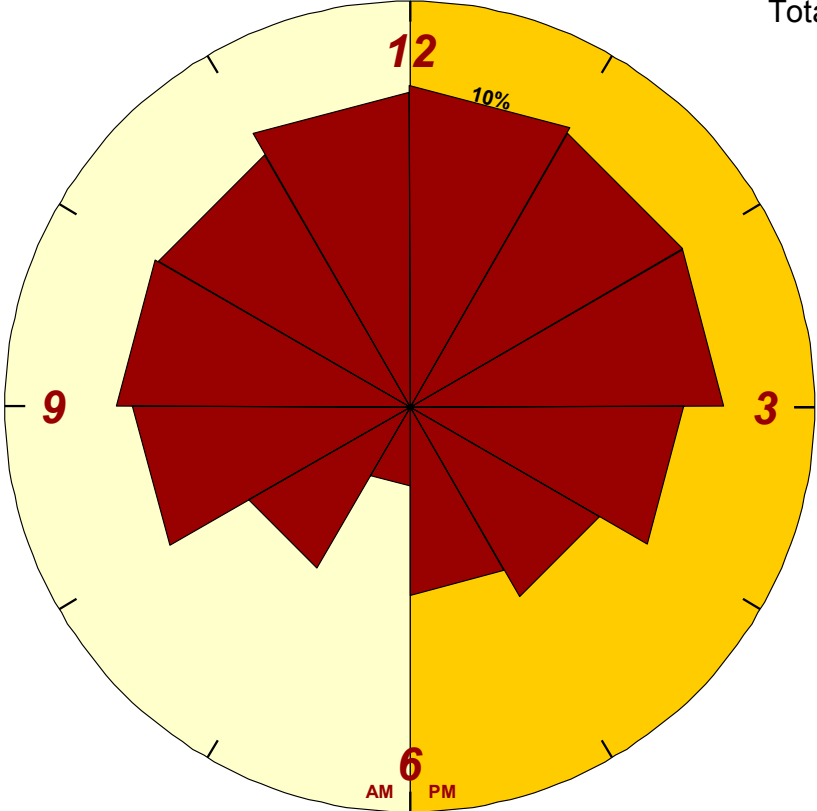
- 1. Some refueling events not recorded/detected due to data noise or incompleteness.
- 2. If tank level at fill was not available, a complete fill up was assumed.

# CDP#42: Refueling by Time of Day

Refueling by Time of Day: DOE Fleet

% of fills b/t 6 AM & 6 PM: 91.1%

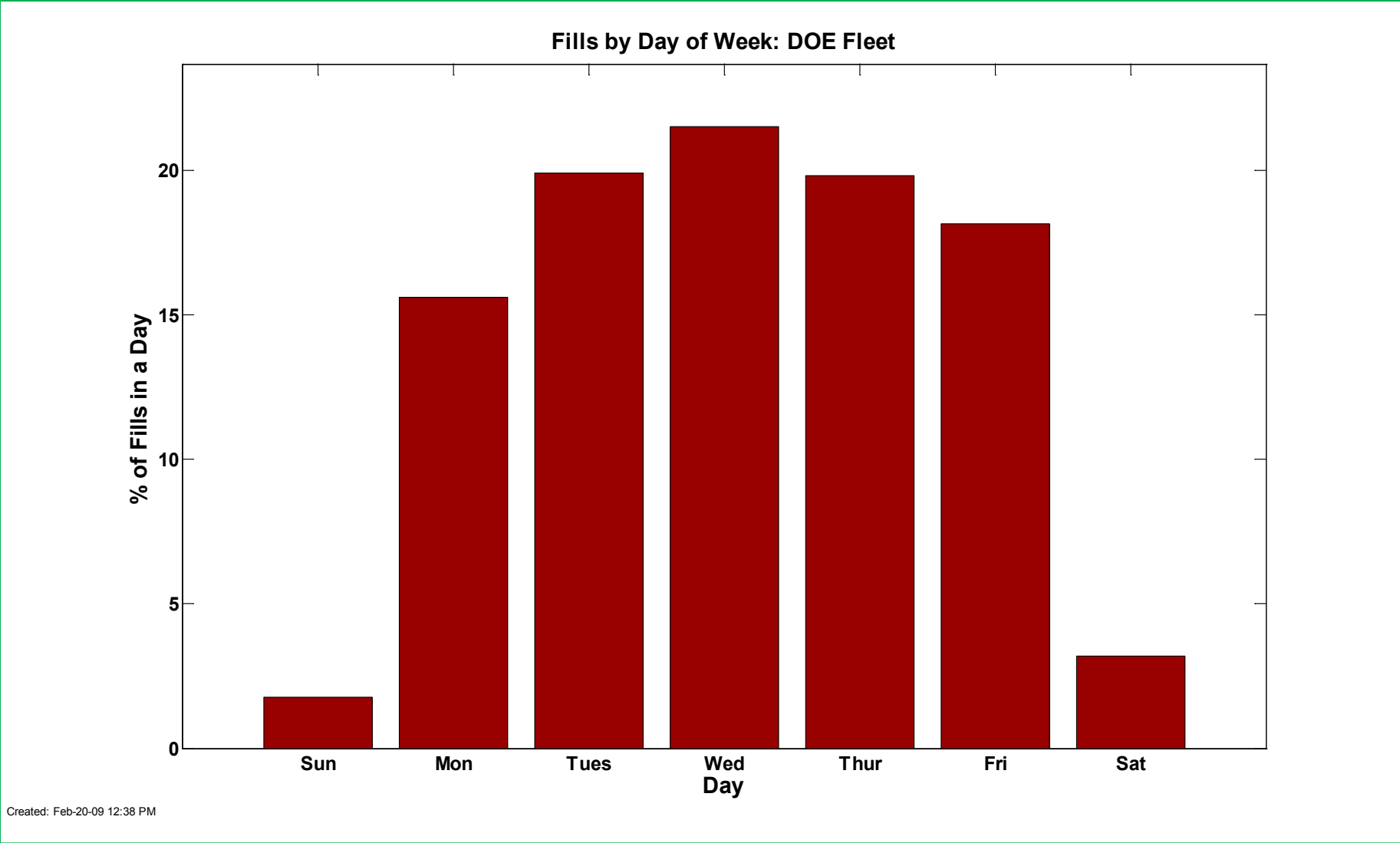
Total Fill<sup>3</sup> Events = 17237



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

Created: Feb-20-09 12:37 PM

# CDP#43: Refueling by Day of Week

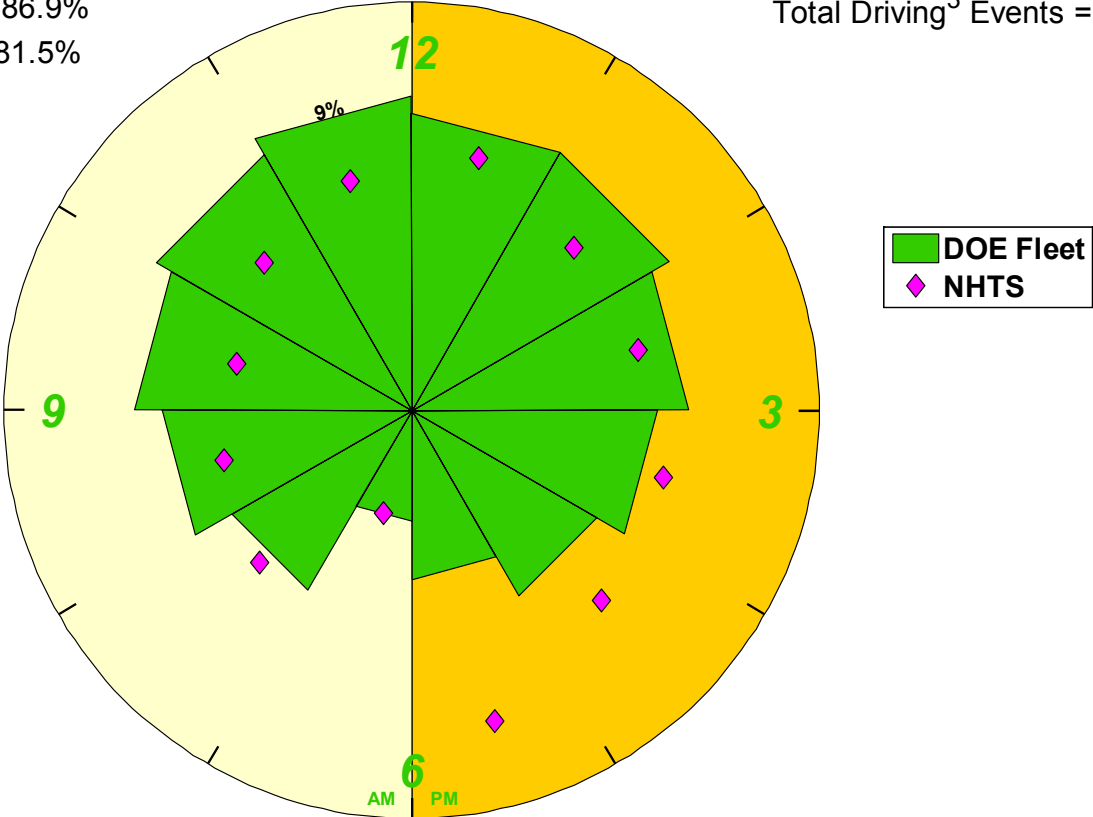


# CDP#44: Driving Start Time – Day

Driving Start Time - Day: DOE Fleet

% of driving trips b/t 6 AM & 6 PM: 86.9%  
 % of NHTS trips b/t 6 AM & 6 PM: 81.5%

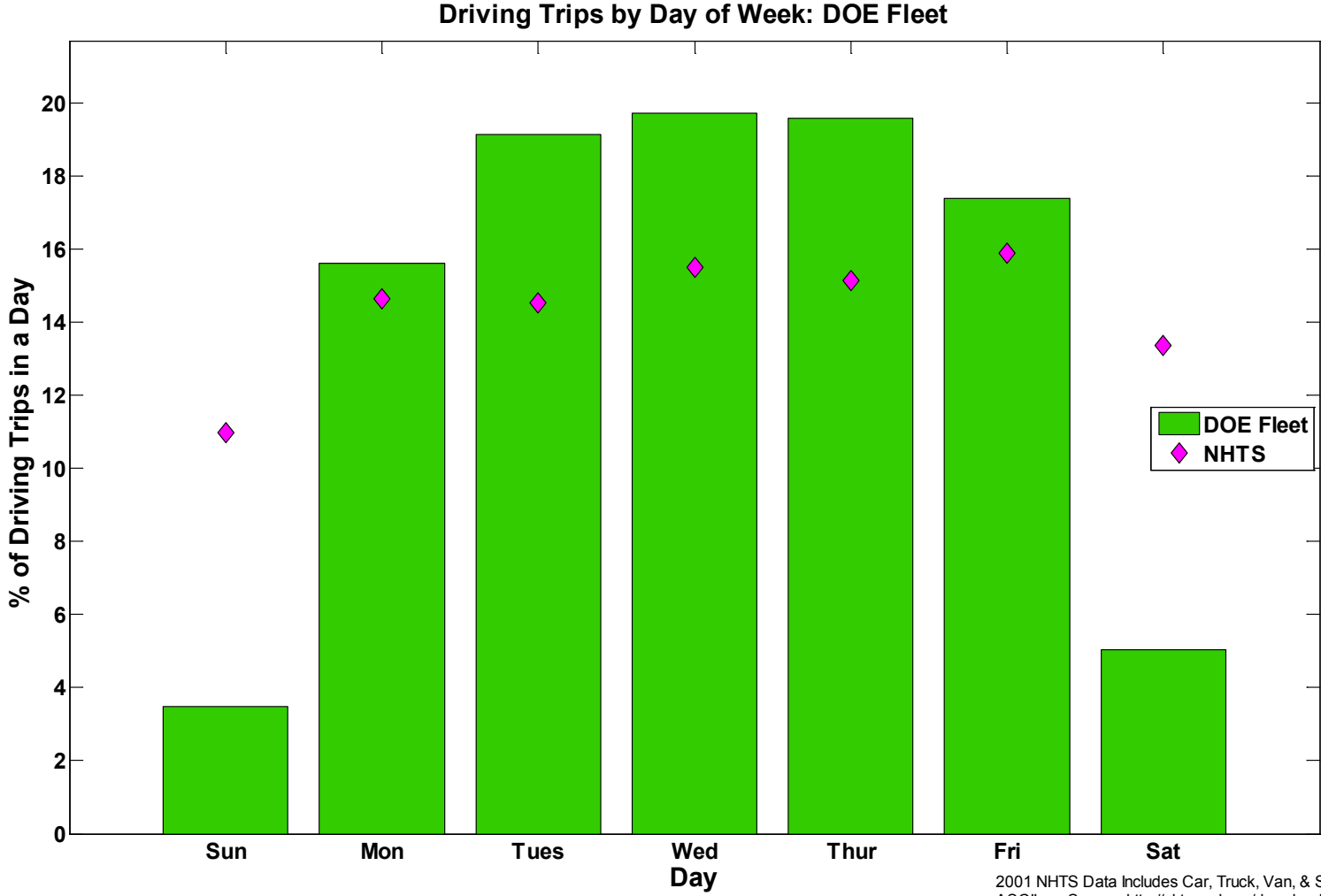
Total Driving<sup>3</sup> Events = 224309



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>

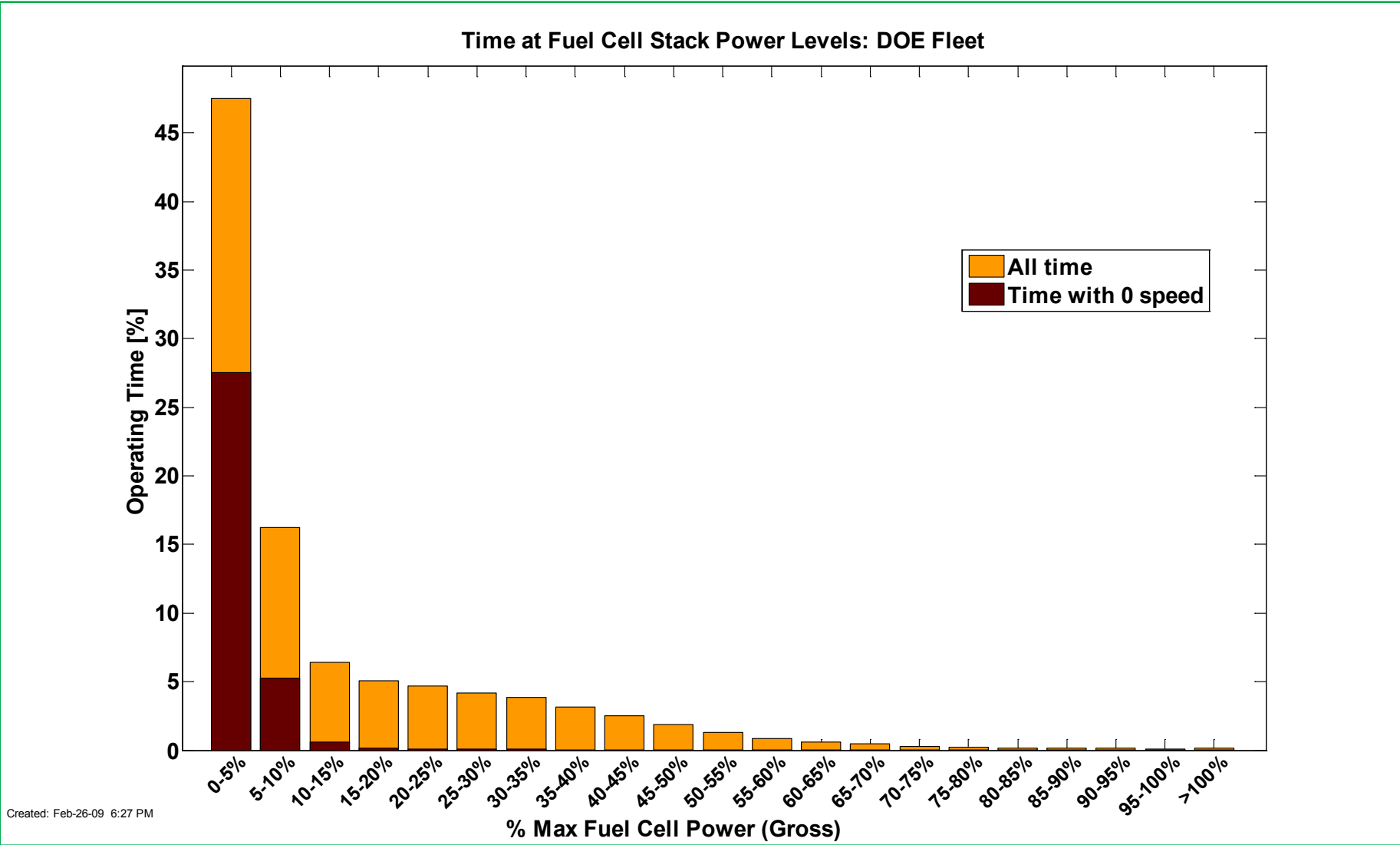
# CDP#45: Driving by Day of Week



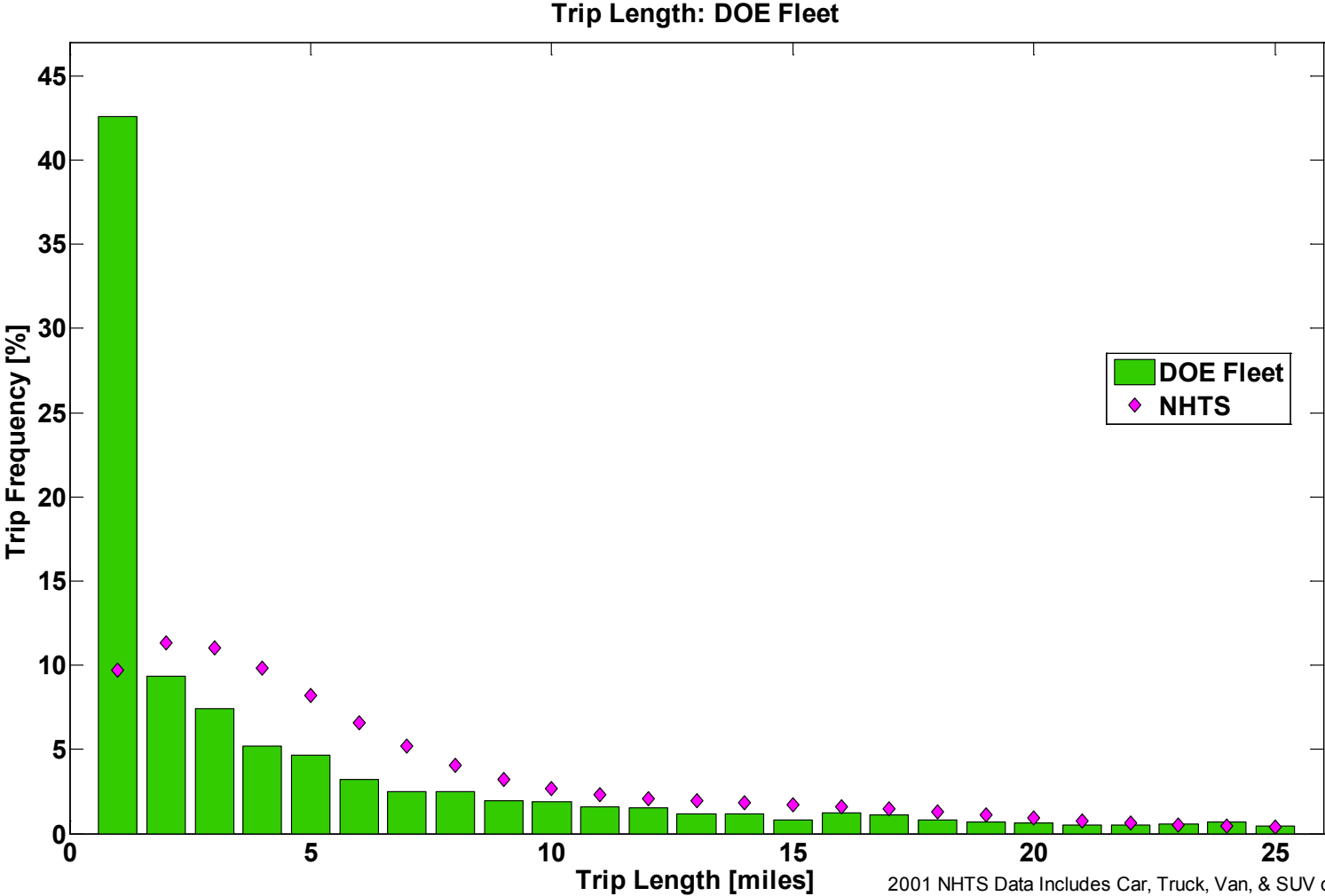
Created: Feb-26-09 6:21 PM

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

# CDP#46: Fuel Cell System Operating Power



# CDP#47: Trip Length

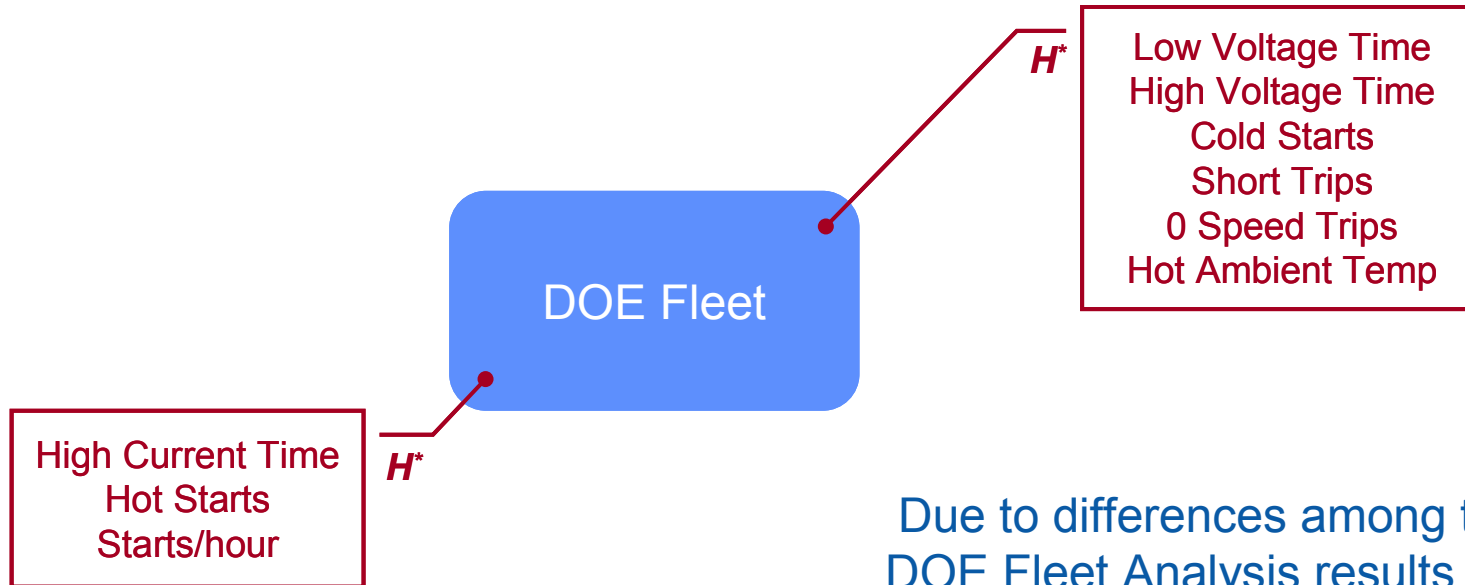


Created: Feb-26-09 6:11 PM

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



# CDP#48: Primary Factors Affecting Learning Demo Fleet Fuel Cell Degradation



Due to differences among teams, the DOE Fleet Analysis results are spread out and concrete conclusions are difficult to draw.

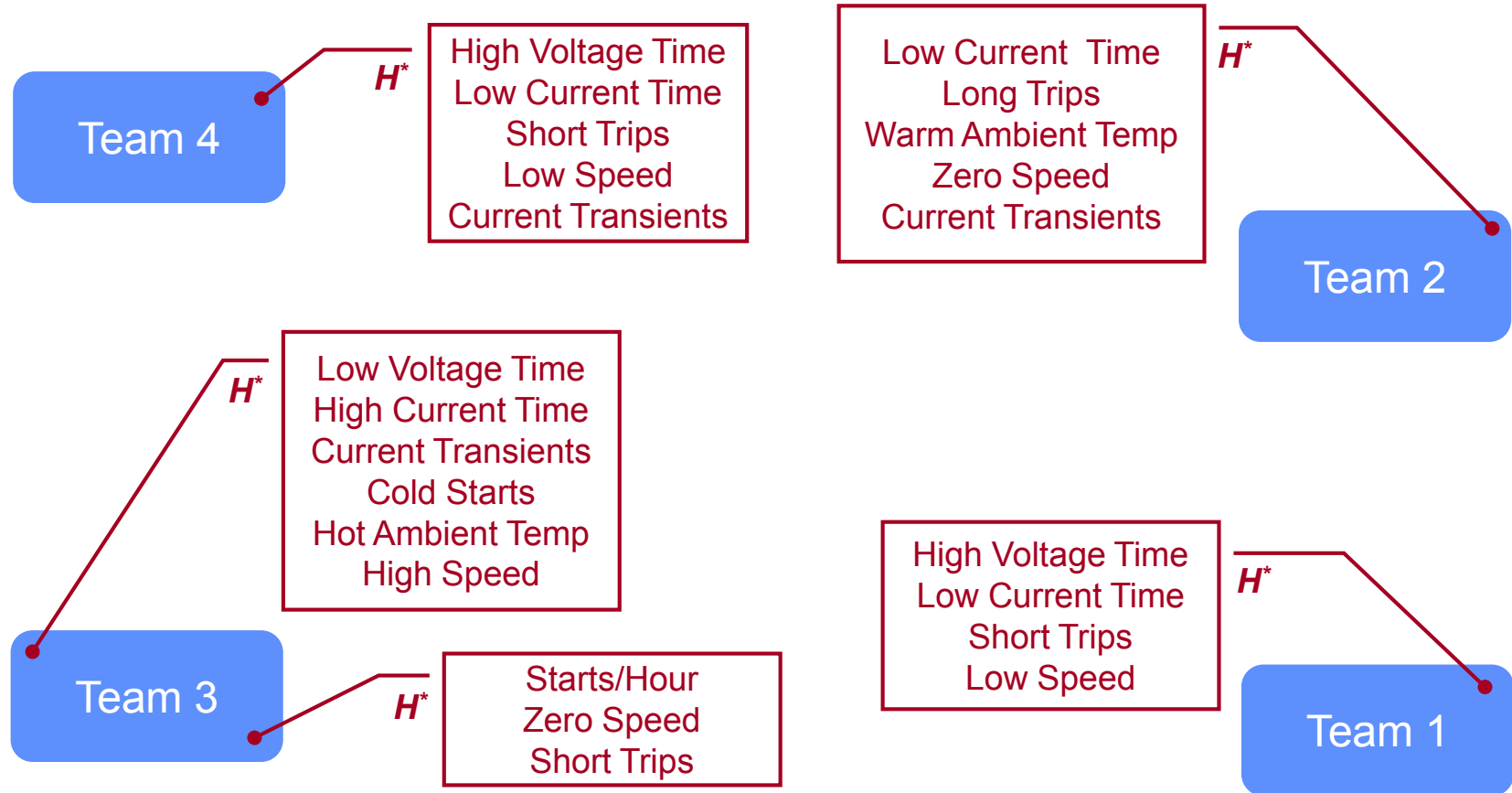
Individual team analyses (CDP#49) focused on patterns within a fleet.

- 1) On-going fuel cell degradation study using Partial Least Squares (PLS) regression model for combined Learning Demonstration Fleet.
- 2) DOE Fleet model has a low percentage of explained decay rate variance.

**H\***: Factor group associated with high decay rate fuel cell stacks  
**L\*\***: Factor group associated with low decay rate fuel cell stacks

# CDP#49: Primary Factors Affecting Learning

## Demo Team Fuel Cell Degradation



- 1) On-going fuel cell degradation study using Partial Least Squares (PLS) regression model for each team's Gen 1 fleet.
- 2) Teams' PLS models have a high percentage of explained decay rate variance, but the models are not robust and results are scattered.
- 3) Factor groups associated with stacks that are opposite to the identified groups here are not specified.

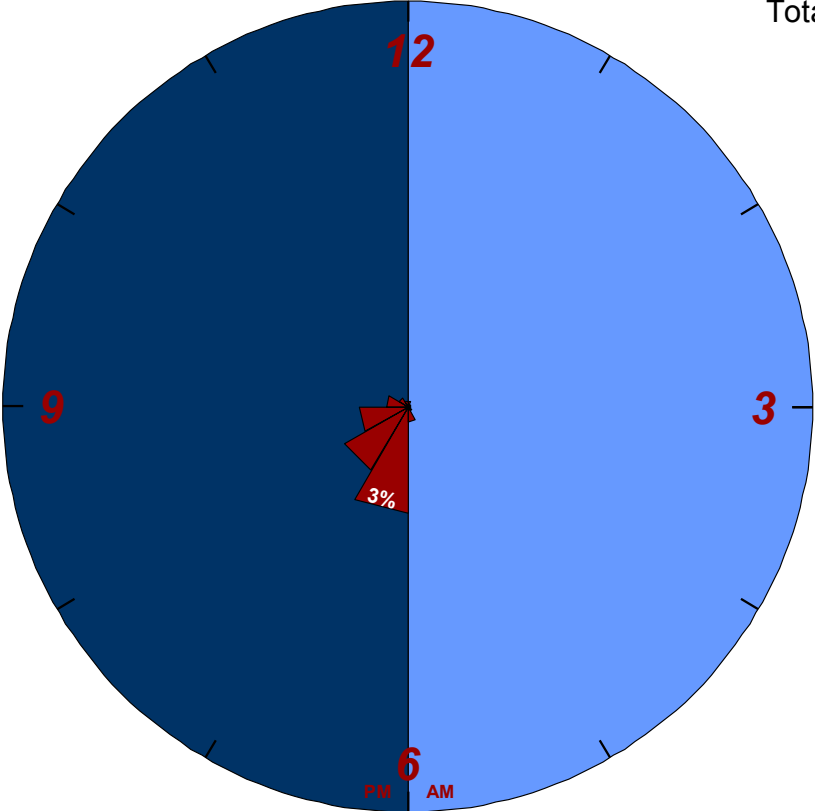
$H^*$ : Factor group associated with high decay rate fuel cell stacks

# CDP#50: Refueling by Time of Night

Refueling by Time of Night: DOE Fleet

% of fills b/t 6 PM & 6 AM: 8.9%

Total Fill<sup>3</sup> Events = 17237



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

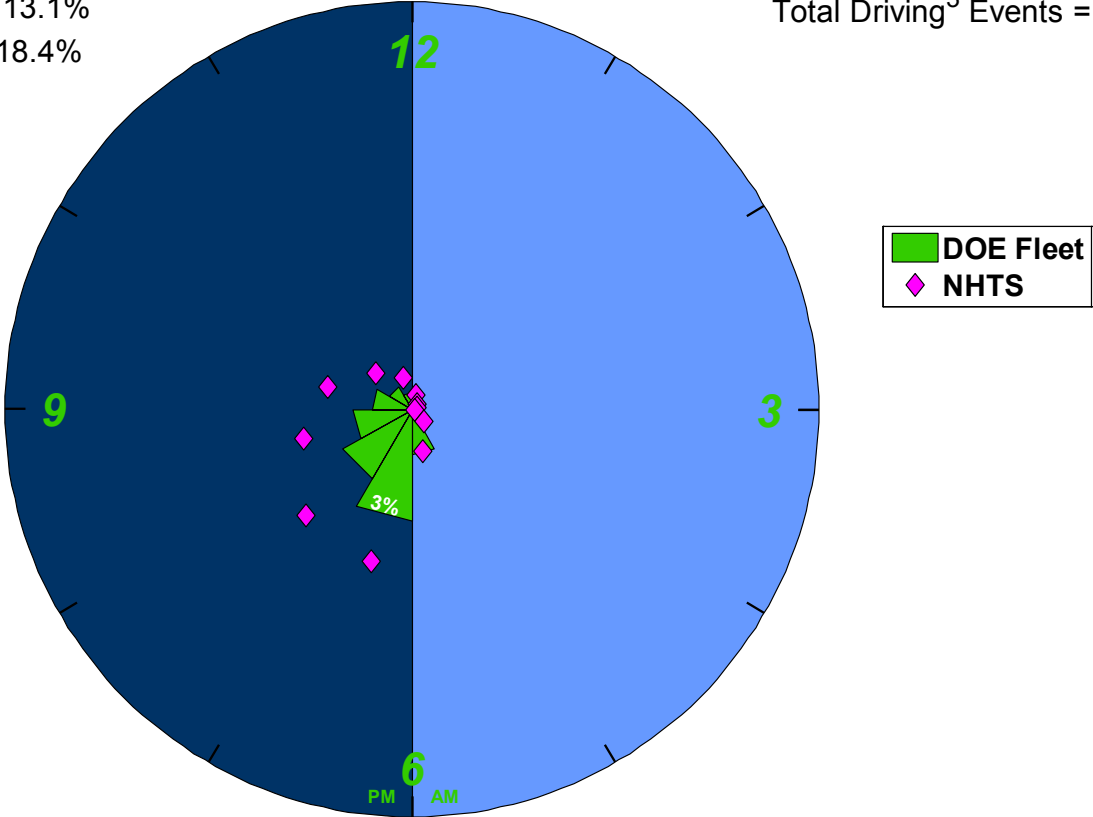
Created: Feb-20-09 12:38 PM

# CDP#51: Driving Start Time – Night

Driving Start Time - Night: DOE Fleet

% of driving trips b/t 6 PM & 6 AM: 13.1%  
 % of NHTS trips b/t 6 PM & 6 AM: 18.4%

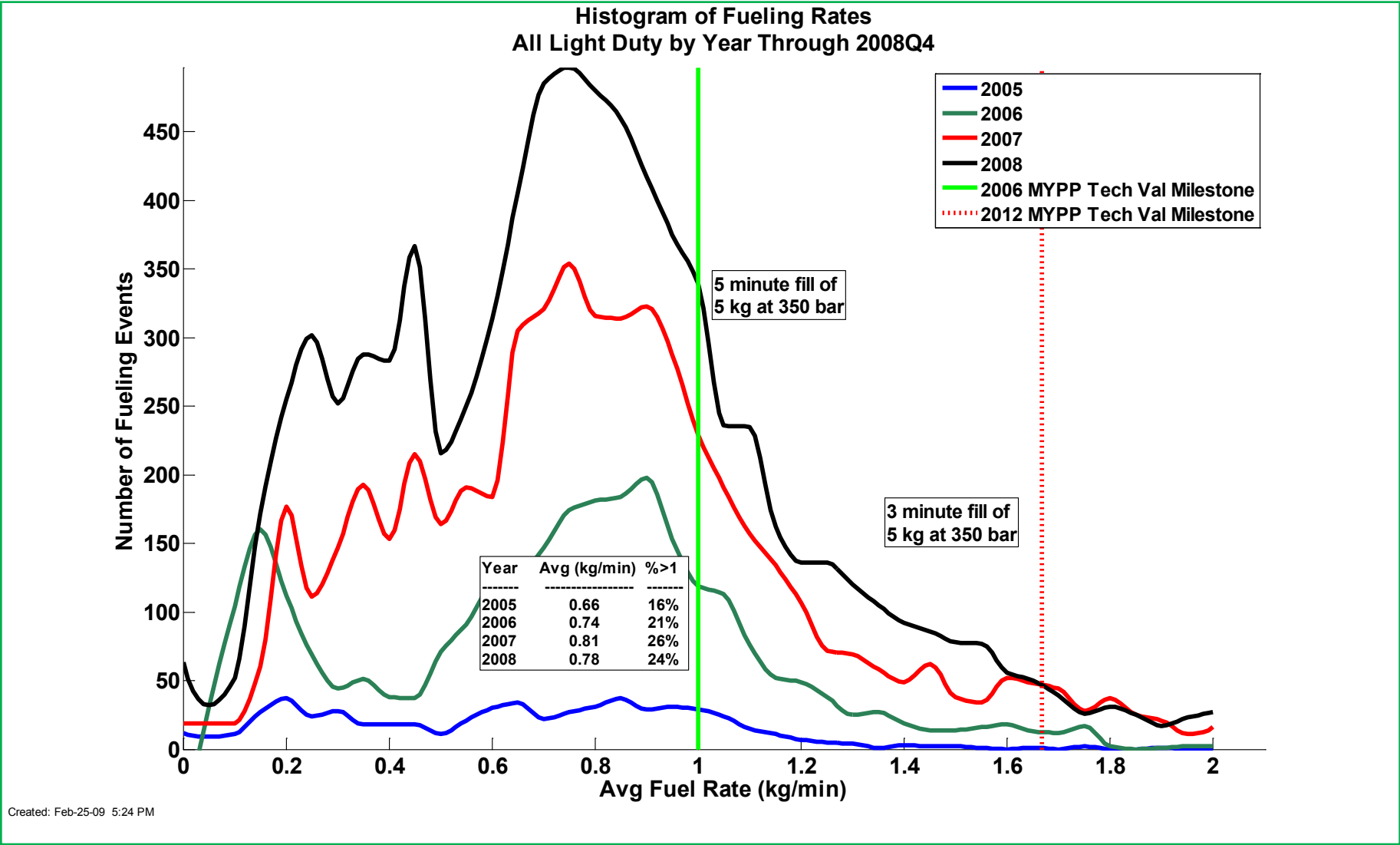
Total Driving<sup>3</sup> Events = 224309



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

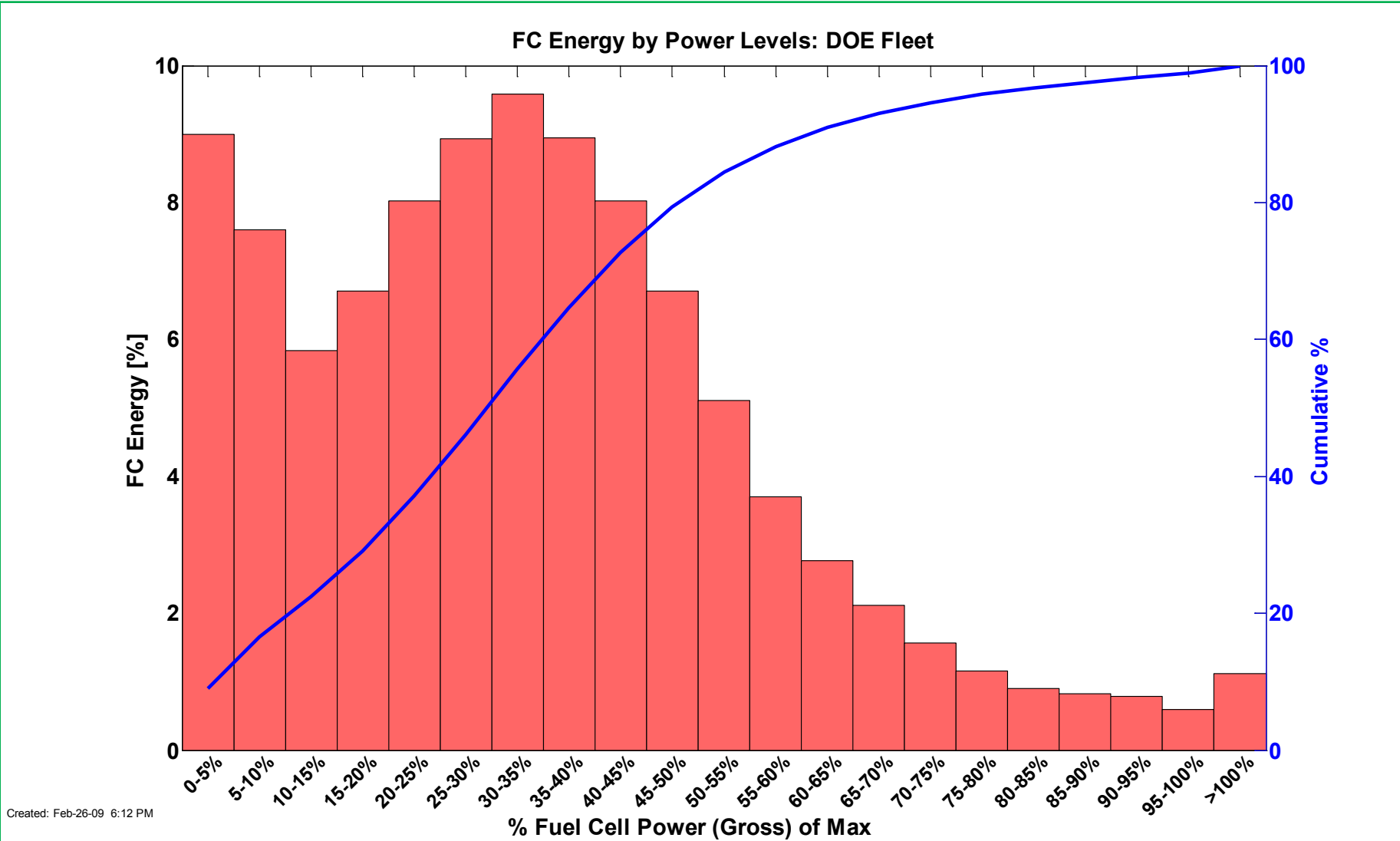
2001 NHTS Data Includes Car, Truck, Van, & SUV day trips  
 ASCII.csv Source: <http://nhts.ornl.gov/download.shtml#2001>

# CDP#52: Refueling Data by Year



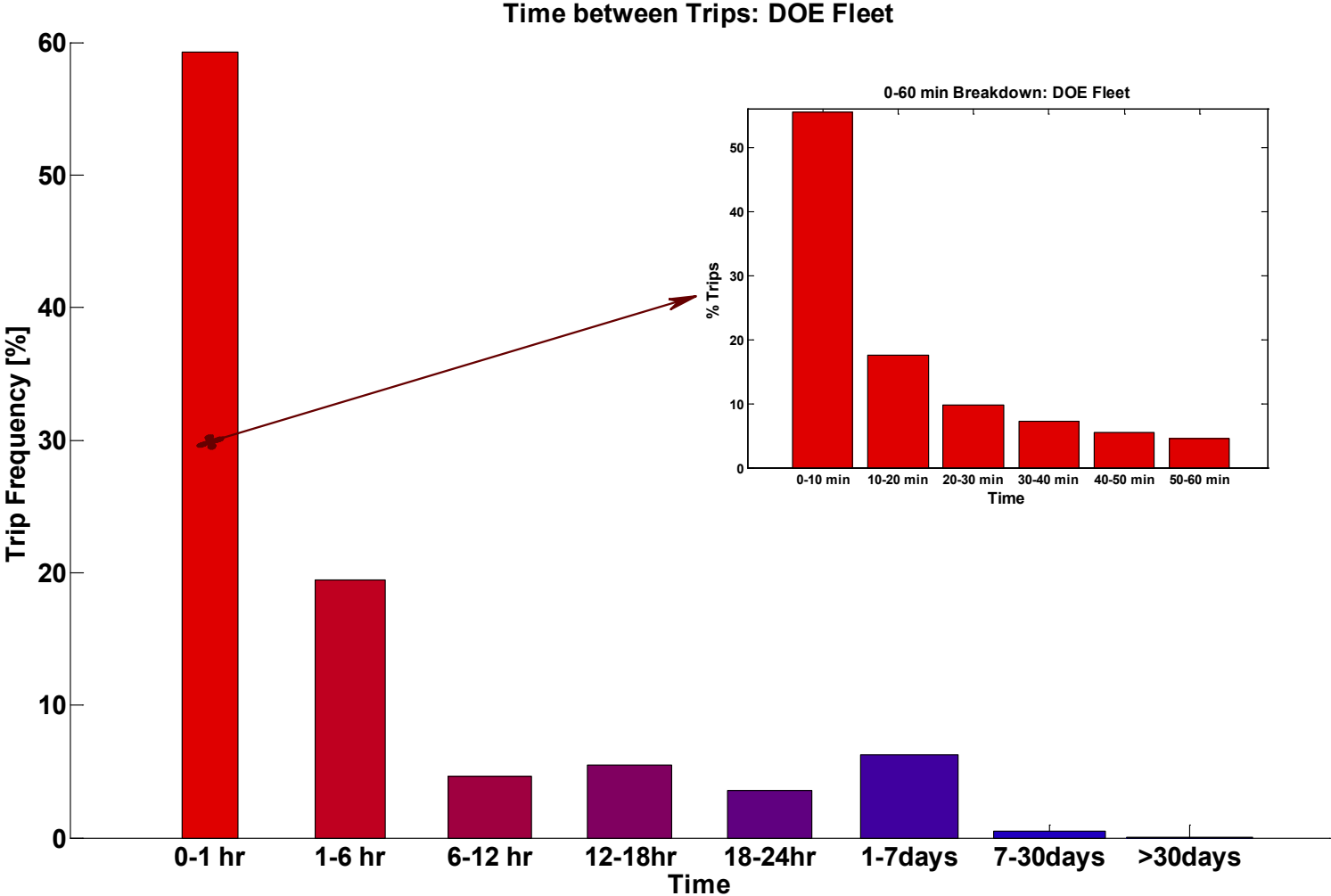
Created: Feb-25-09 5:24 PM

# CDP#53: Fuel Cell System Energy within Power Levels



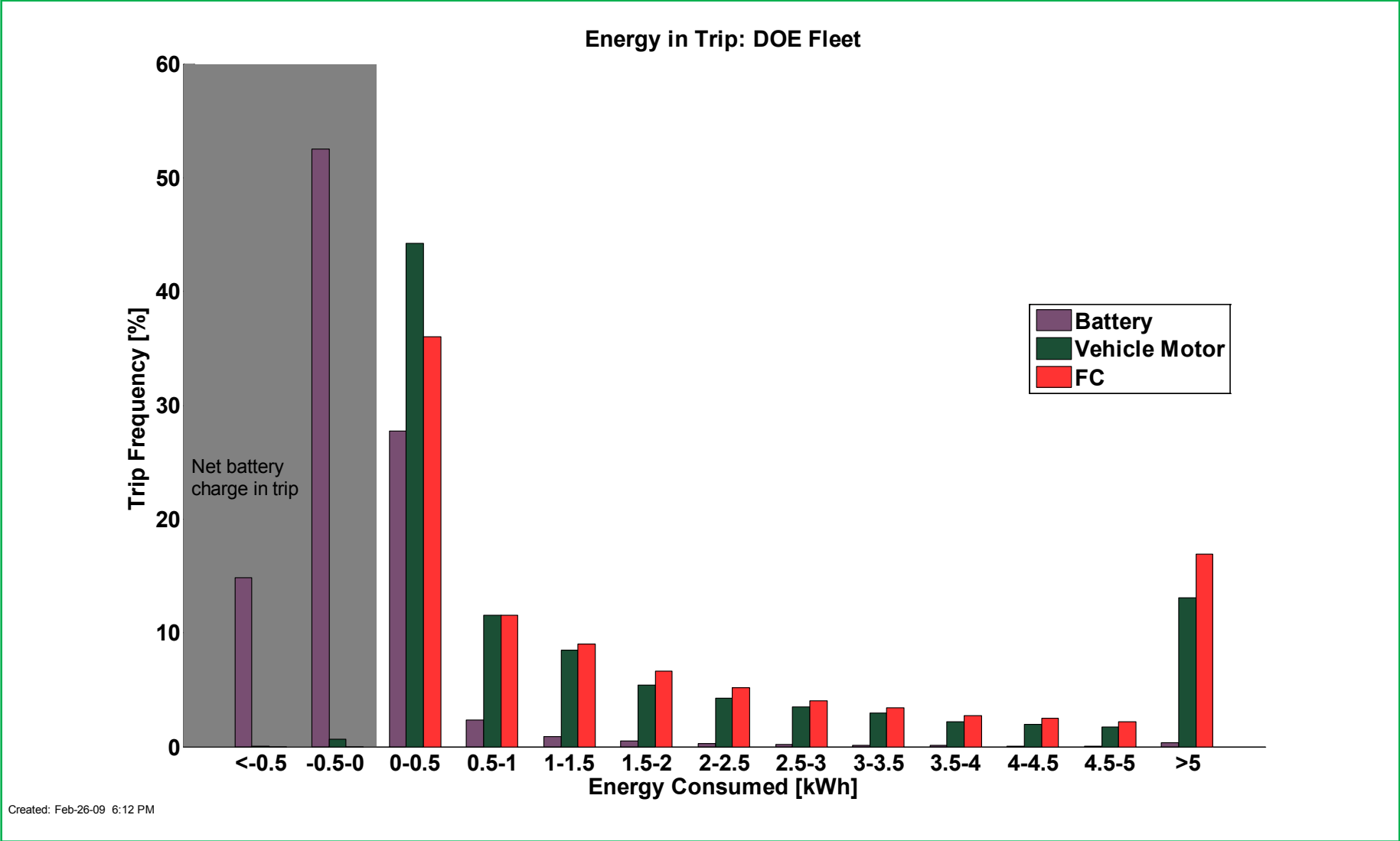
Created: Feb-26-09 6:12 PM

# CDP#54: Time Between Trips



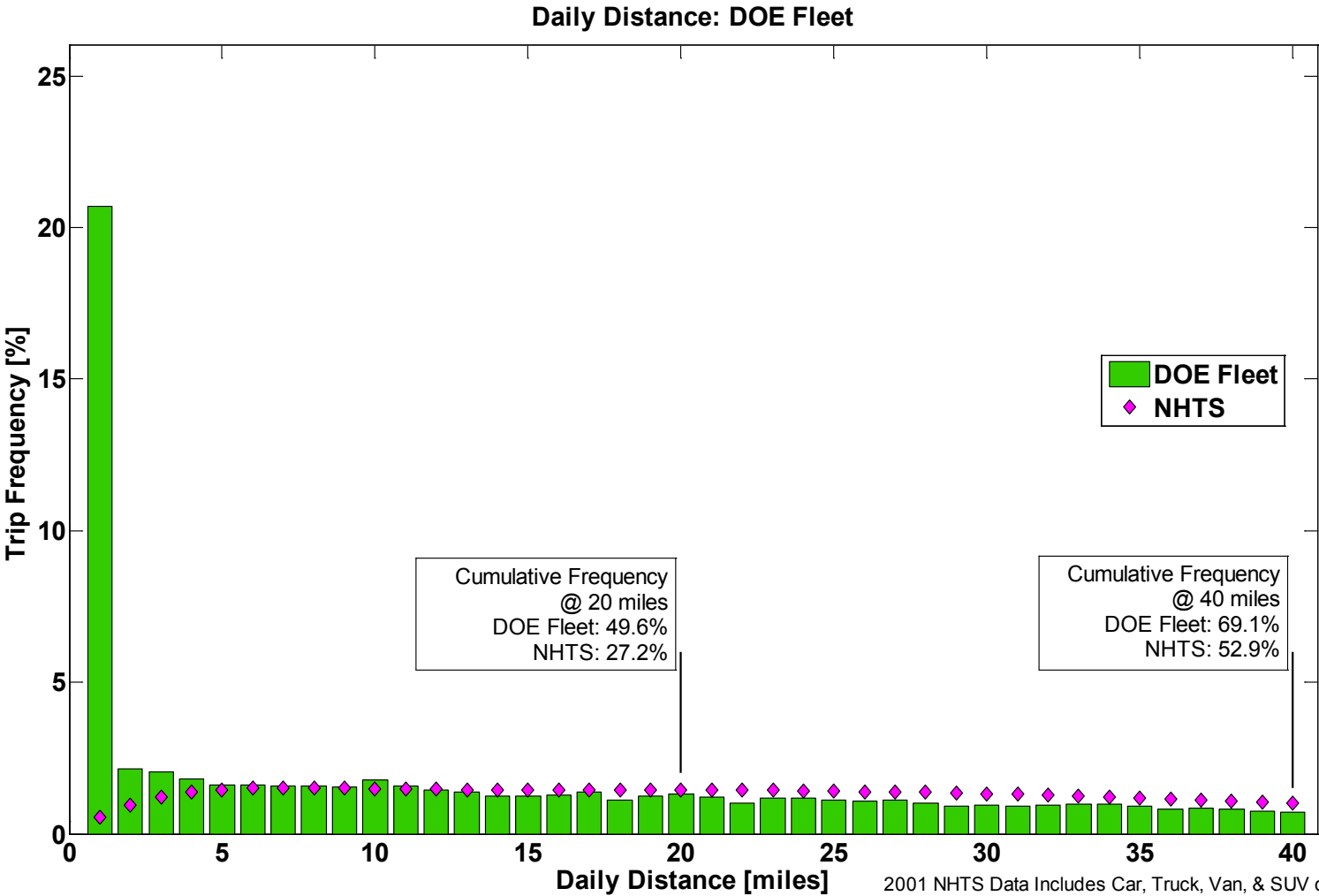
Created: Feb-26-09 5:56 PM

# CDP#55: Fuel Cell System Energy





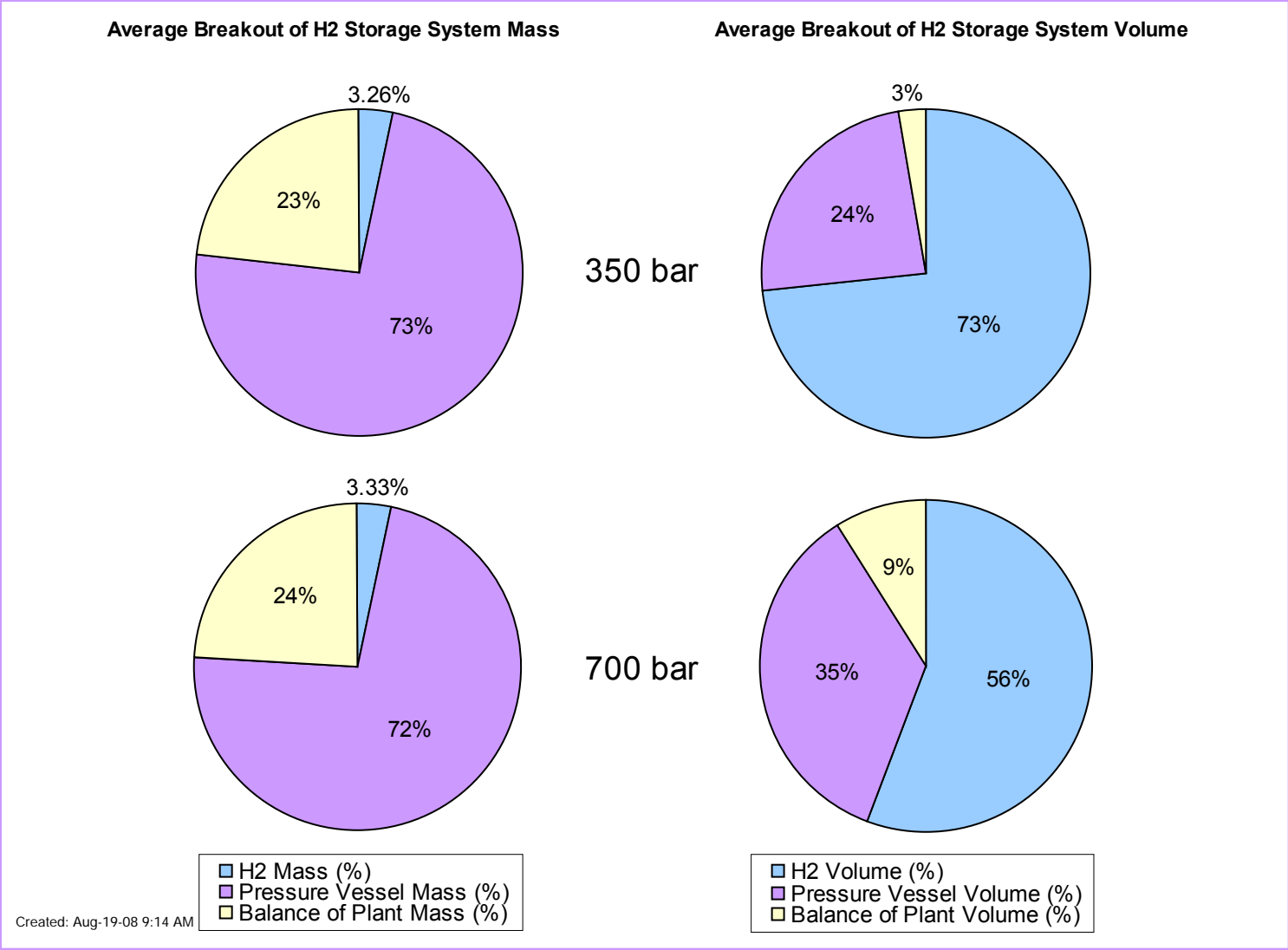
# CDP#56: Daily Driving Distance



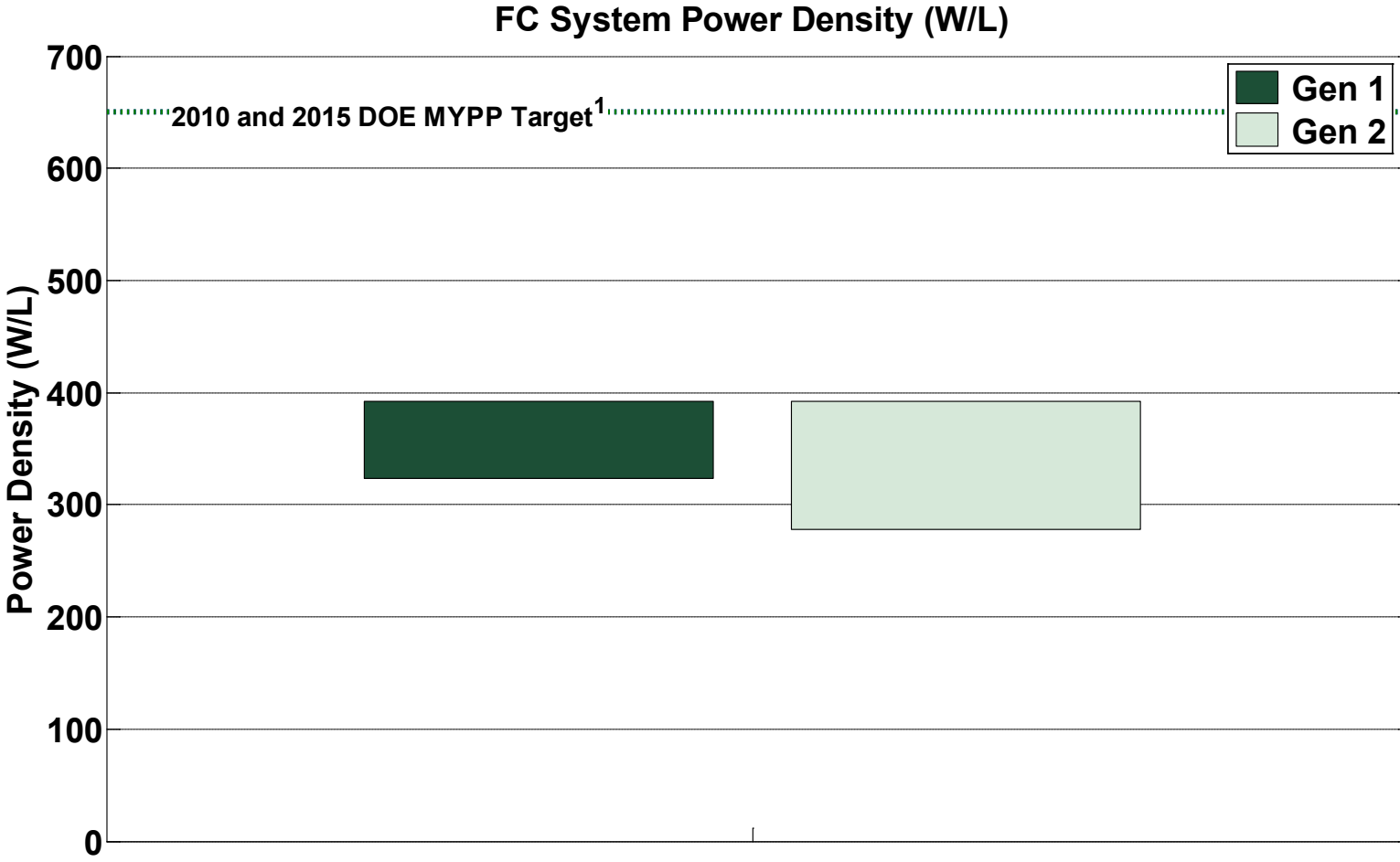
Created: Feb-26-09 6:12 PM

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

# CDP#57: H2 Storage System Mass and Volume Breakdown

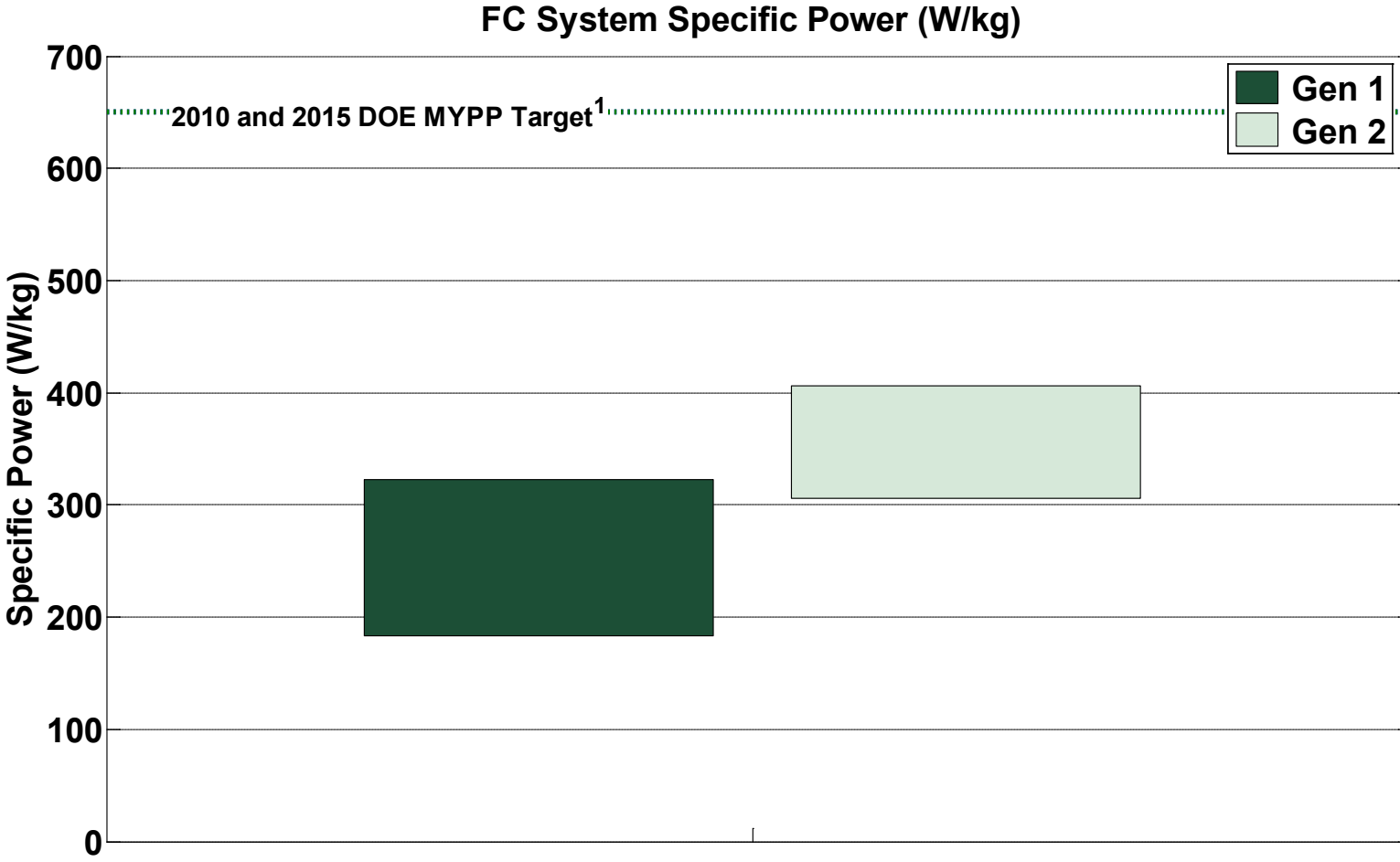


# CDP#58: Fuel Cell System Power Density



(1) Fuel cell system includes fuel cell stack and BOP but excludes H2 storage, power electronics, and electric drive.

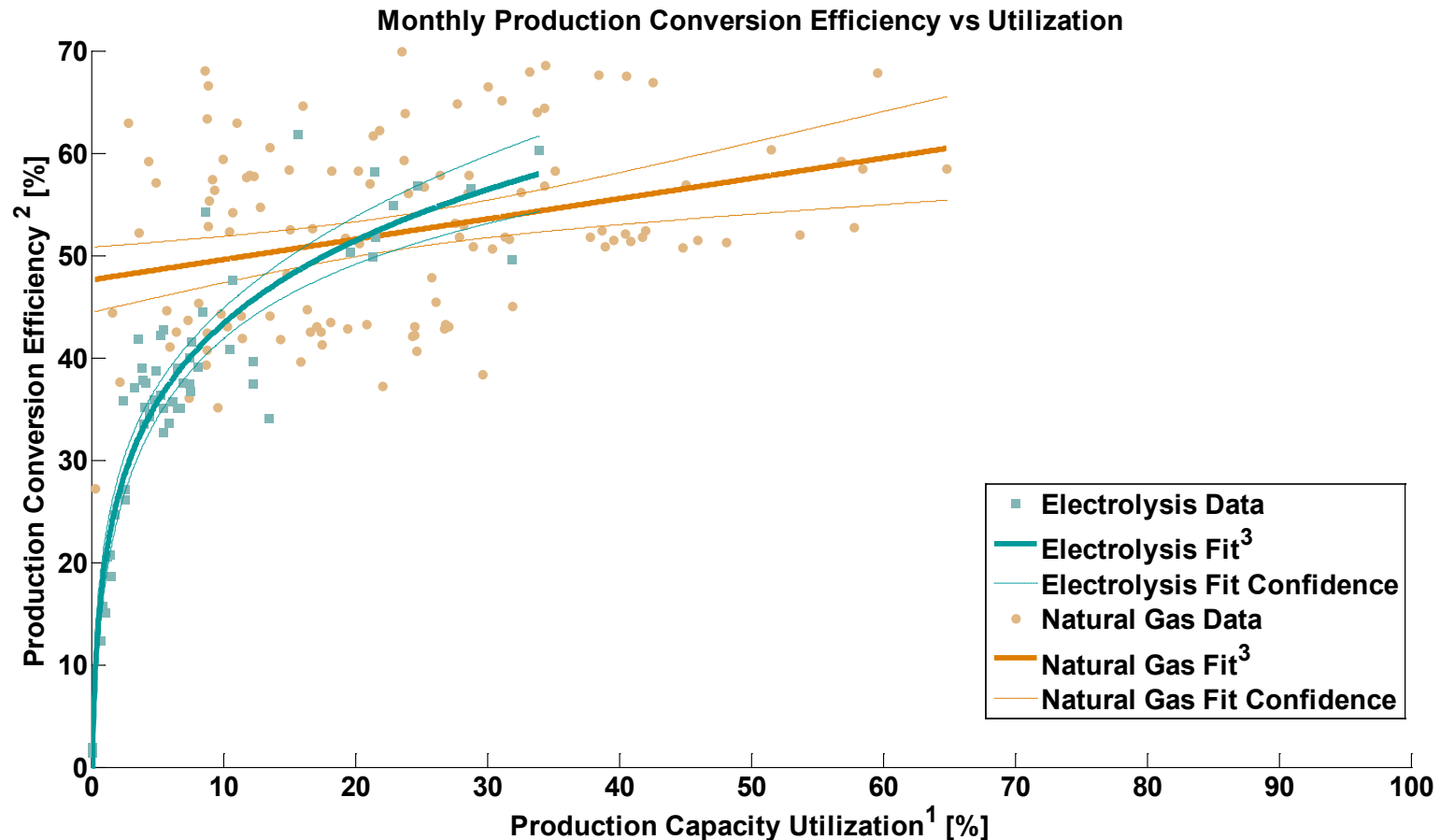
# CDP#59: Fuel Cell System Specific Power



Created: Sep-17-08 10:30 AM

(1) Fuel cell system includes fuel cell stack and BOP but excludes H2 storage, power electronics, and electric drive.

# CDP#60: On-Site Hydrogen Production Efficiency vs. Capacity Utilization



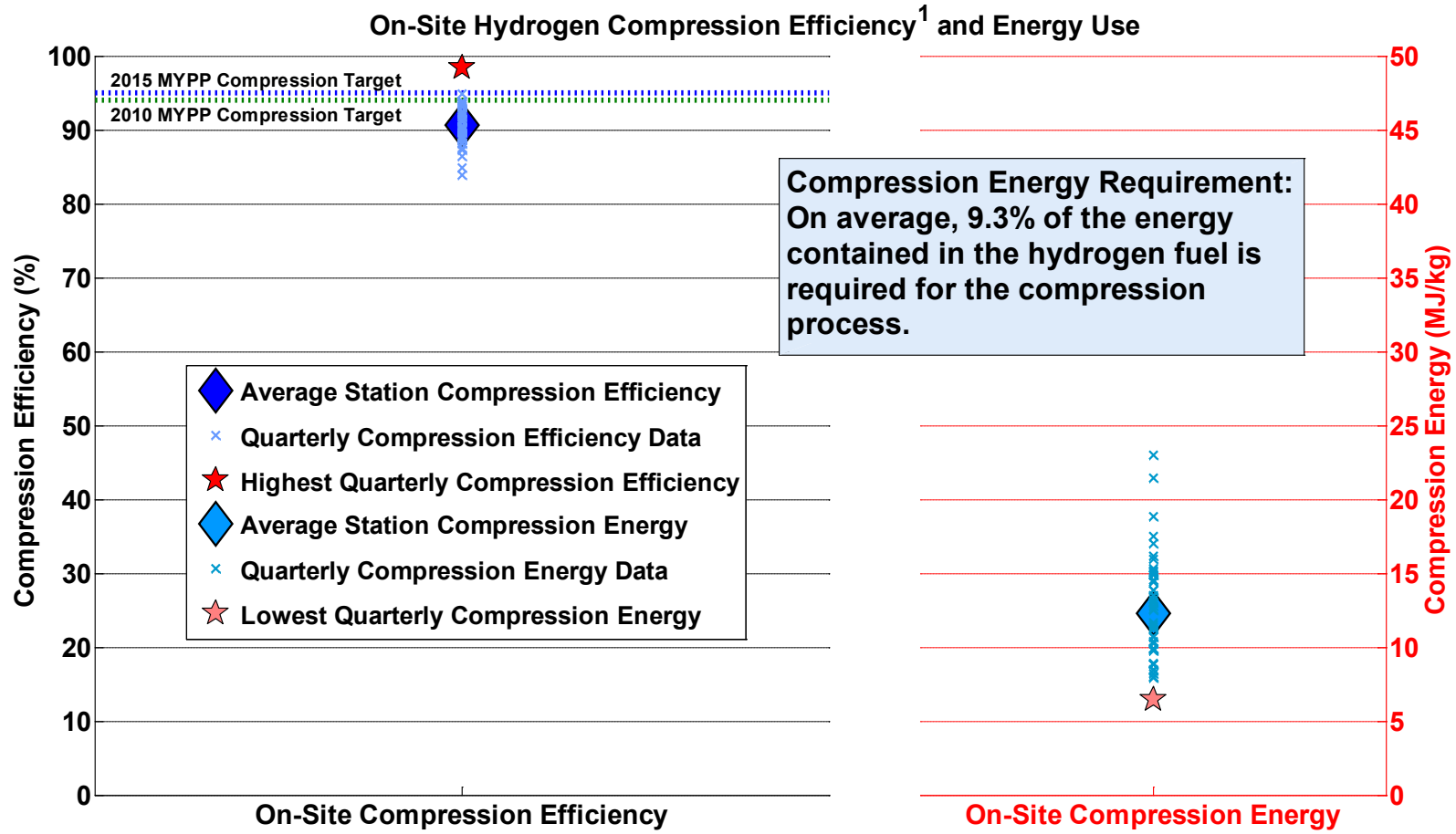
1) 100% production utilization assumes operation 24 hrs a day, 7 days a week

2) Production conversion efficiency is defined as the energy of the hydrogen out of the process (on a LHV basis) divided by the sum of the energy into the production process from the feedstock and all other energy as needed. Conversion efficiency does not include energy used for compression, storage, and dispensing.

3) High correlation with electrolysis data ( $R^2 = 0.87$ ) & low correlation with natural gas data ( $R^2 = 0.018$ )

Created: Mar-02-09 9:09 AM

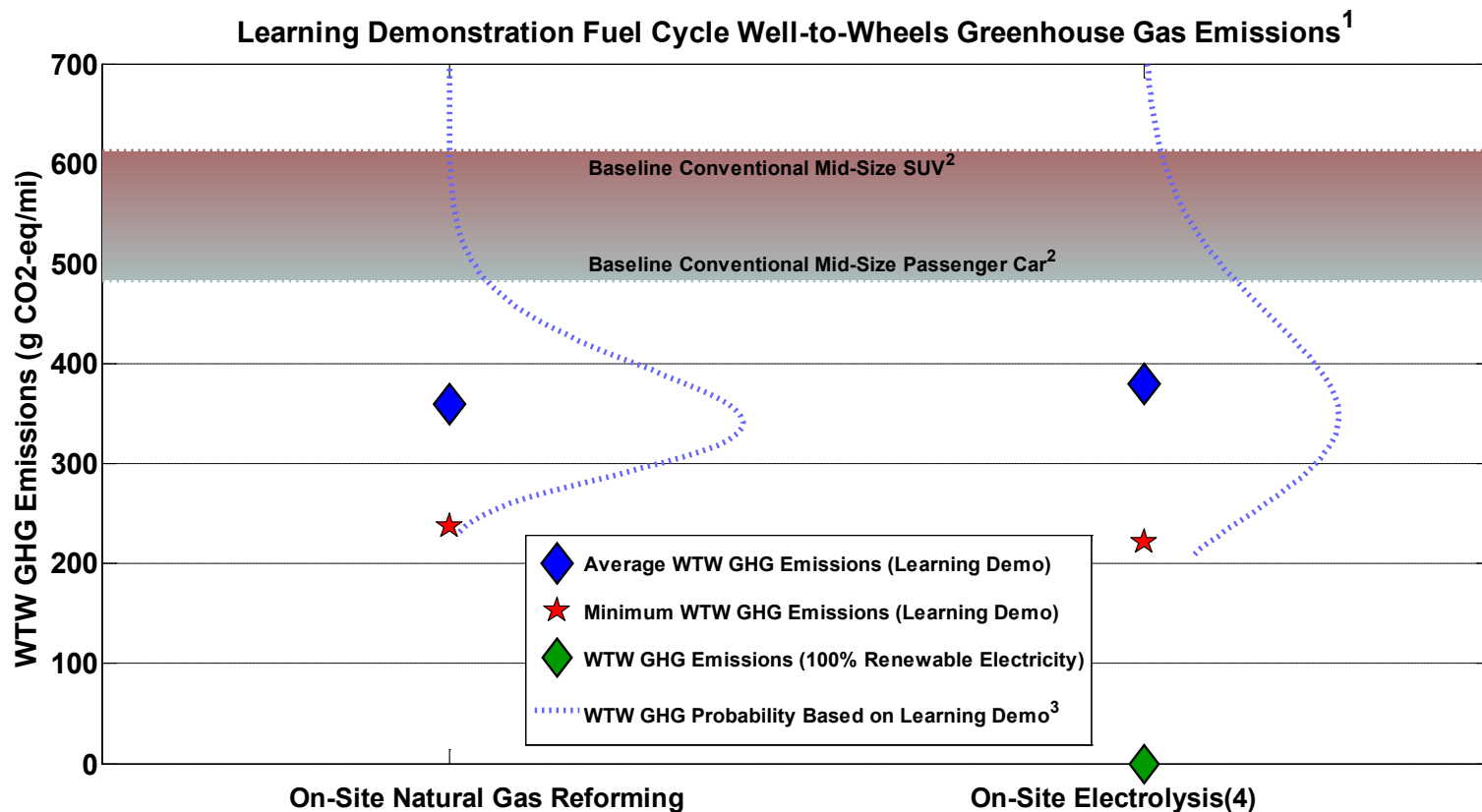
# CDP#61: Refueling Station Compressor Efficiency



<sup>1</sup>Consistent with the MYPP, compression efficiency is defined as the energy of the hydrogen out of the process (on an LHV basis) divided by the sum of the energy of the hydrogen output plus all other energy needed for the compression process. Data shown for on-site hydrogen production and storage facilities only, not delivered hydrogen sites.

Created: Mar-02-09 8:35 AM

# CDP#62: Learning Demonstration Vehicle Greenhouse Gas Emissions



1. Well-to-Wheels greenhouse gas emissions based on DOE's GREET model, version 1.8b. Analysis uses default GREET values except for FCV fuel economy, hydrogen production conversion efficiency, and electricity grid mix. Fuel economy values are the Gen 1 and Gen 2 window-sticker fuel economy data for all teams (as used in CDP #6); conversion efficiency values are the production efficiency data used in CDP #13.

2. Baseline conventional passenger car and light duty truck GHG emissions are determined by GREET 1.8b, based on the EPA window-sticker fuel economy of a conventional gasoline mid-size passenger car and mid-size SUV, respectively. The Learning Demonstration fleet includes both passenger cars and SUVs.

3. The Well-to-Wheels GHG probability distribution represents the range and likelihood of GHG emissions resulting from the hydrogen FCV fleet based on window-sticker fuel economy data and monthly conversion efficiency data from the Learning Demonstration.

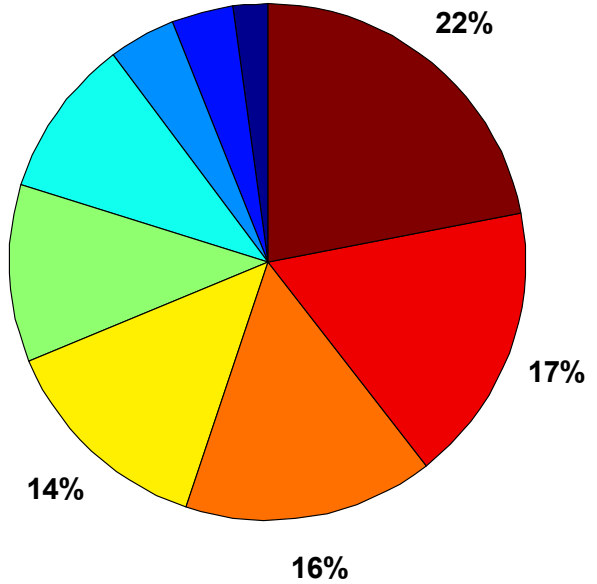
4. On-site electrolysis GHG emissions are based on the average mix of electricity production used by the Learning Demonstration production sites, which includes both grid-based electricity and renewable on-site solar electricity. GHG emissions associated with on-site production of hydrogen from electrolysis are highly dependent on electricity source. GHG emissions from a 100% renewable electricity mix would be zero, as shown. If electricity were supplied from the U.S. average grid mix, average GHG emissions would be 1241 g/mile.

Created: Feb-26-09 11:32 AM

# CDP#63: Hydrogen Fueling Station Maintenance by System

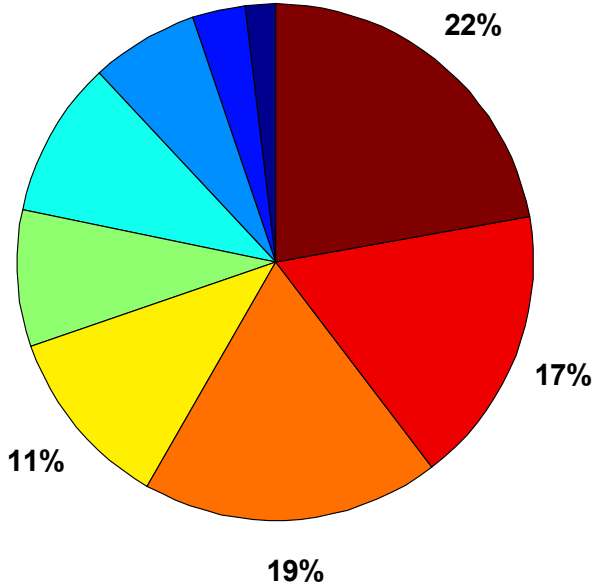
Hydrogen Fueling Station Maintenance

By Number of Events  
Total Number of Events = 1860



- system control & safety
- compressor
- electrolyzer
- reformer
- dispenser
- other
- electrical
- valves & piping
- storage

By Labor Hours  
Total Hours = 9093



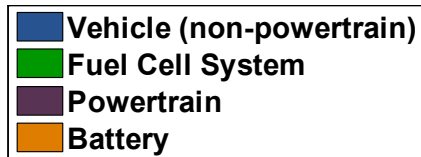
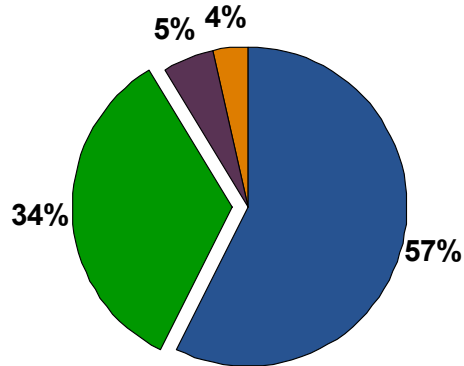
Created: Mar-03-09 3:50 PM



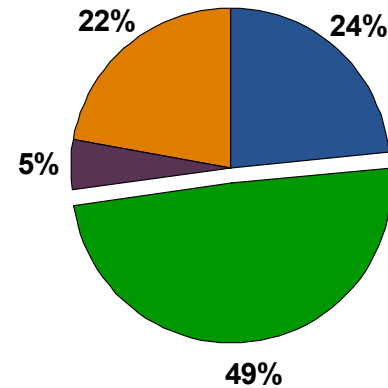
# CDP#64: Fuel Cell Vehicle Maintenance by System

## Fuel Cell Vehicle Maintenance Events and Labor Hours

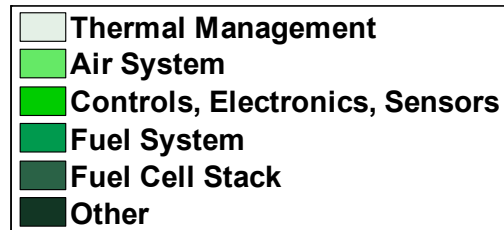
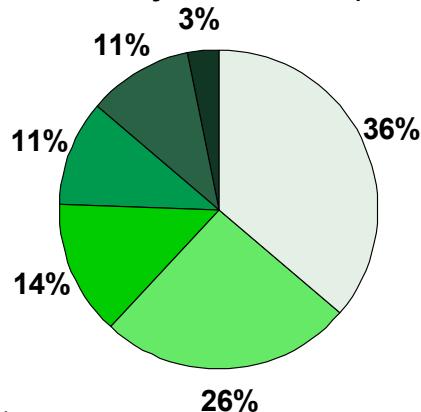
Fuel Cell Vehicle Events (9357)



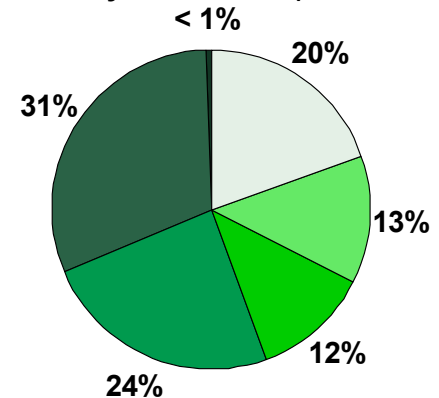
Fuel Cell Vehicle Labor (10216 hours)



Fuel Cell System Events (3175)



Fuel Cell System Labor (5035 hours)



Created: Mar-09-09 3:16 PM

# REPORT DOCUMENTATION PAGE

*Form Approved*  
*OMB No. 0704-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.**

<b>1. REPORT DATE (DD-MM-YYYY)</b> March 2009			<b>2. REPORT TYPE</b> Technical Report		<b>3. DATES COVERED (From - To)</b>	
<b>4. TITLE AND SUBTITLE</b> Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project: Spring 2009				<b>5a. CONTRACT NUMBER</b> DE-AC36-08-GO28308		
				<b>5b. GRANT NUMBER</b>		
				<b>5c. PROGRAM ELEMENT NUMBER</b>		
<b>6. AUTHOR(S)</b> K. Wipke, S. Sprik, J. Kurtz, and T. Ramsden				<b>5d. PROJECT NUMBER</b> NREL/TP-560-45451		
				<b>5e. TASK NUMBER</b> FC087810		
				<b>5f. WORK UNIT NUMBER</b>		
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b> NREL/TP-560-45451		
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b> NREL		
				<b>11. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>		
<b>12. DISTRIBUTION AVAILABILITY STATEMENT</b> National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161						
<b>13. SUPPLEMENTARY NOTES</b>						
<b>14. ABSTRACT (Maximum 200 Words)</b> Graphs of composite data products produced by DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation project through March 2009.						
<b>15. SUBJECT TERMS</b> hydrogen; hydrogen demonstration; hydrogen validation						
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  UL	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>	
<b>a. REPORT</b> Unclassified	<b>b. ABSTRACT</b> Unclassified	<b>c. THIS PAGE</b> Unclassified			<b>19b. TELEPHONE NUMBER (Include area code)</b>	

**Standard Form 298** (Rev. 8/98)  
Prescribed by ANSI Std. Z39.18