National Renewable Energy Laboratory
Innovation for Our Energy Future
A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

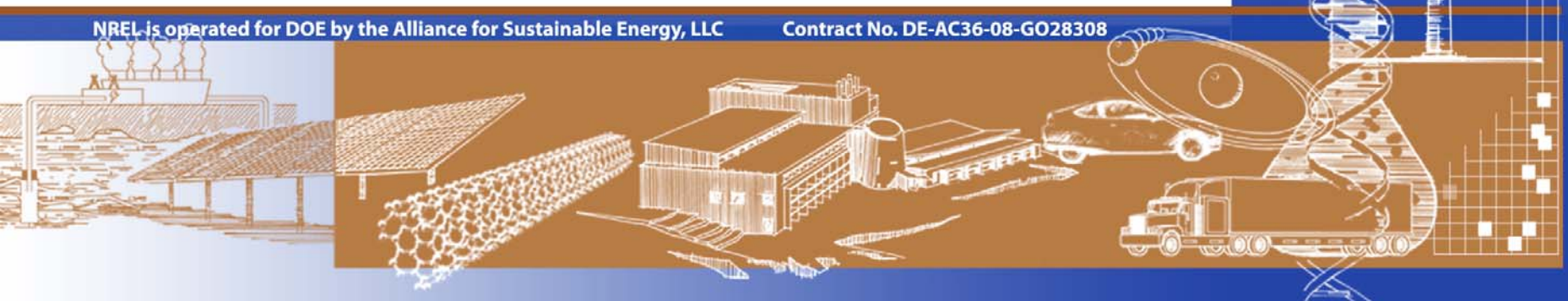
Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Fall 2008

Composite Data Products
Final Version September 24, 2008

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

Technical Report
NREL/TP-560-44256
October 2008



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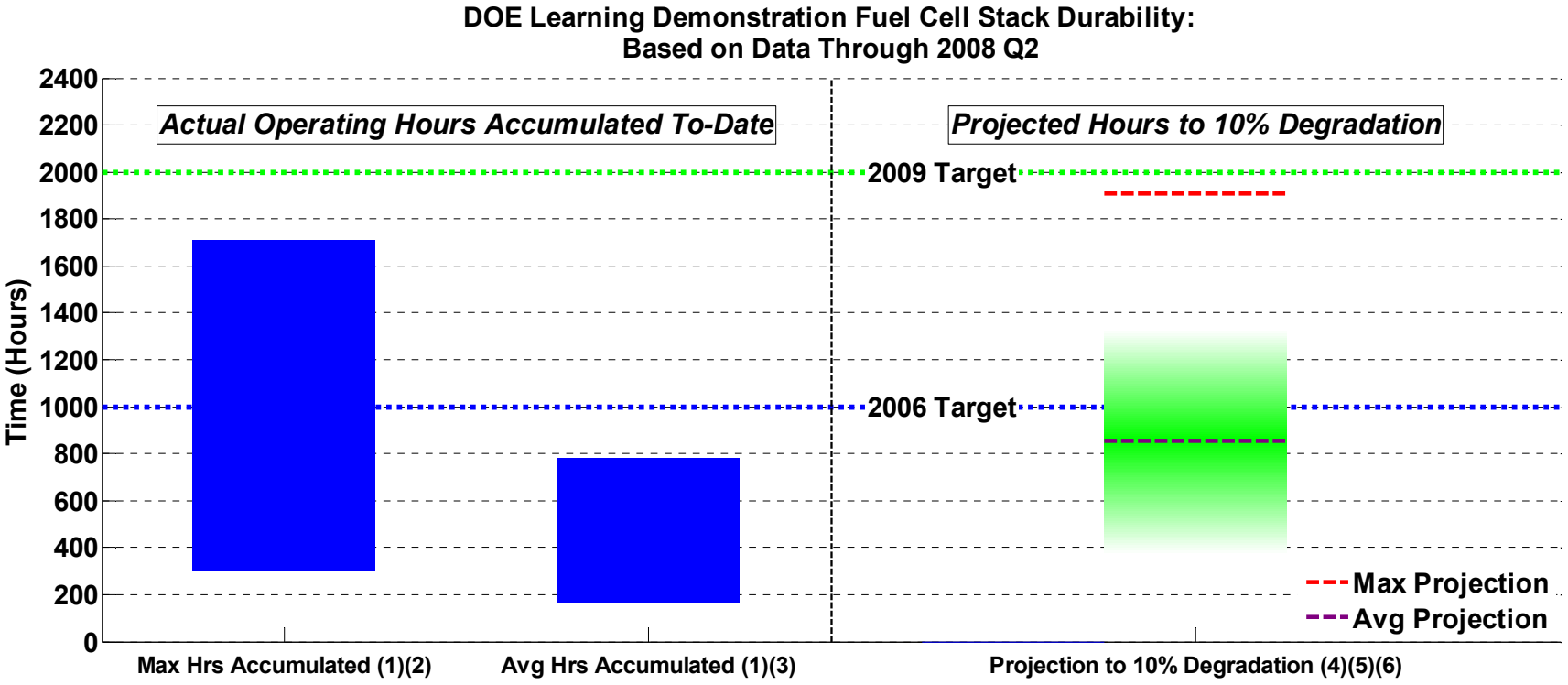
CDP#1: Hours Accumulated and Projected Hours to 10% Stack Voltage Degradation



(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.

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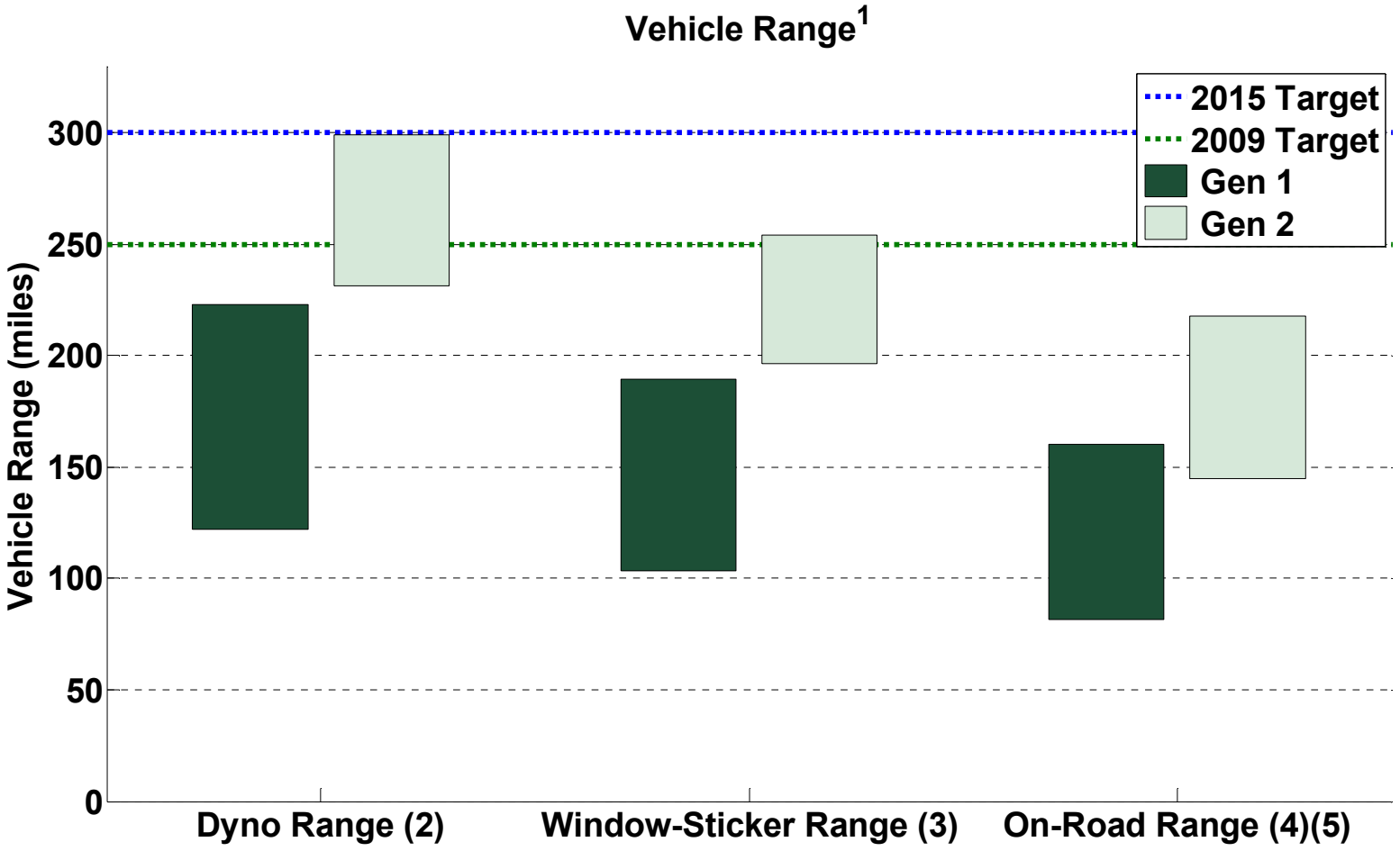
CDP#2: Vehicle Range



(1) Range is based on fuel economy and usable hydrogen on-board the vehicle. One data point for each make/model.
(2) Fuel economy from unadjusted combined City/Hwy per DRAFT SAE J2572.
(3) Fuel economy from EPA Adjusted combined City/Hwy (0.78 x Hwy, 0.9 x City).
(4) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(5) Fuel economy calculated from on-road fuel cell stack current or mass flow readings.

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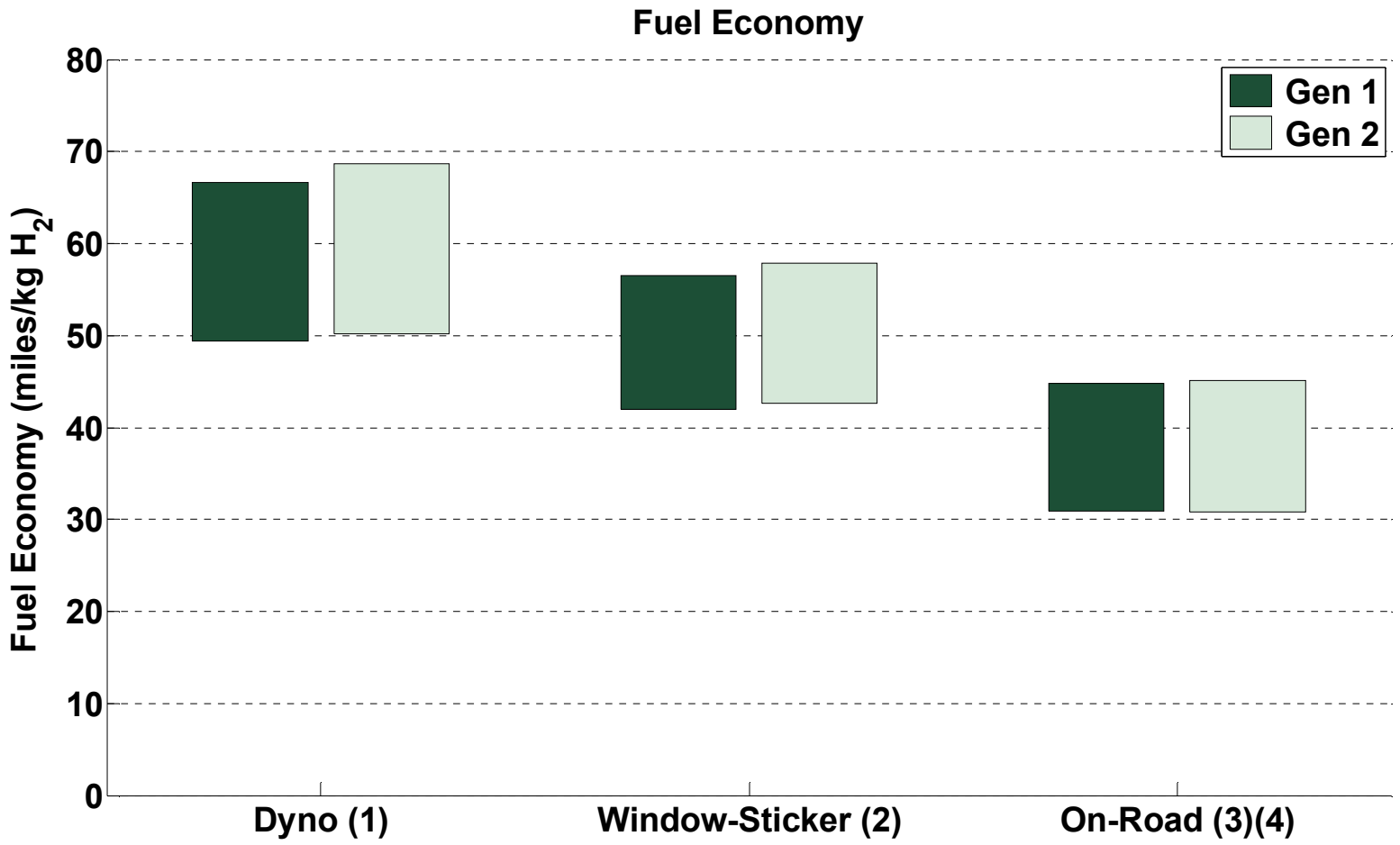
CDP#6: Fuel Economy



(1) One data point for each make/model. Combined City/Hwy fuel economy per DRAFT SAE J2572.
(2) Adjusted combined City/Hwy fuel economy (0.78 x Hwy, 0.9 x City).
(3) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(4) Calculated from on-road fuel cell stack current or mass flow readings.

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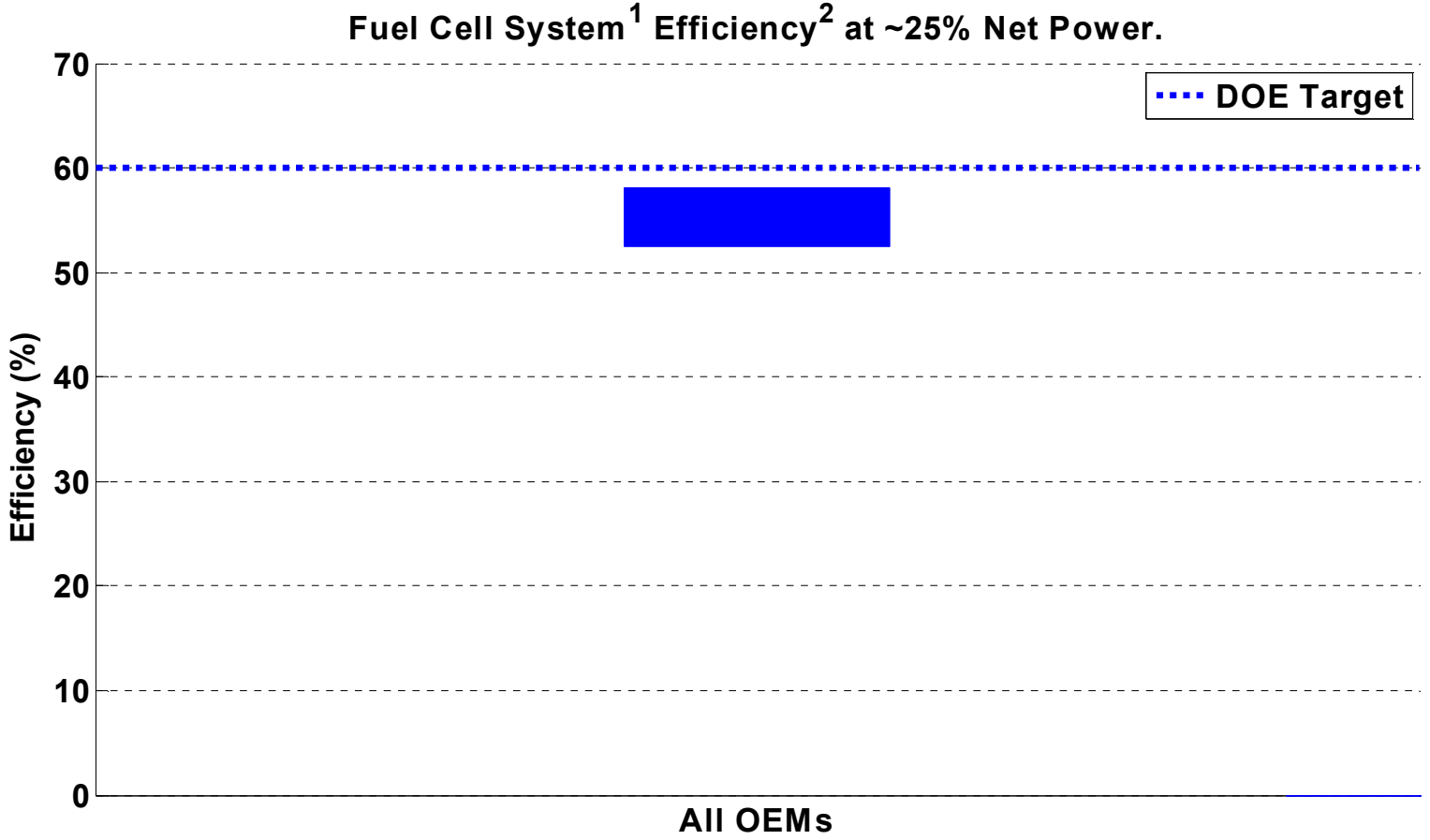
CDP#8: FC System Efficiency



[1] Gross stack power minus fuel cell system auxiliaries, per DRAFT SAEJ2615.

[2] Ratio of DC output energy to the lower heating value of the input fuel (hydrogen). Excludes power electronics and electric drive.

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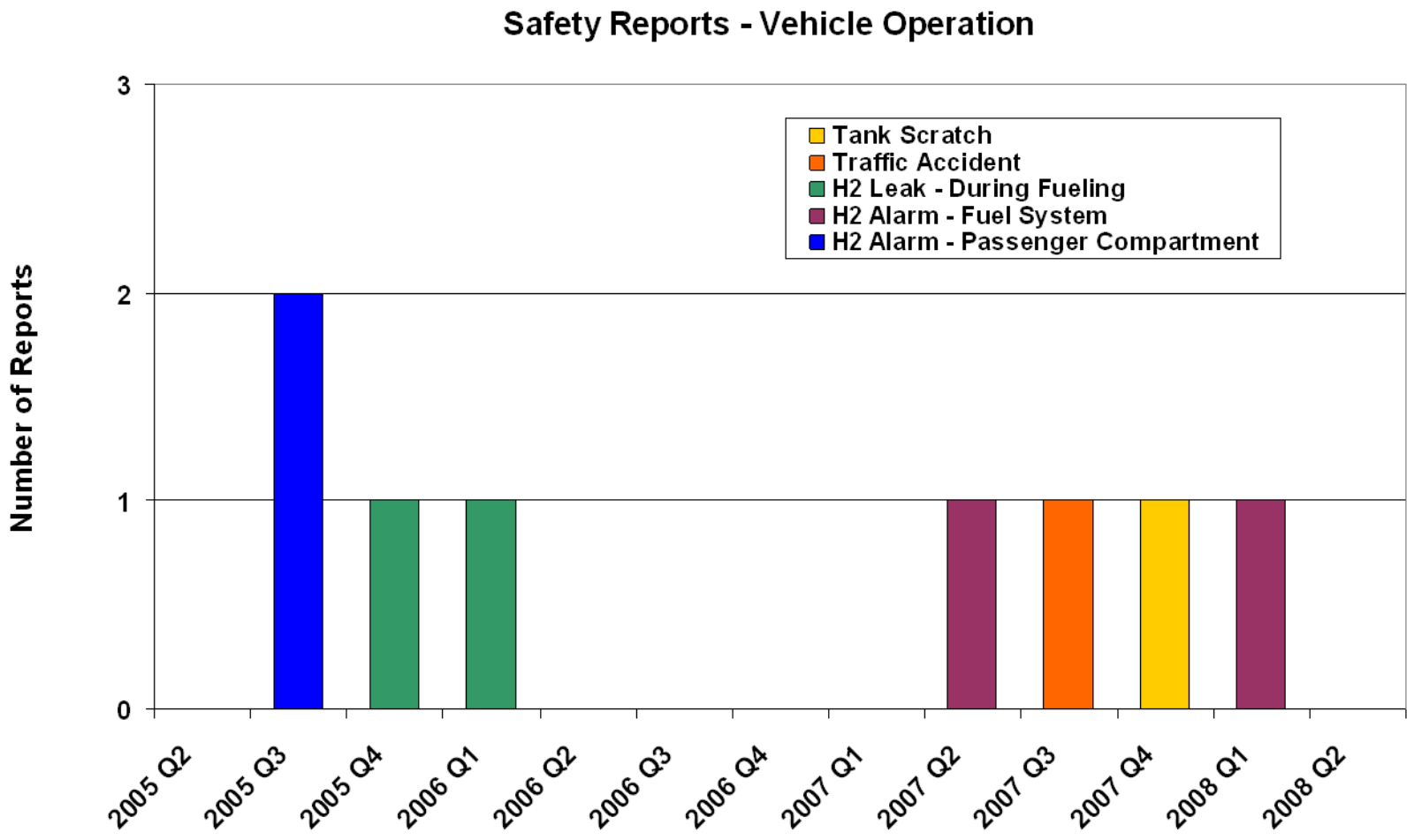
CDP#9: Safety Reports – Vehicles



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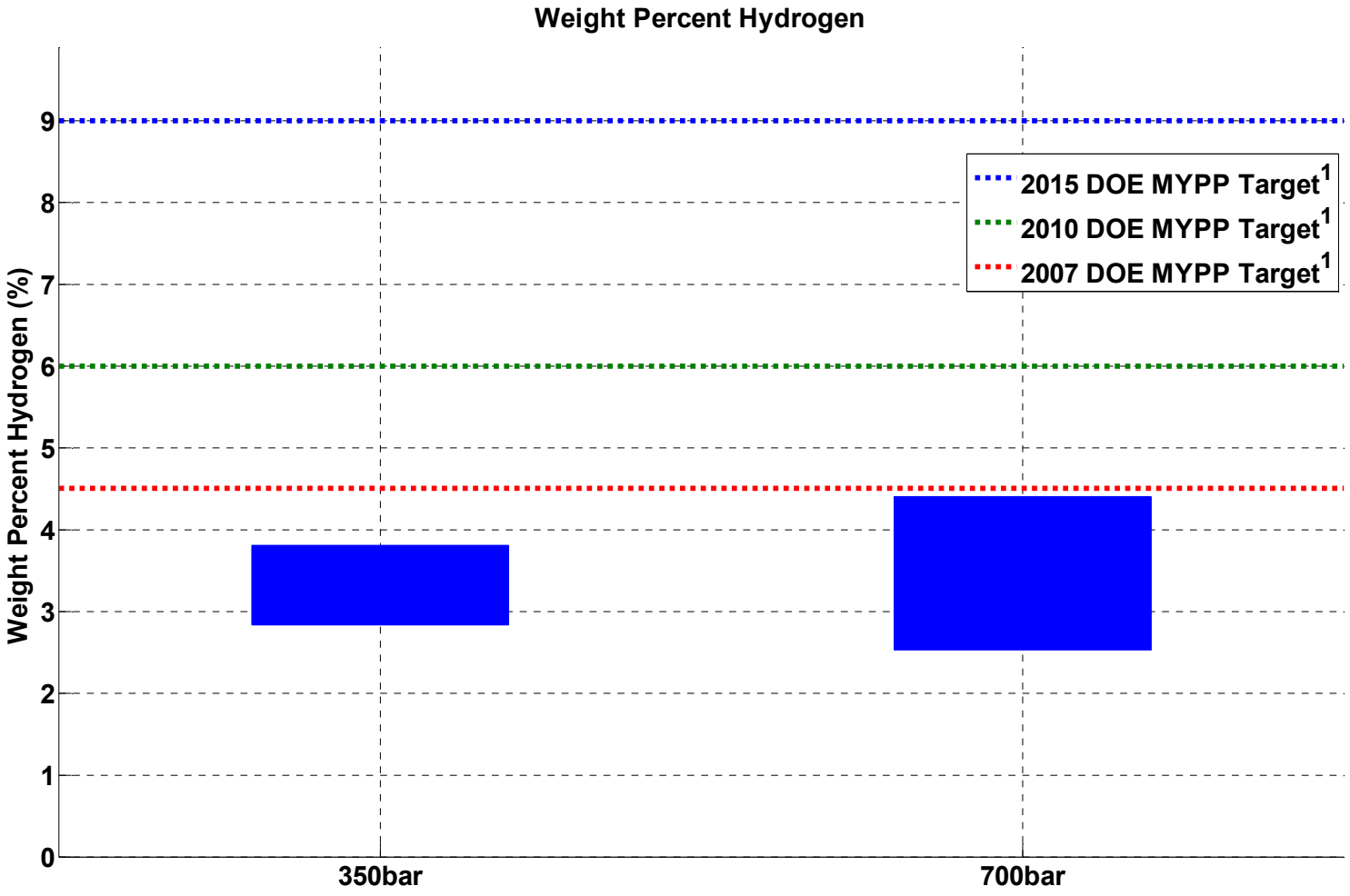
CDP#10: Storage Weight % Hydrogen



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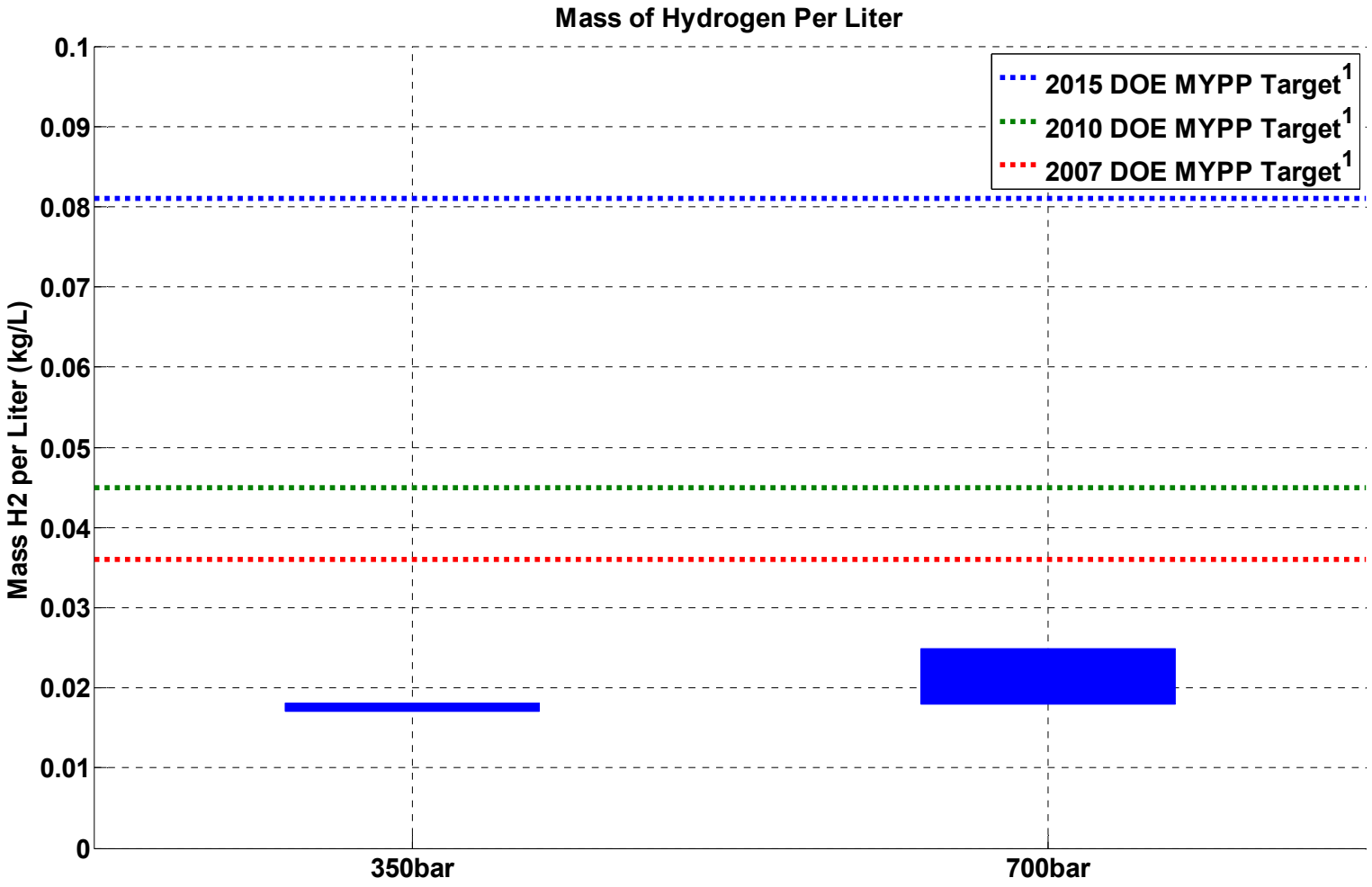
[1]Targets are set for advanced materials-based hydrogen storage technologies.

CDP#11: Volumetric Capacity of H2 Storage



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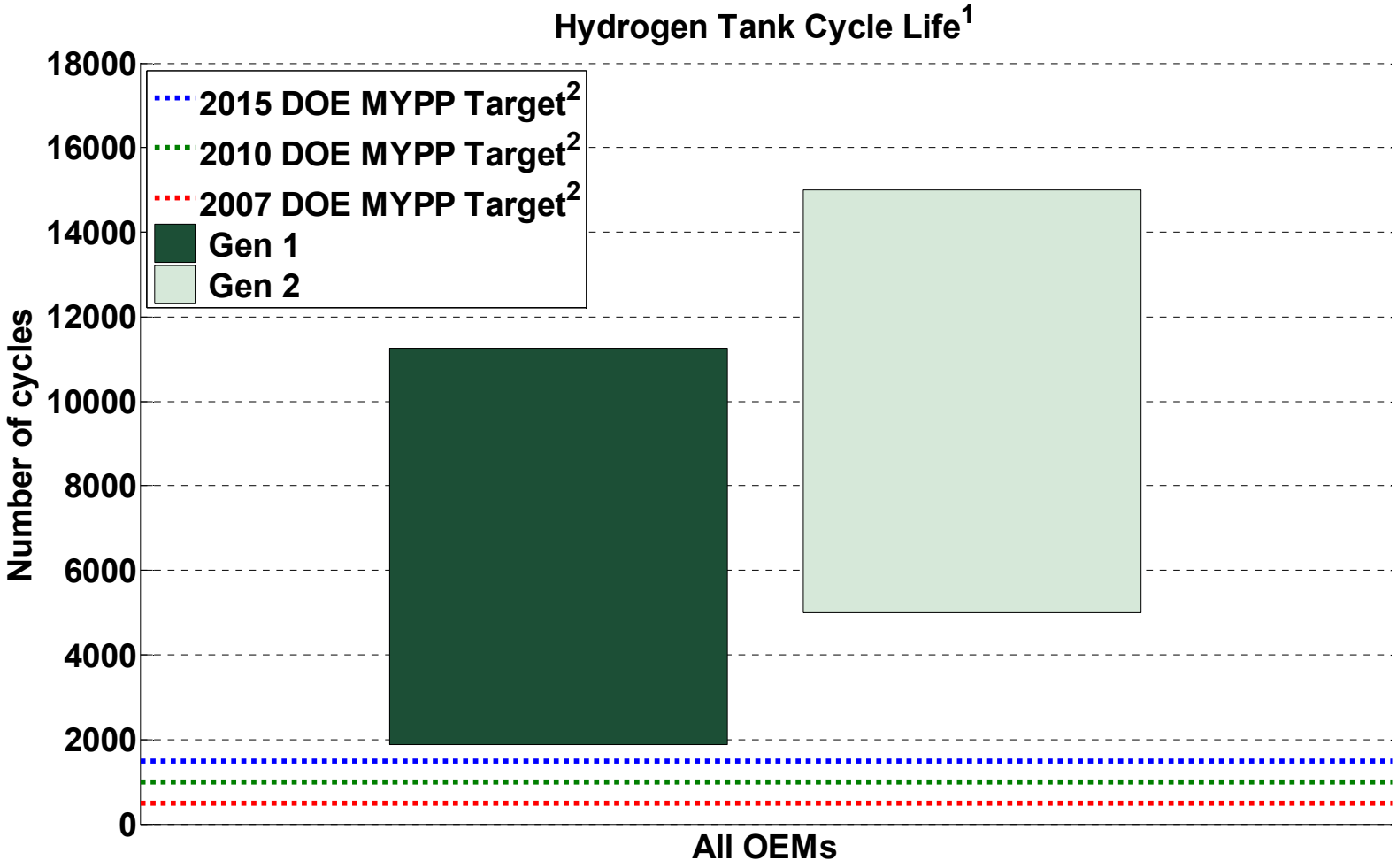
[1]Targets are set for advanced materials-based hydrogen storage technologies.

CDP#12: Vehicle Hydrogen Tank Cycle Life



[1]Data reported reference NGV2, HGV2, or EIHP standards.

[2]Some near-term targets have been achieved with compressed and liquid tanks. Emphasis is on advanced materials-based technologies.

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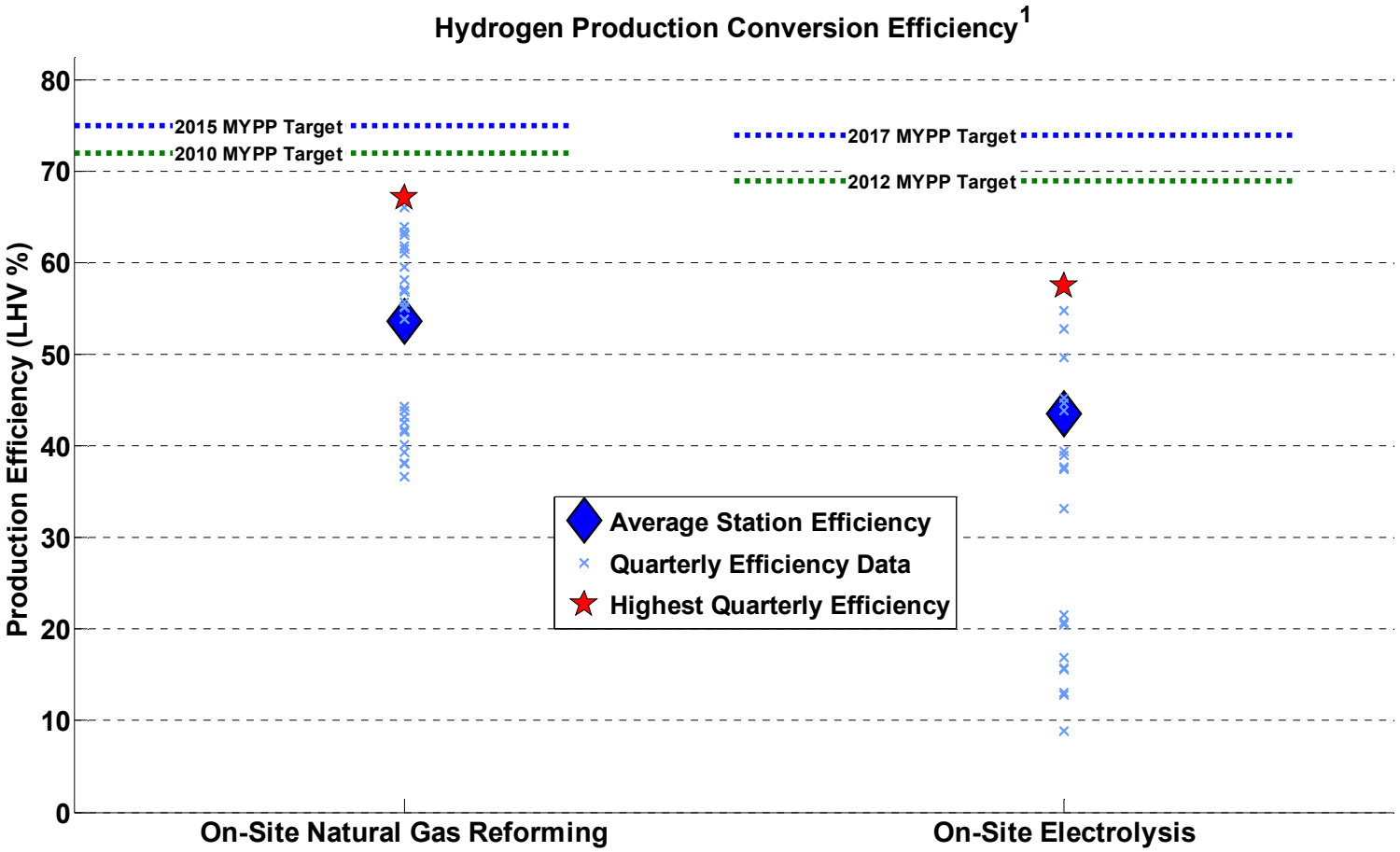
CDP#13: On-Site Hydrogen Production Efficiency



[1]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.

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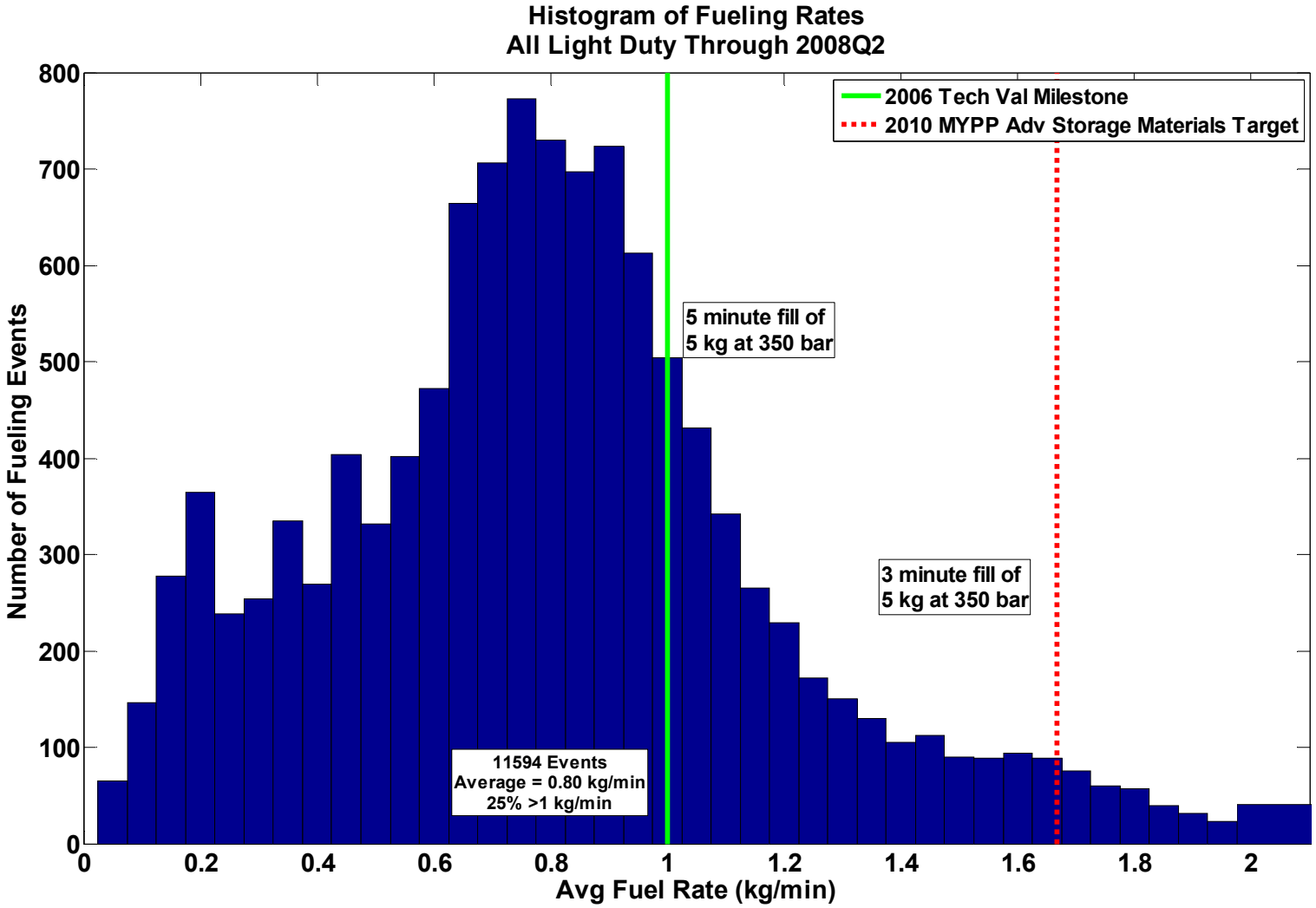
CDP#18: Refueling Rates



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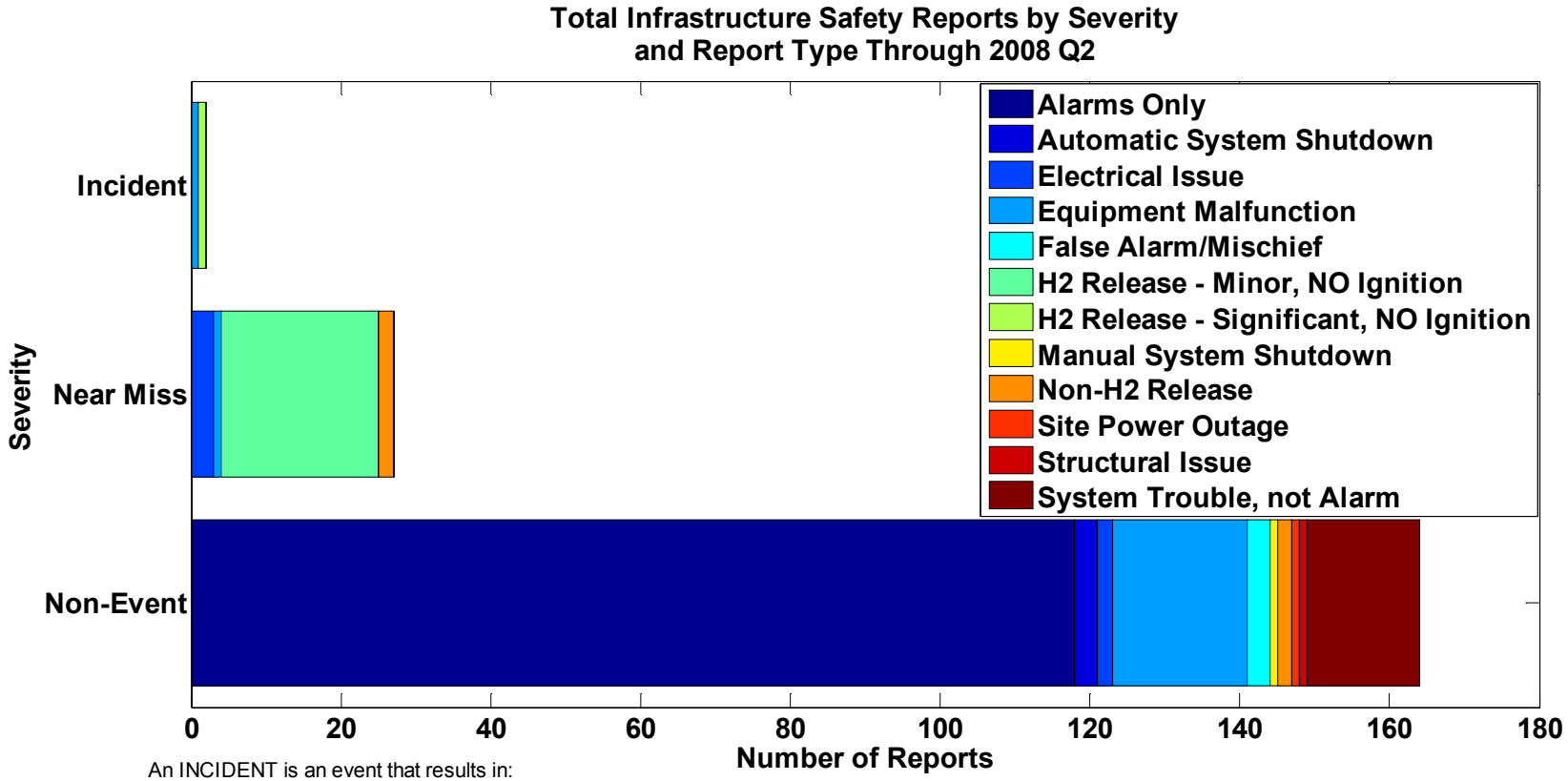
CDP#20: Safety Reports – Infrastructure



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

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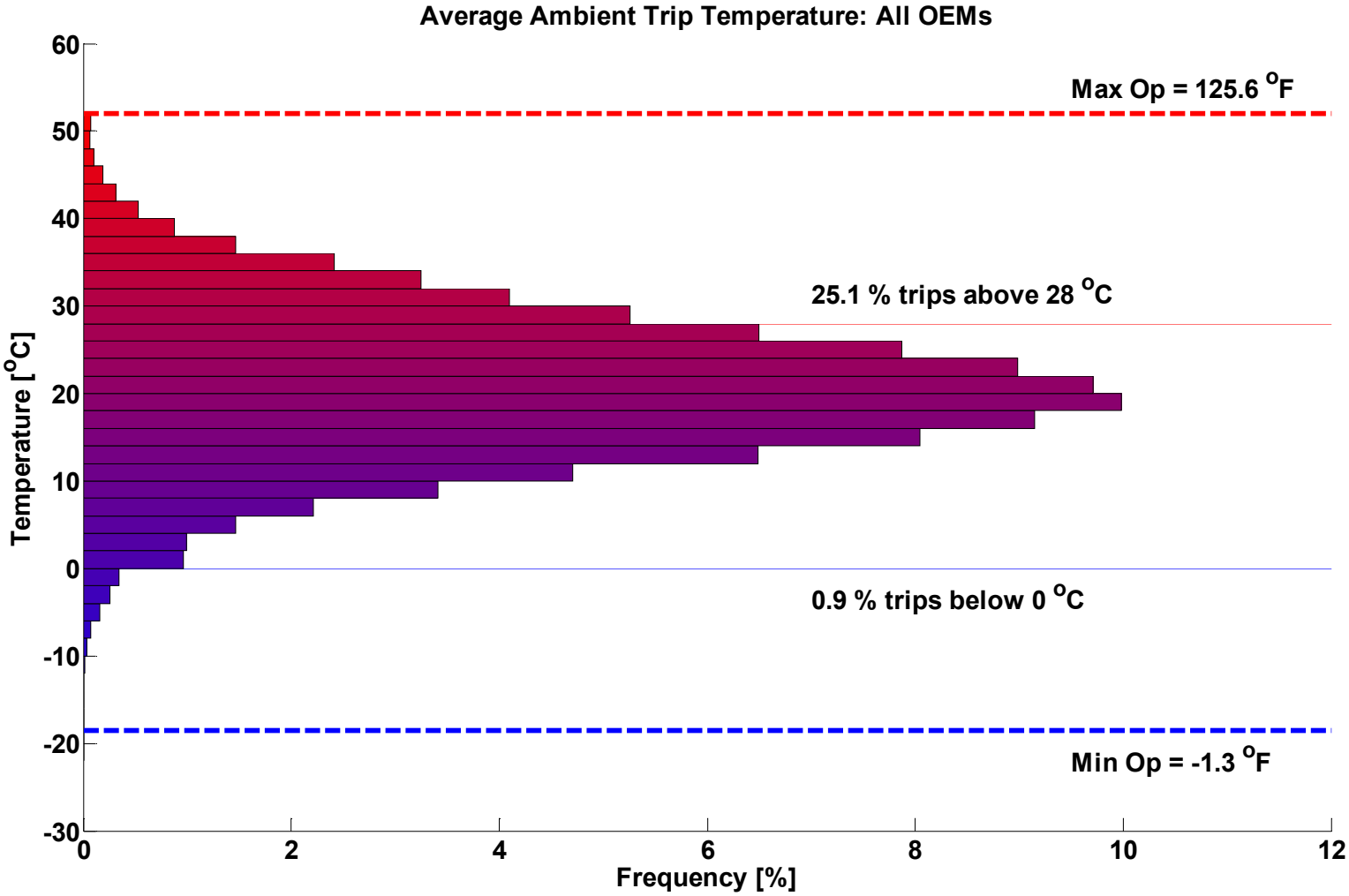
CDP#21: Range of Ambient Temperature During Vehicle Operation



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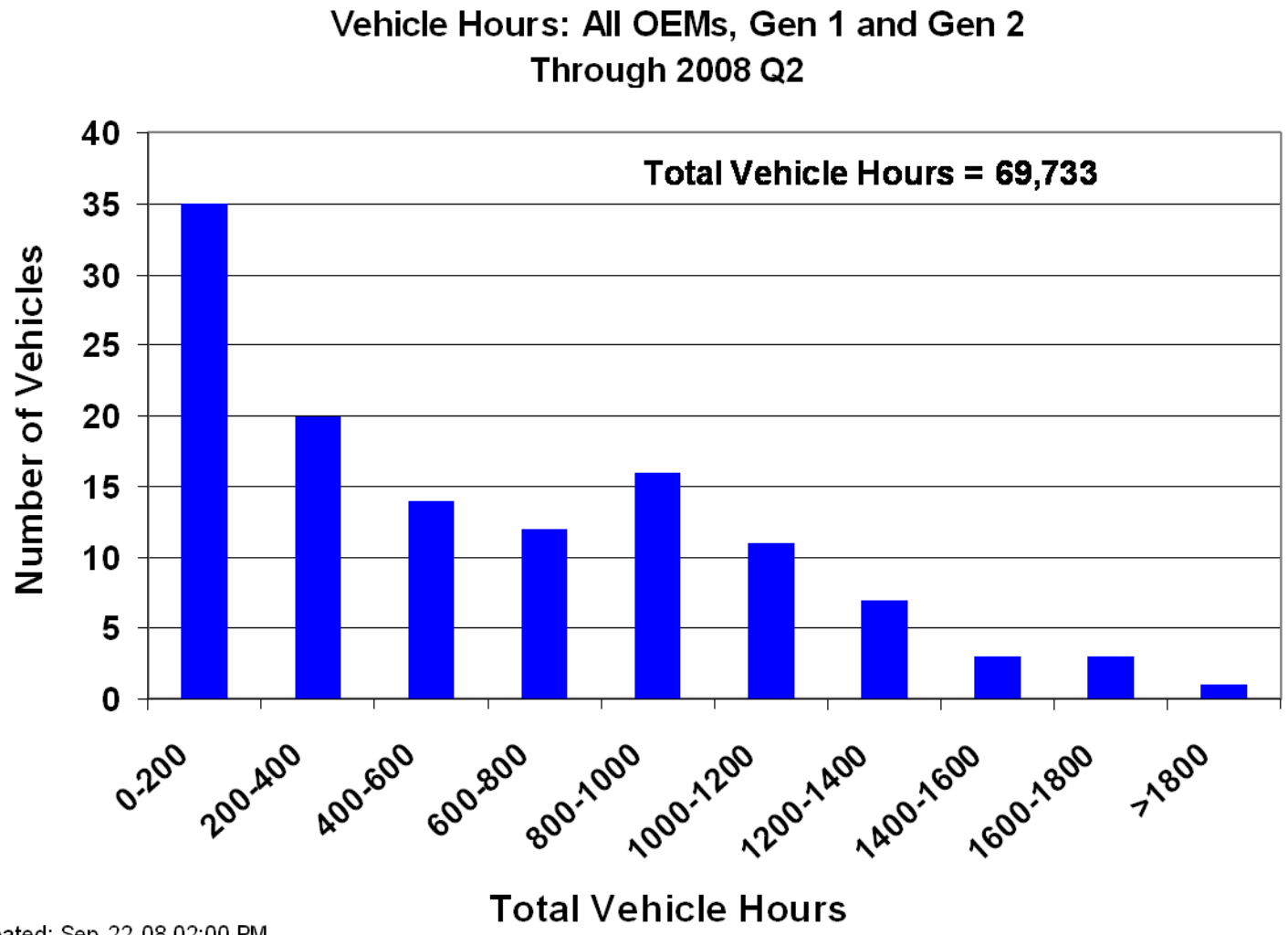
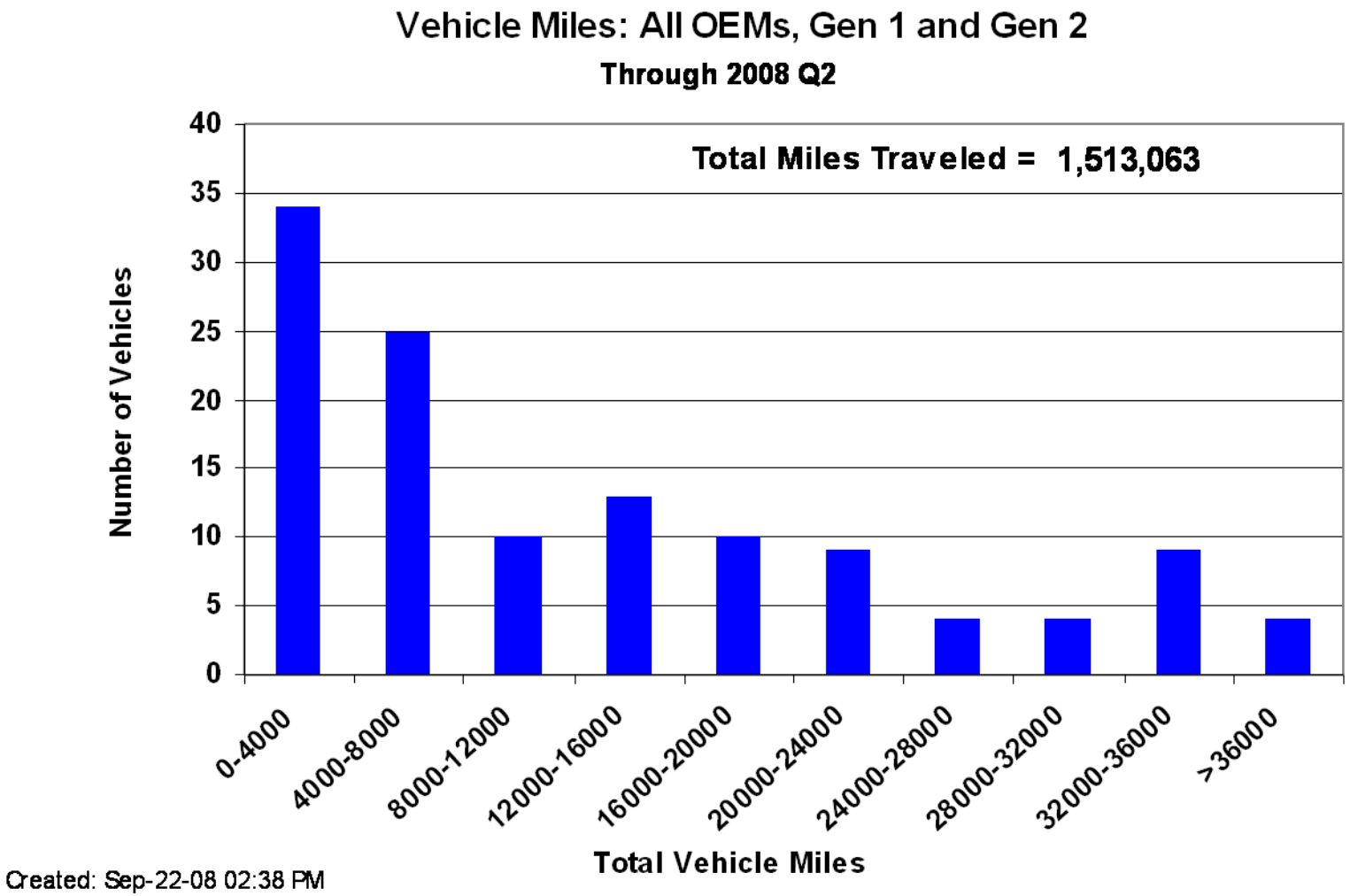
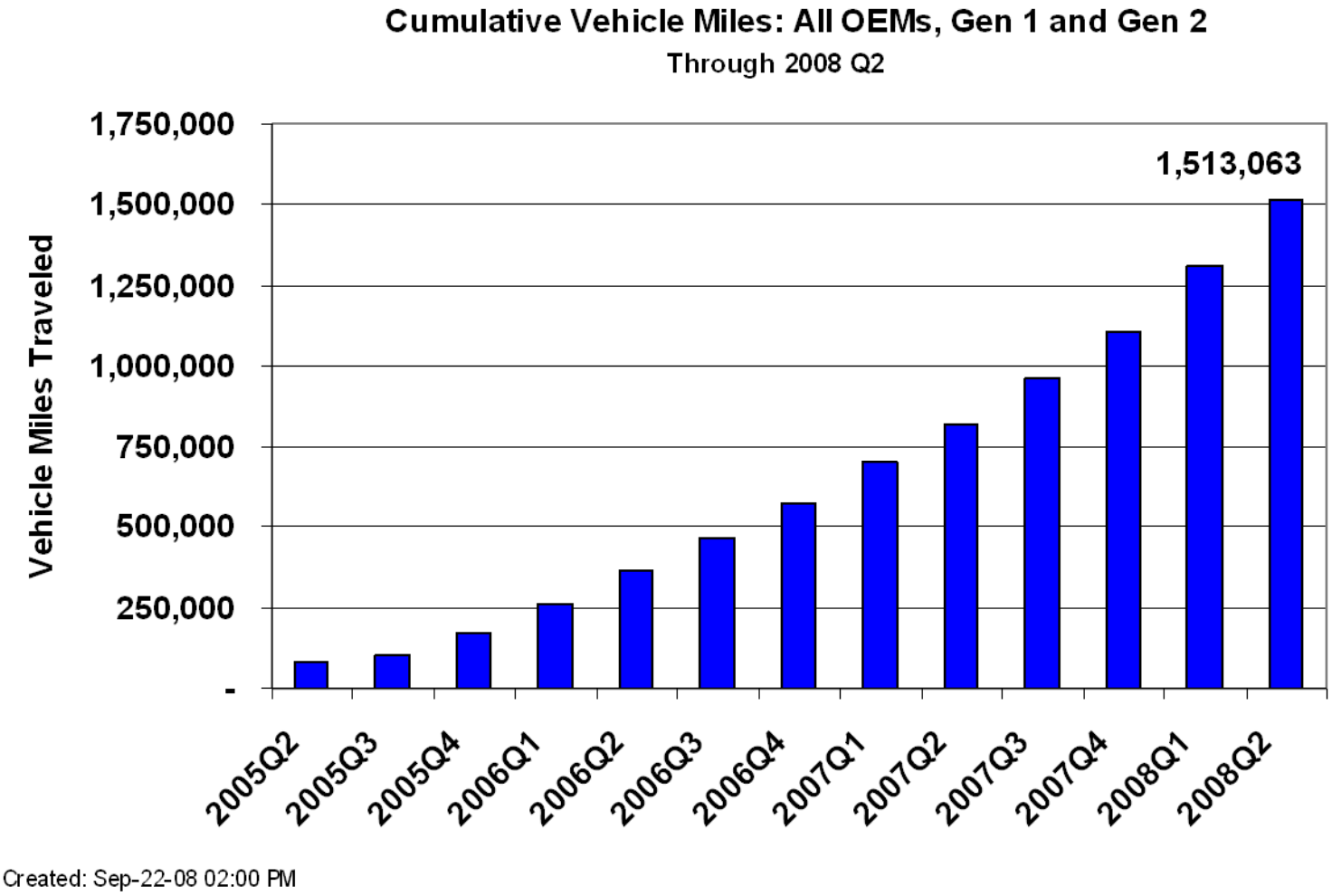
CDP#22: Vehicle Operating Hours



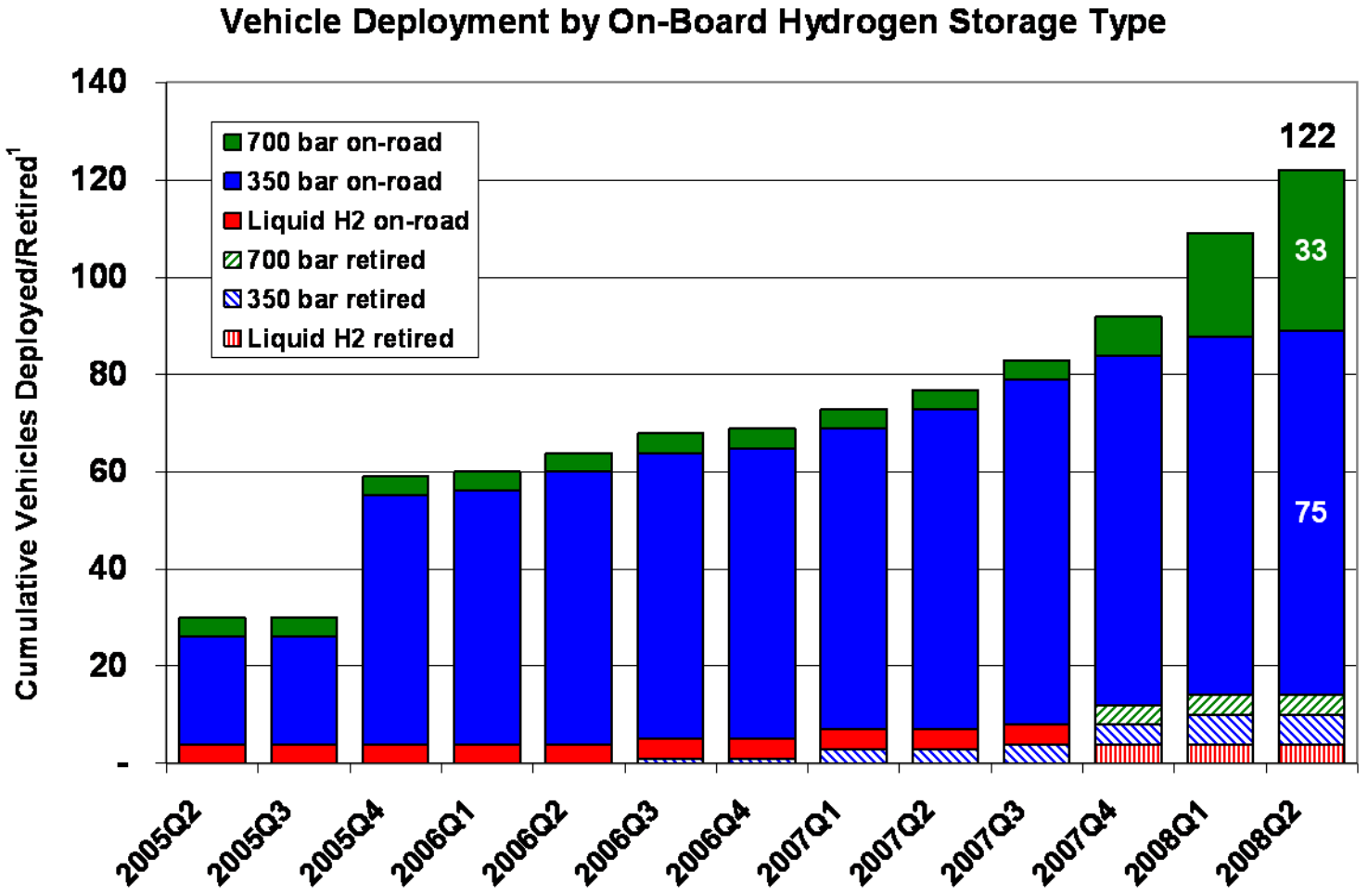
CDP#23: Vehicles vs. Miles Traveled



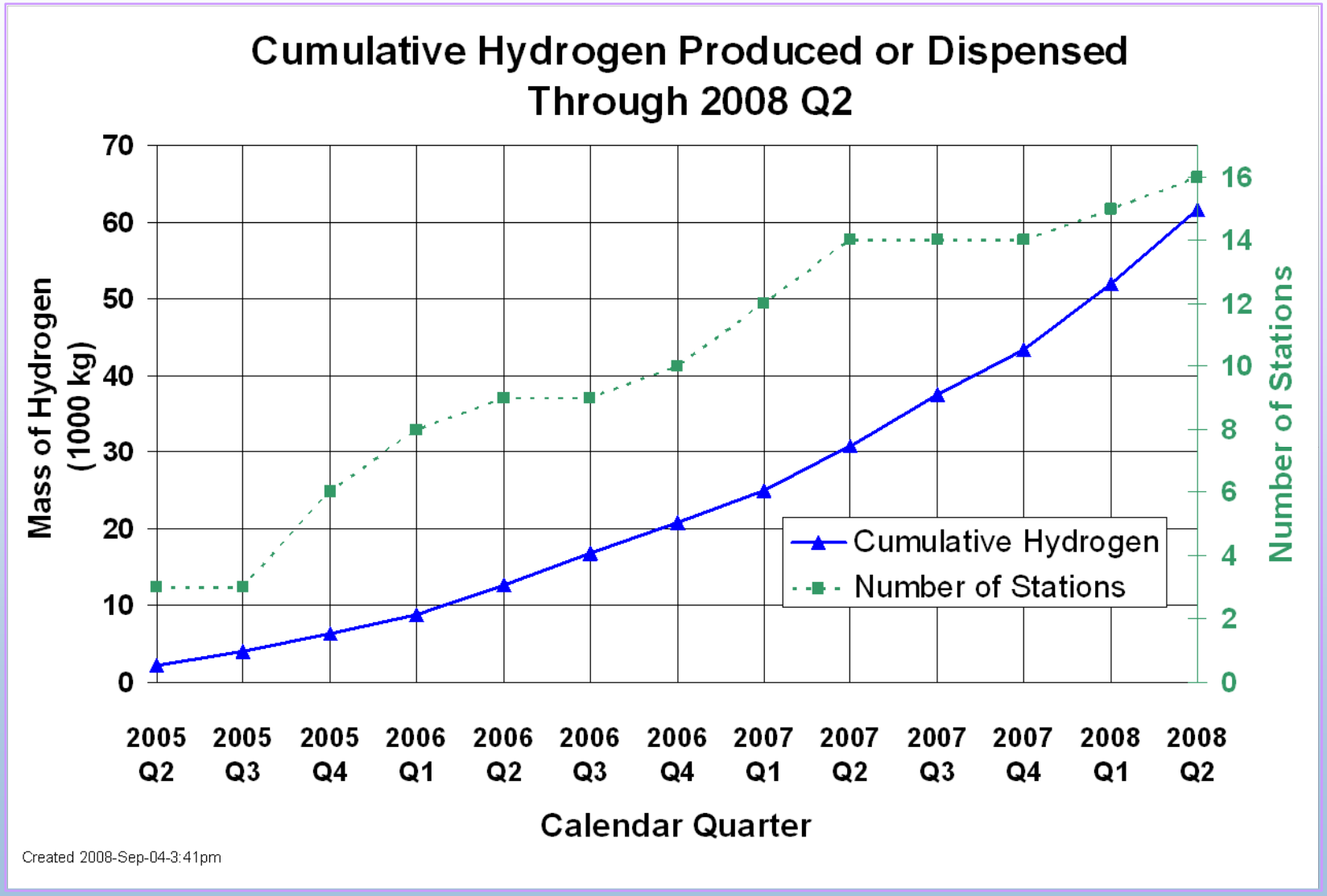
CDP#24: Cumulative Vehicle Miles Traveled



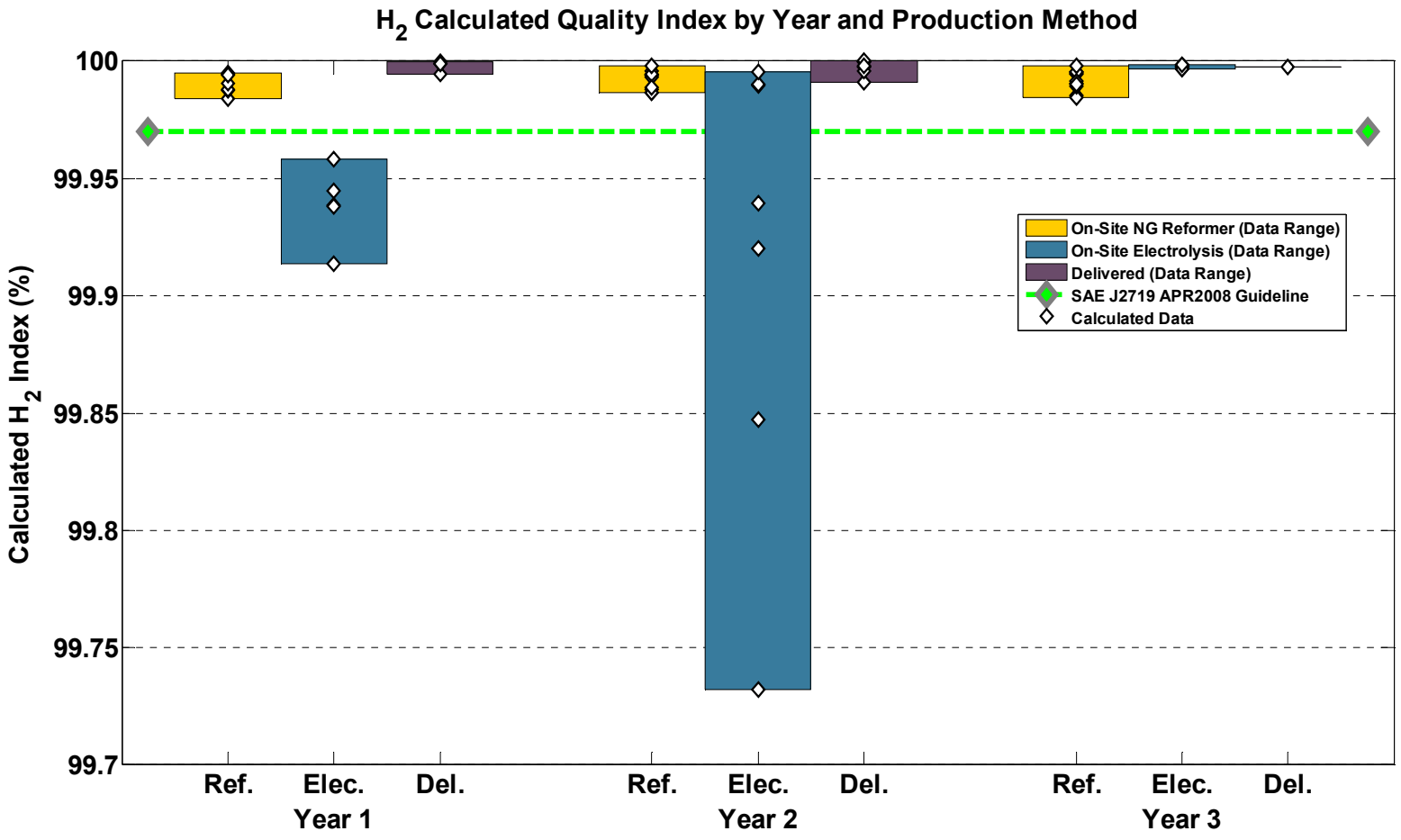
CDP#25: Vehicle H2 Storage Technologies



CDP#26: Cumulative H2 Produced or Dispensed



CDP#27: Hydrogen Quality Index



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

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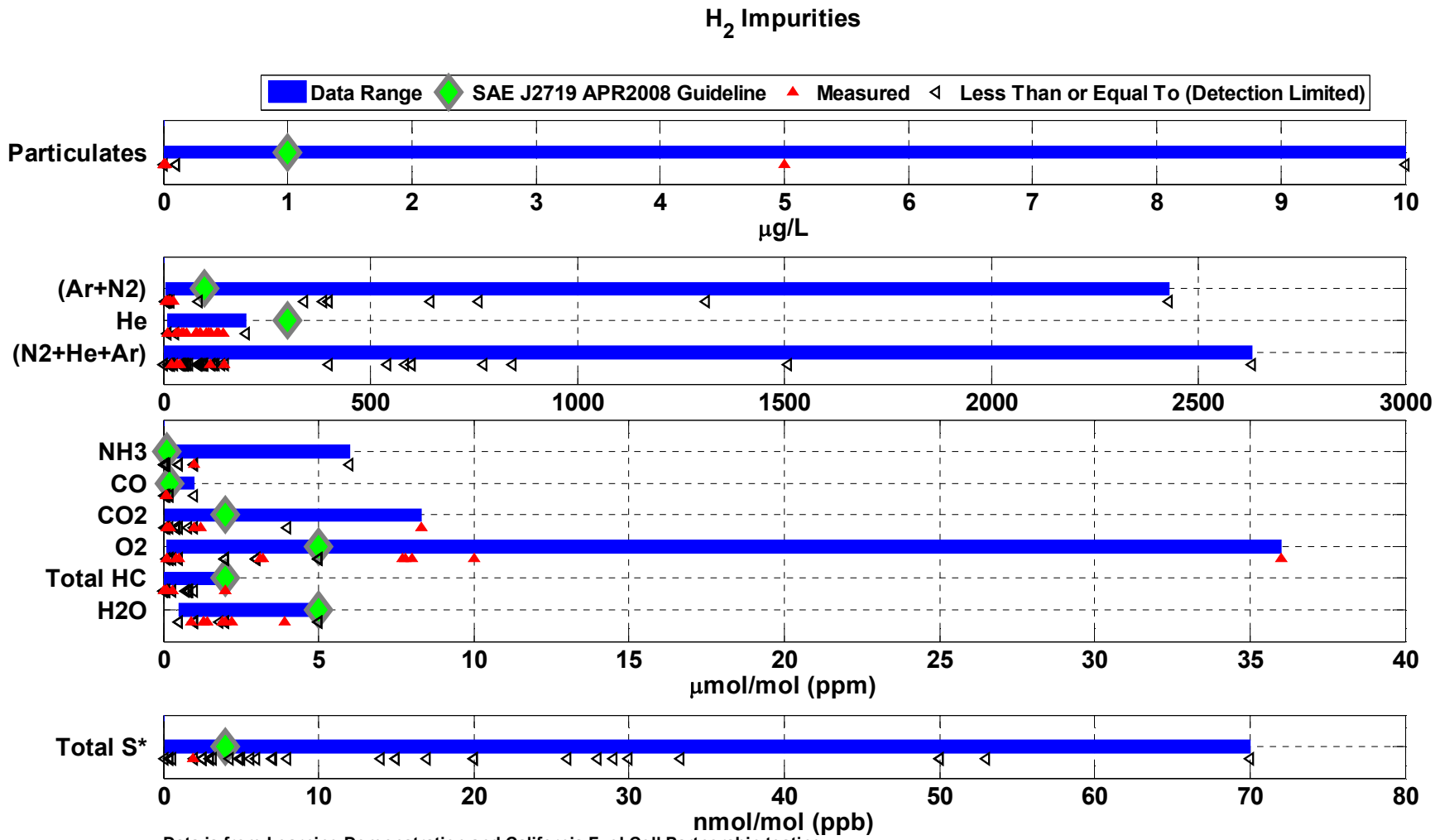
CDP #28: Hydrogen Impurities



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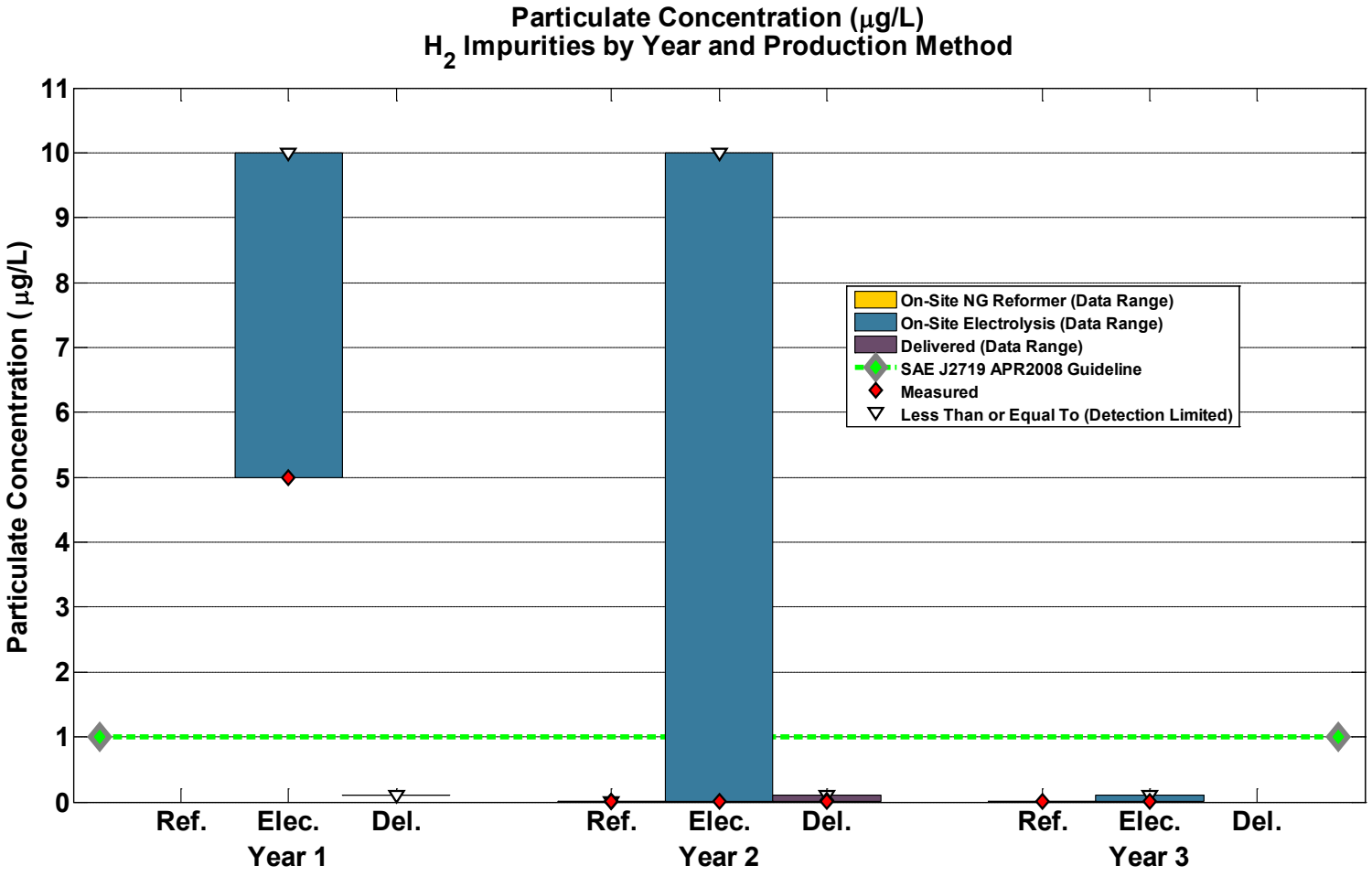
CDP#28 Supplemental: Hydrogen Impurities by Year and Production Method



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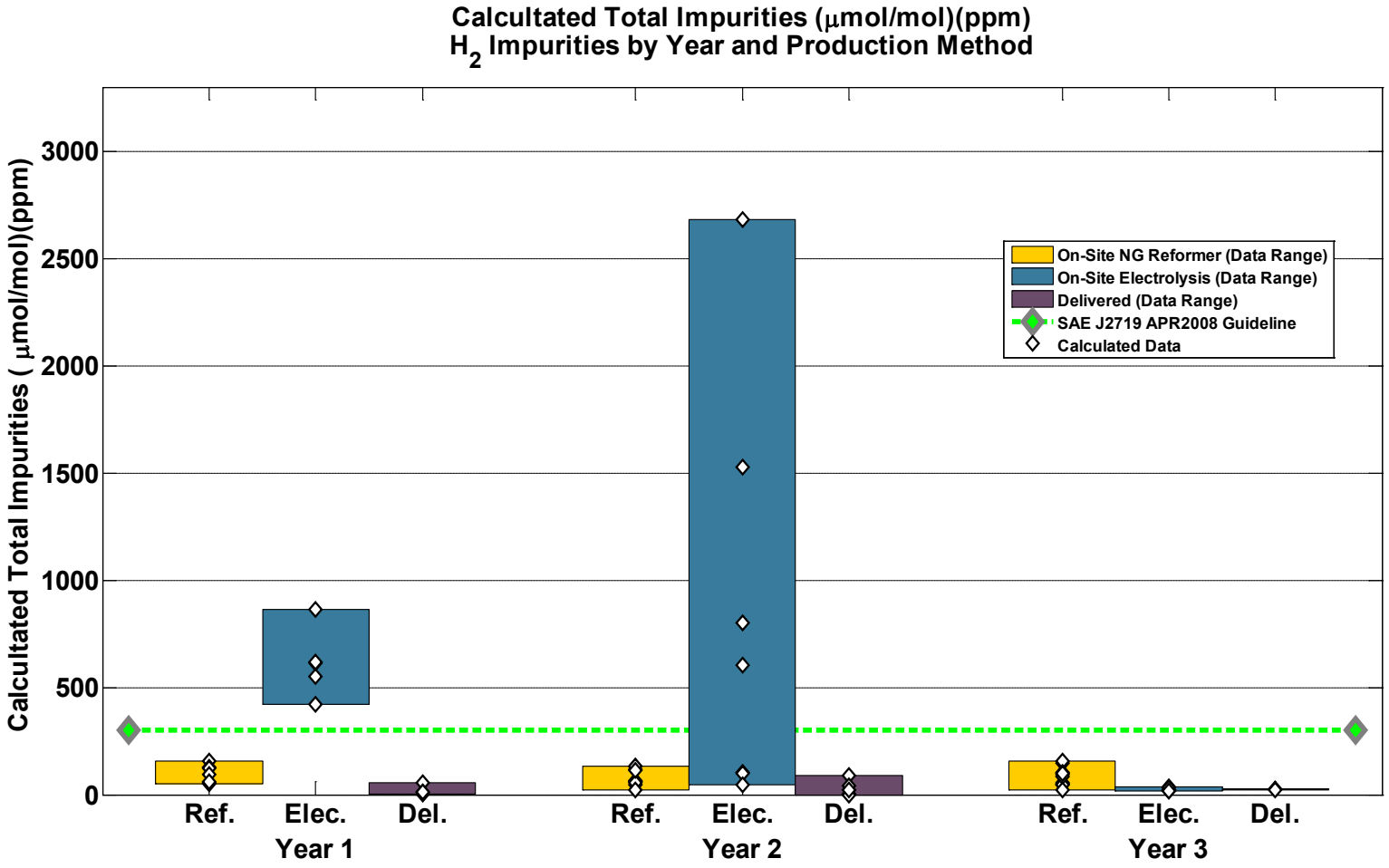

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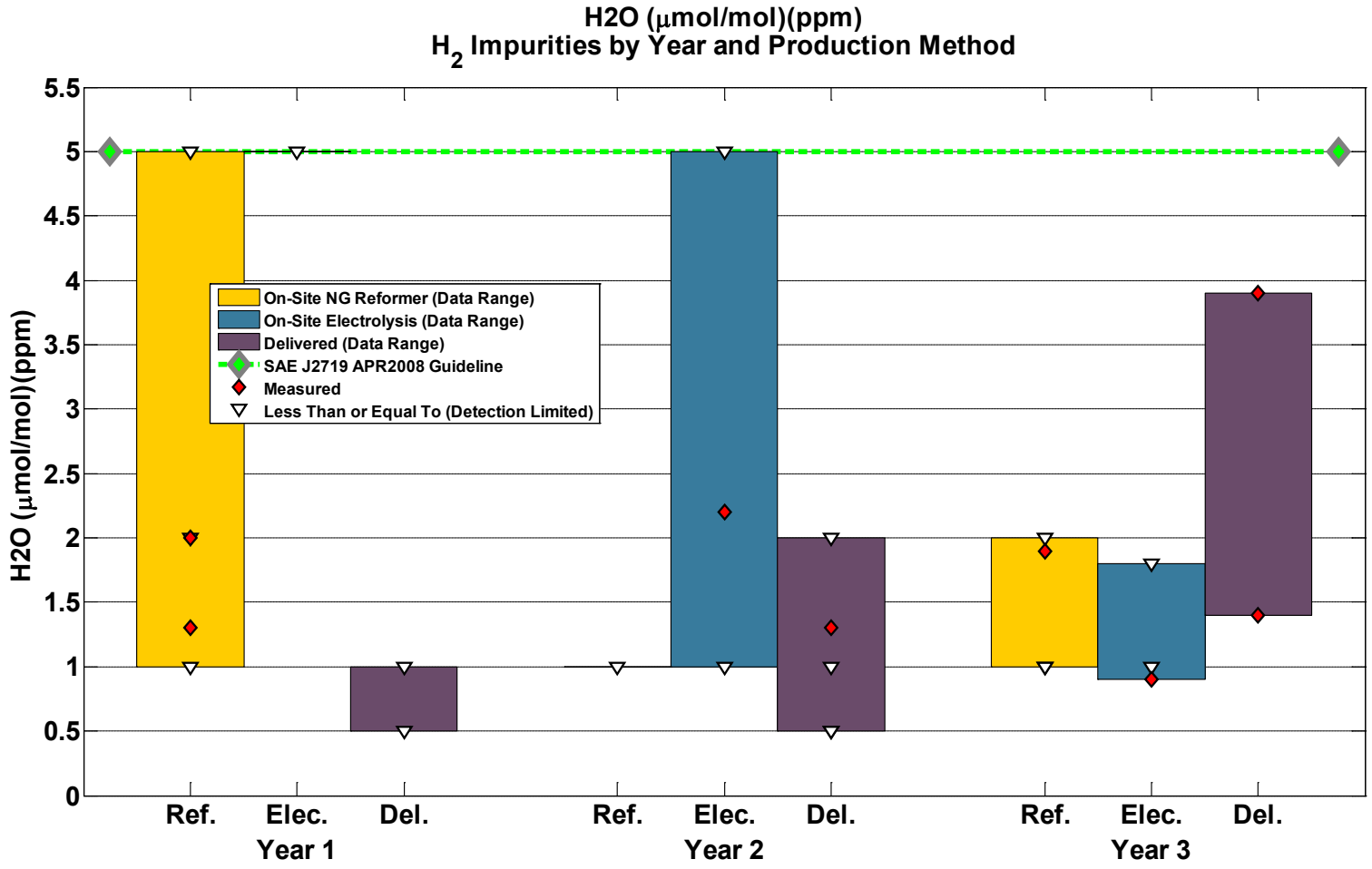

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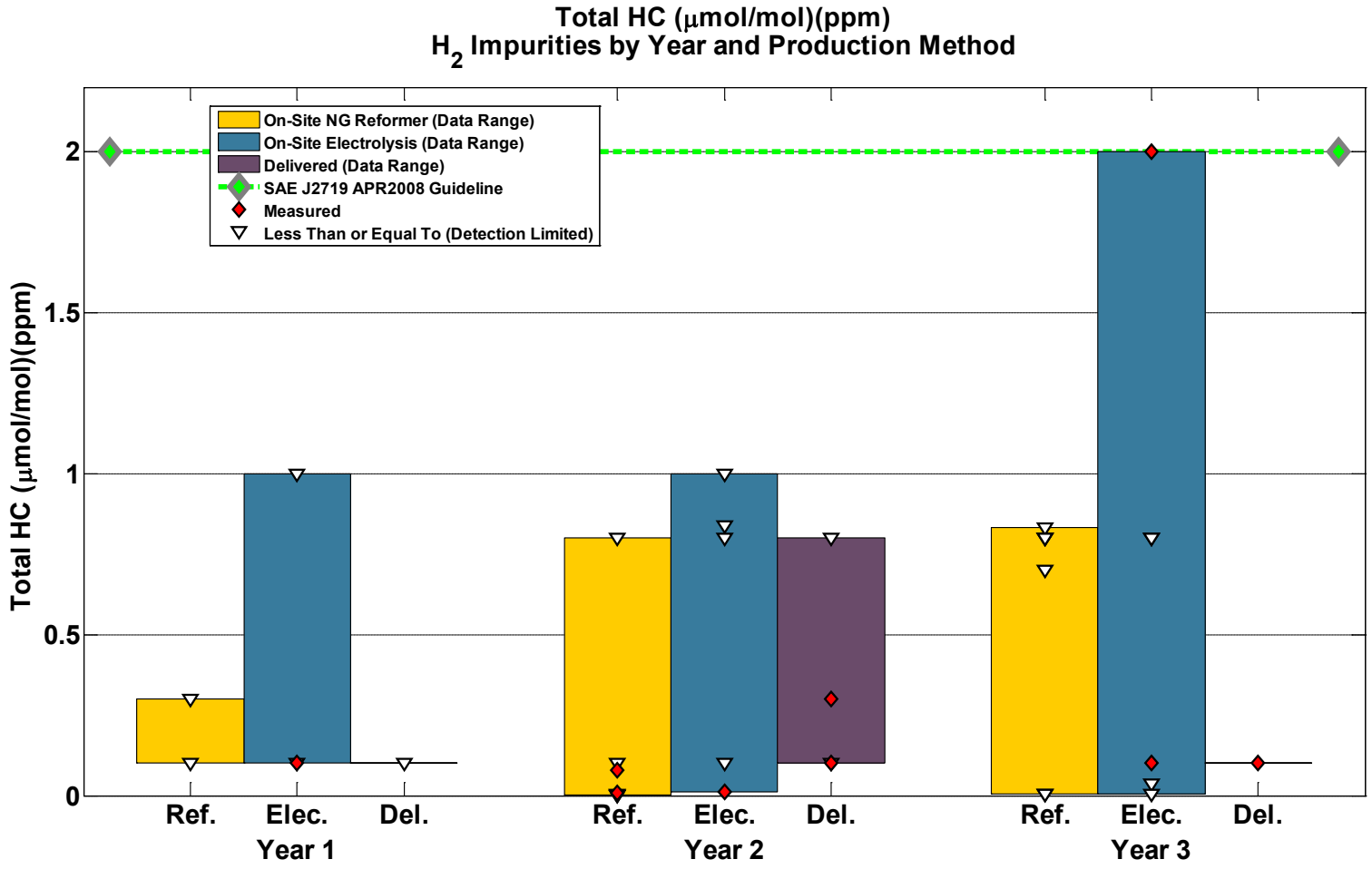

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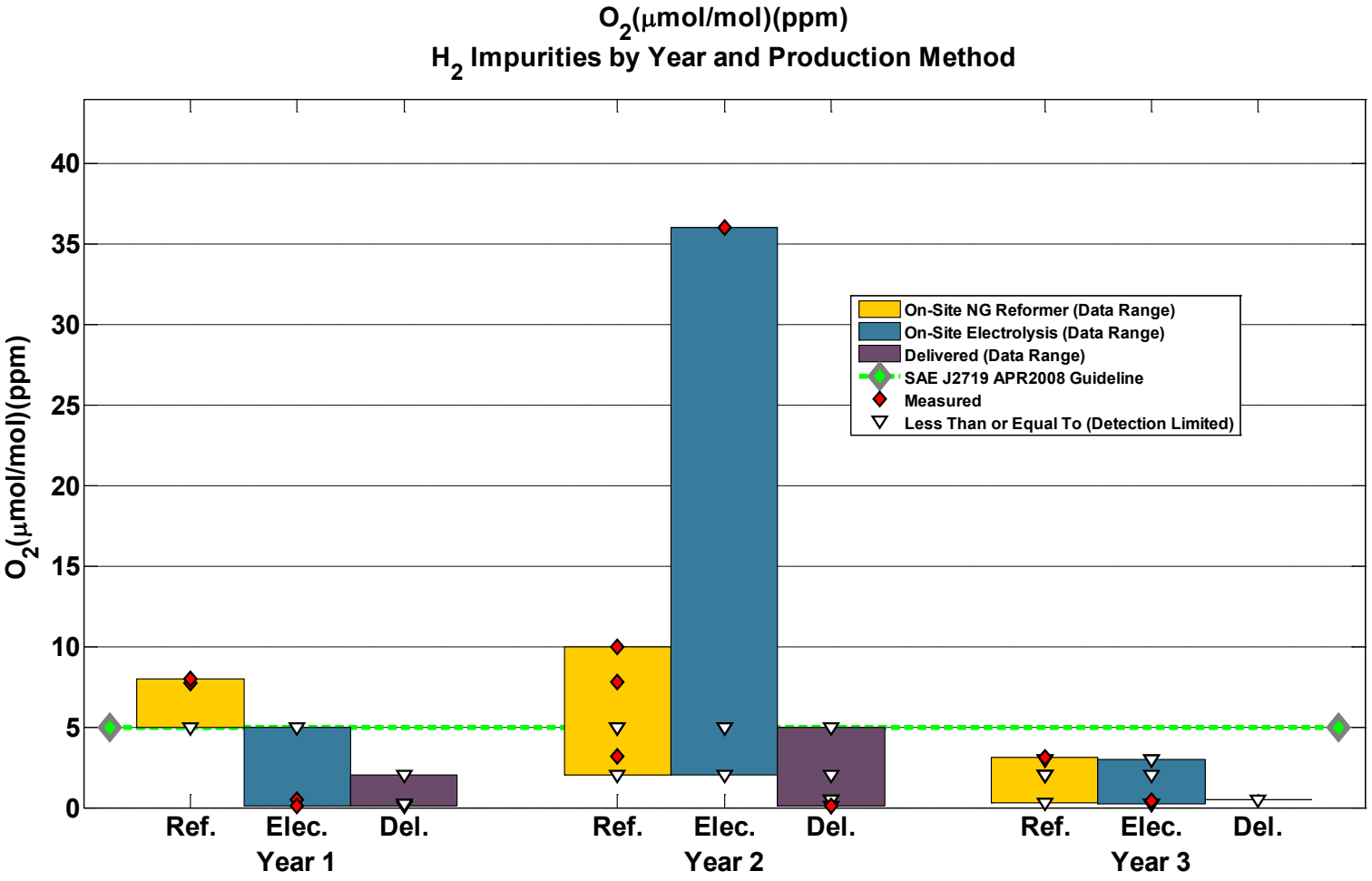

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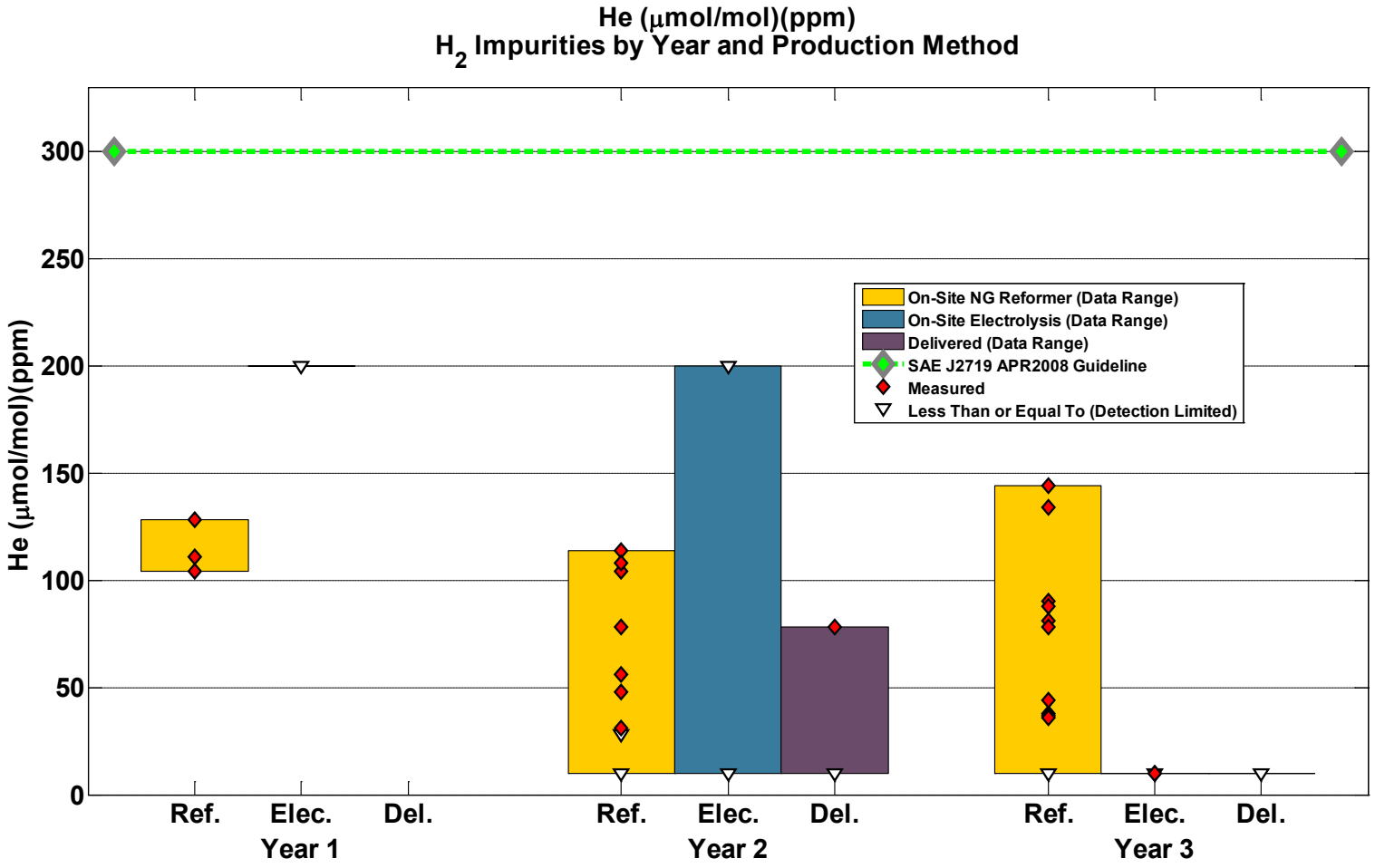

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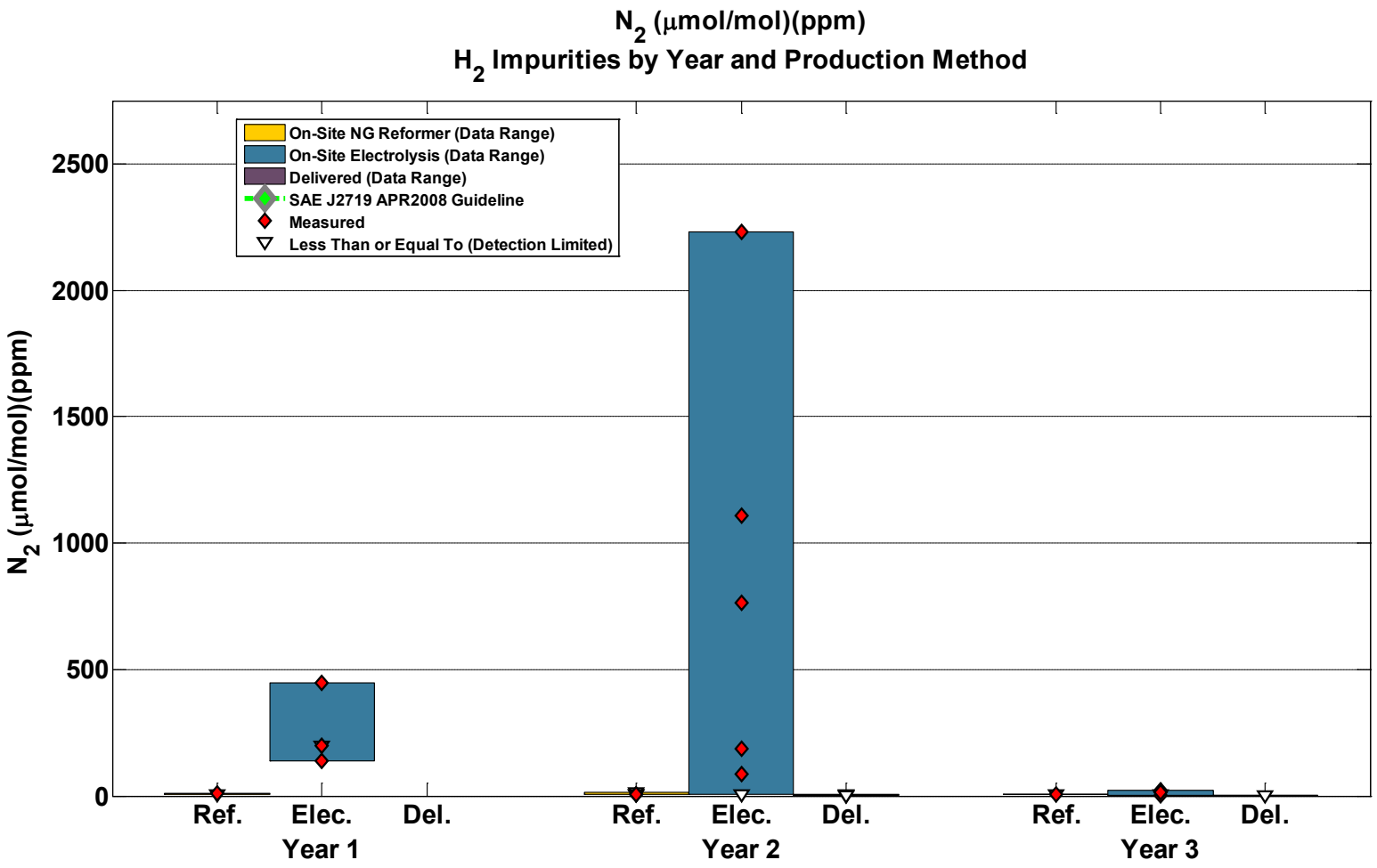

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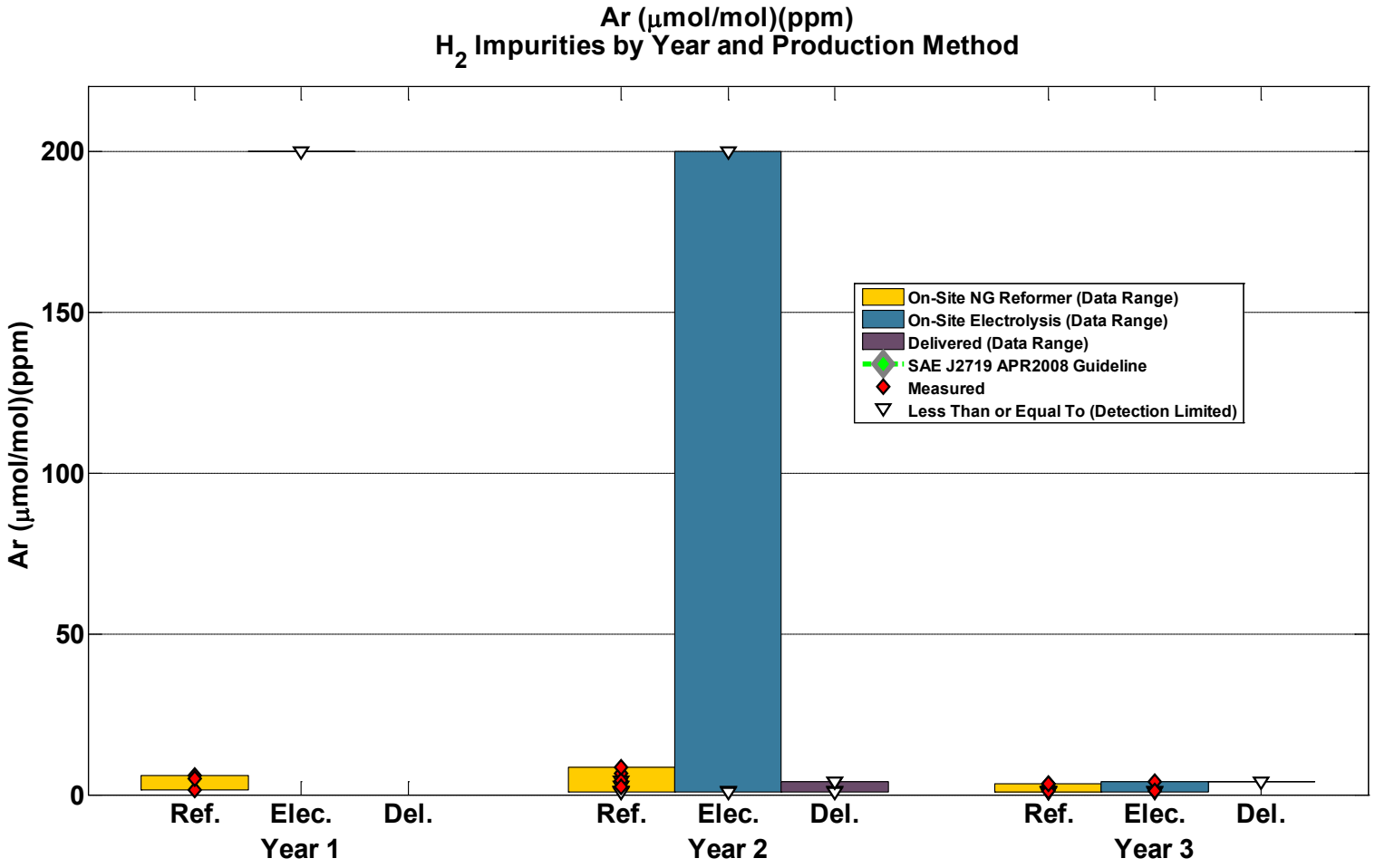

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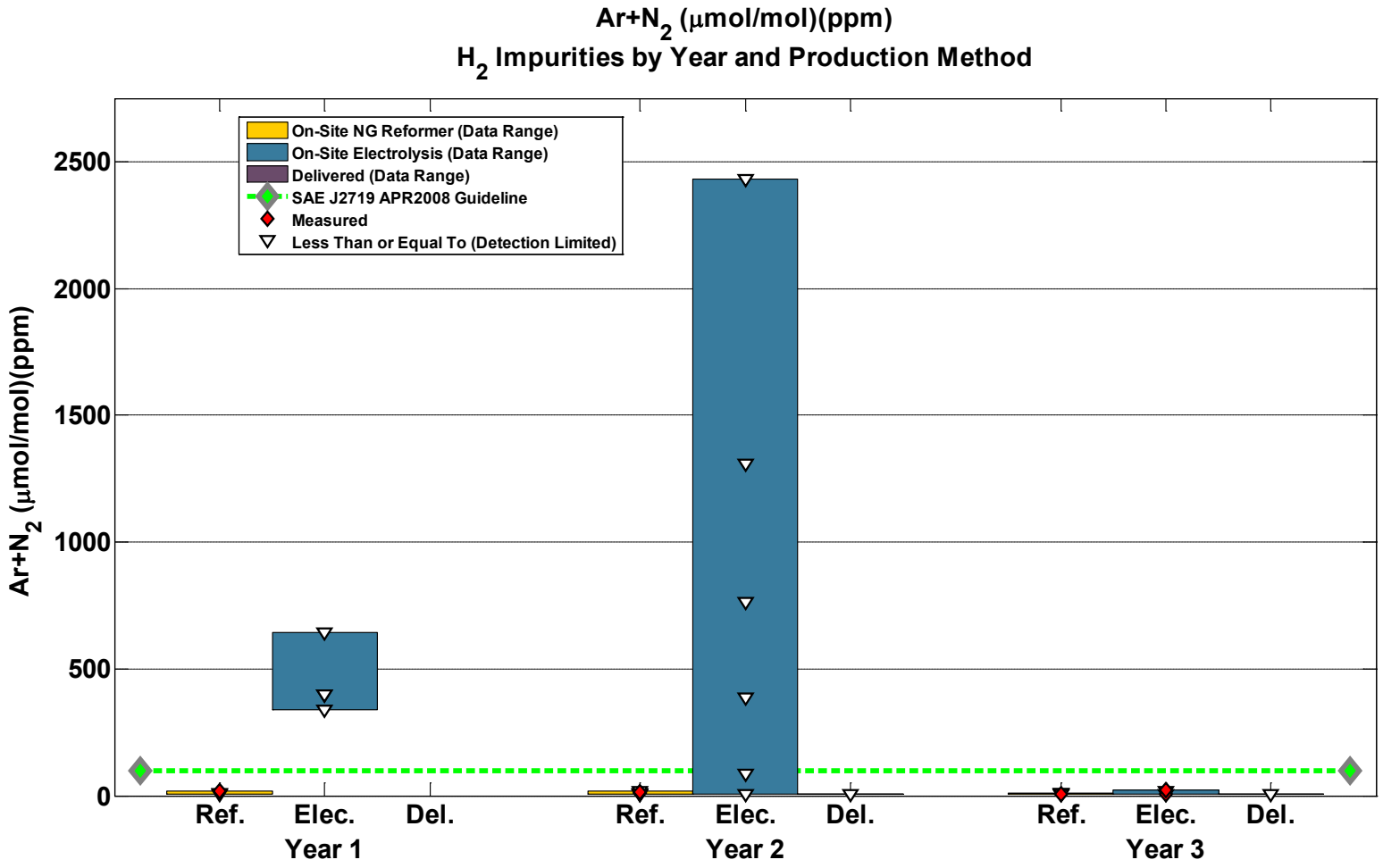

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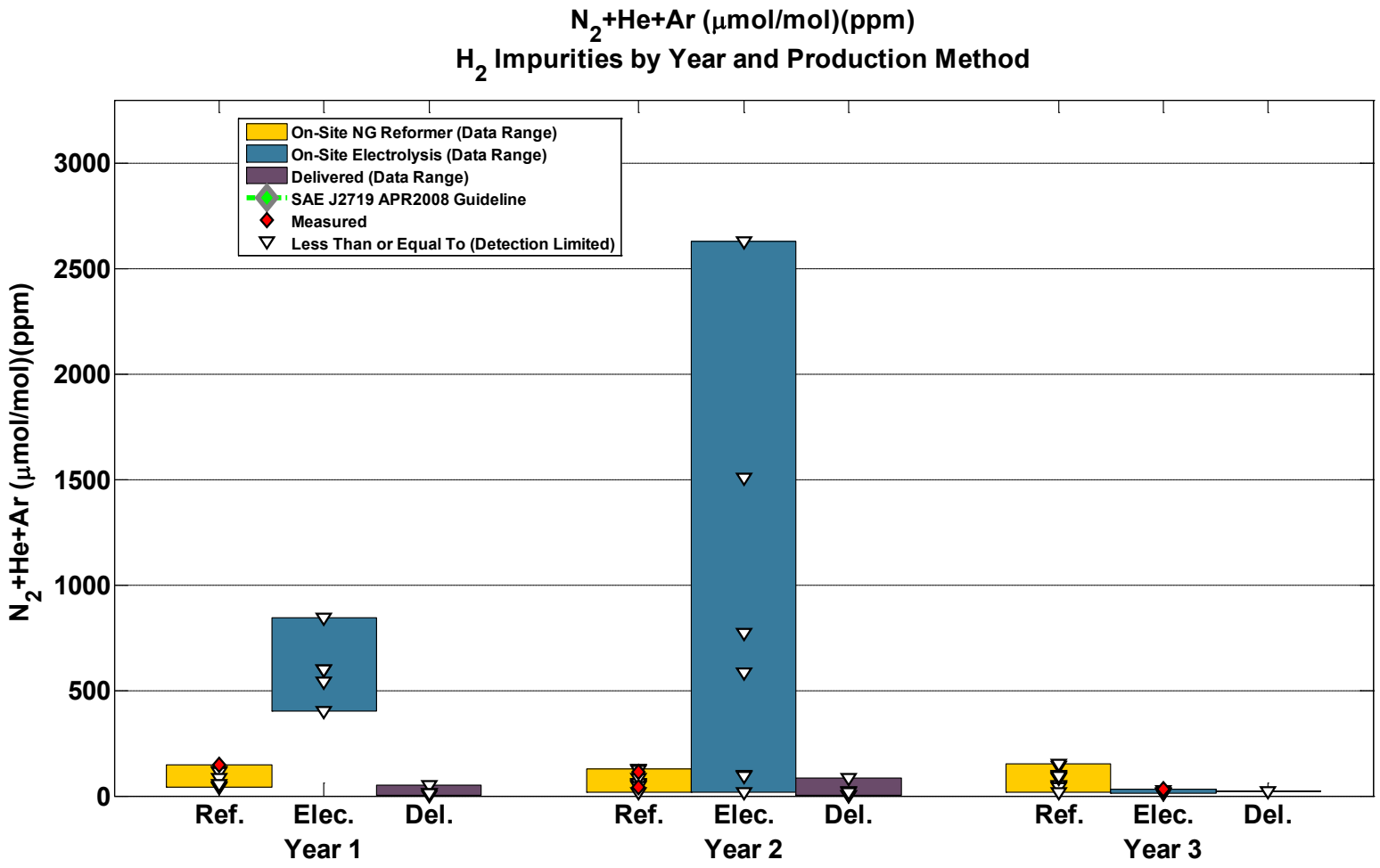

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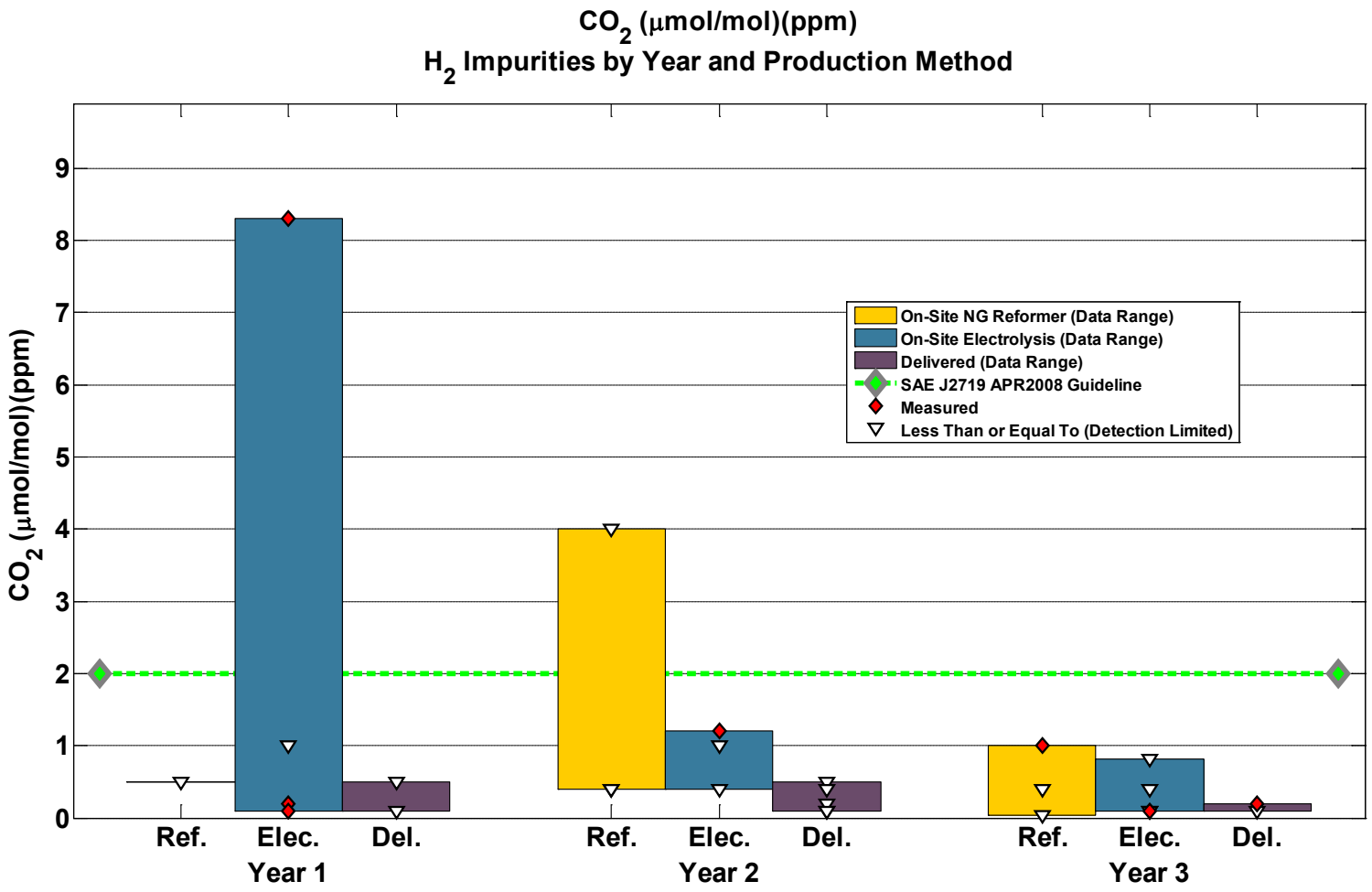

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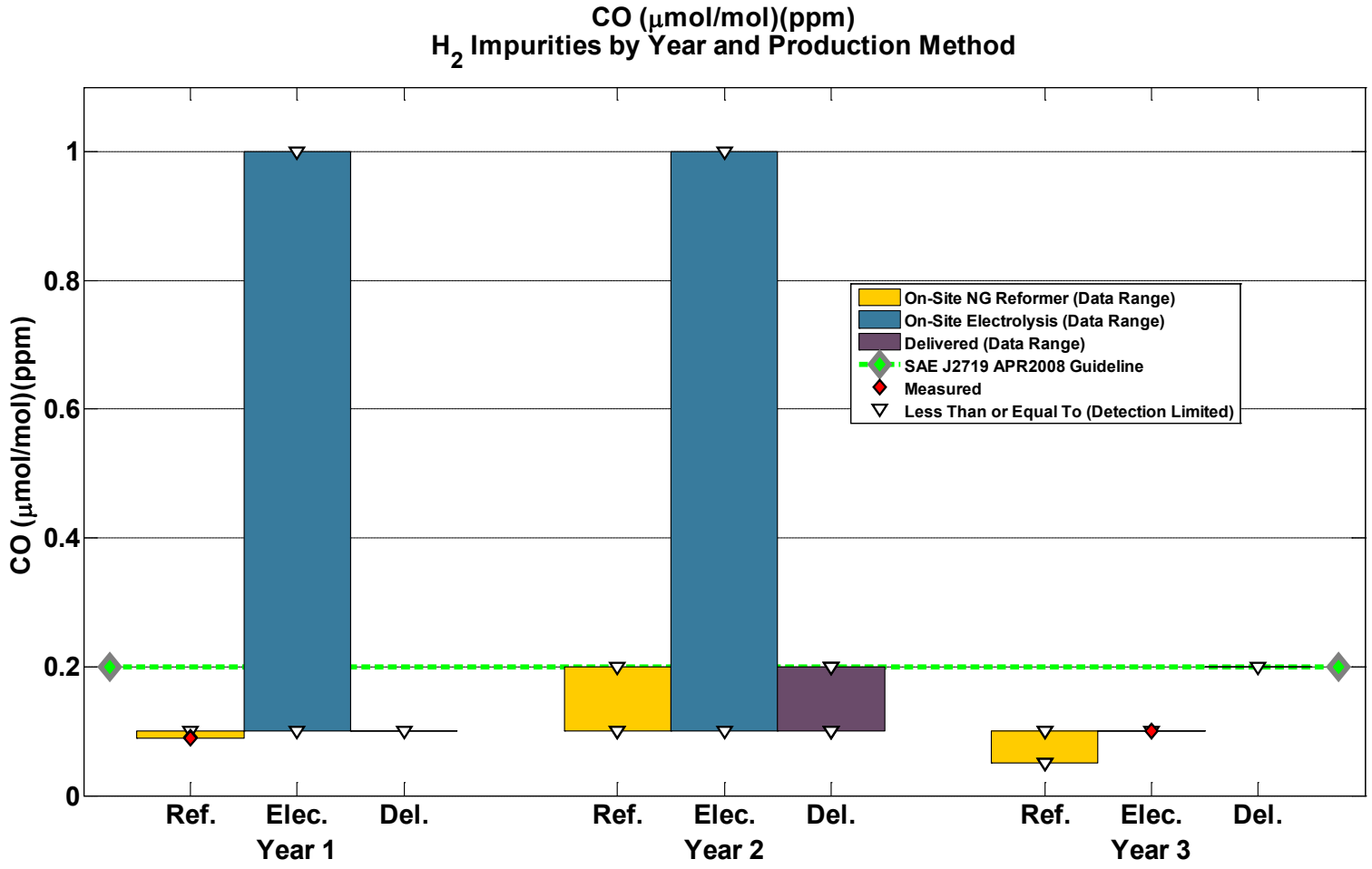
CDP#28 Supplemental: Hydrogen Impurities by Year and Production Method



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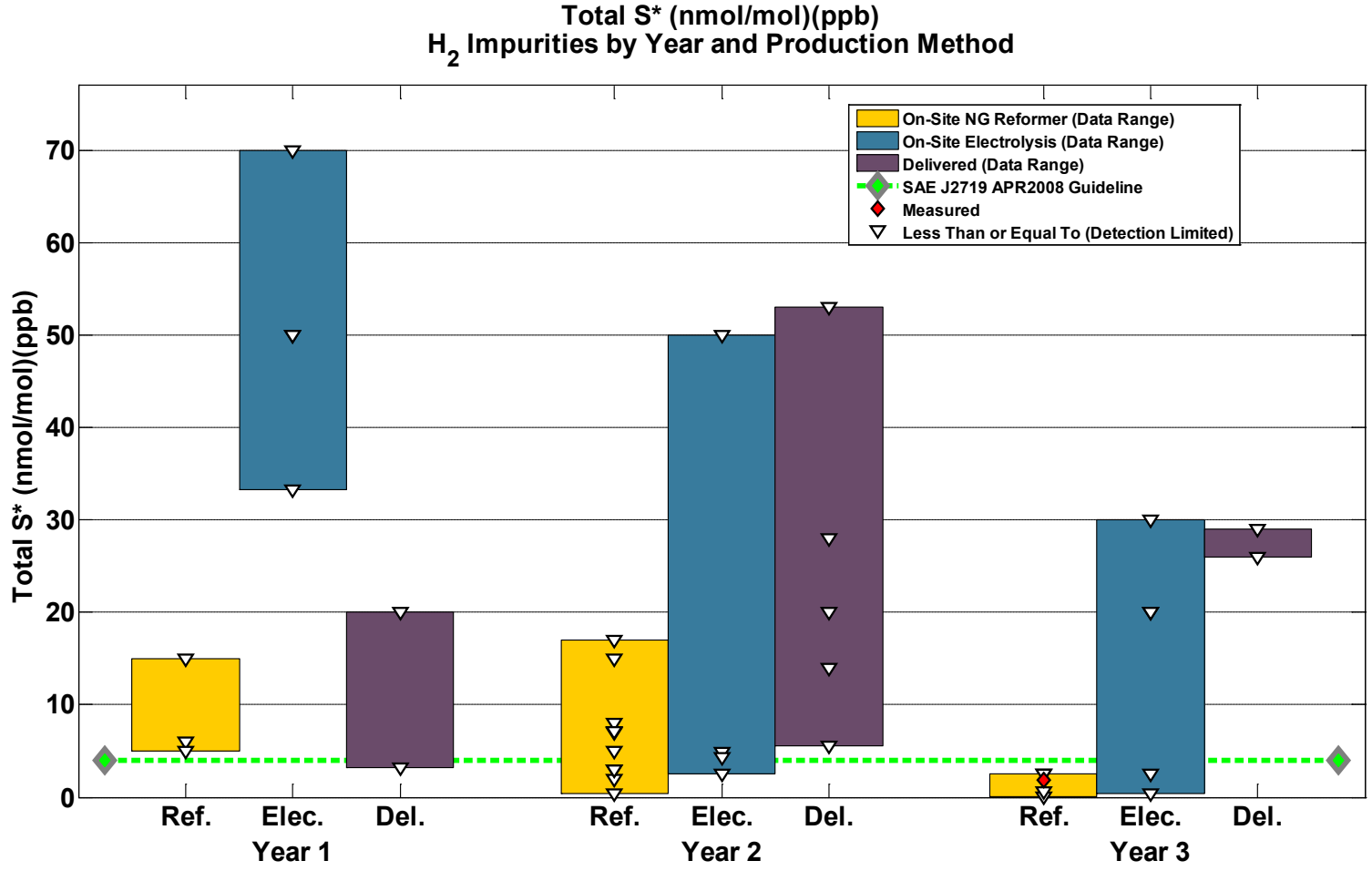
CDP#28 Supplemental: Hydrogen Impurities by Year and Production Method



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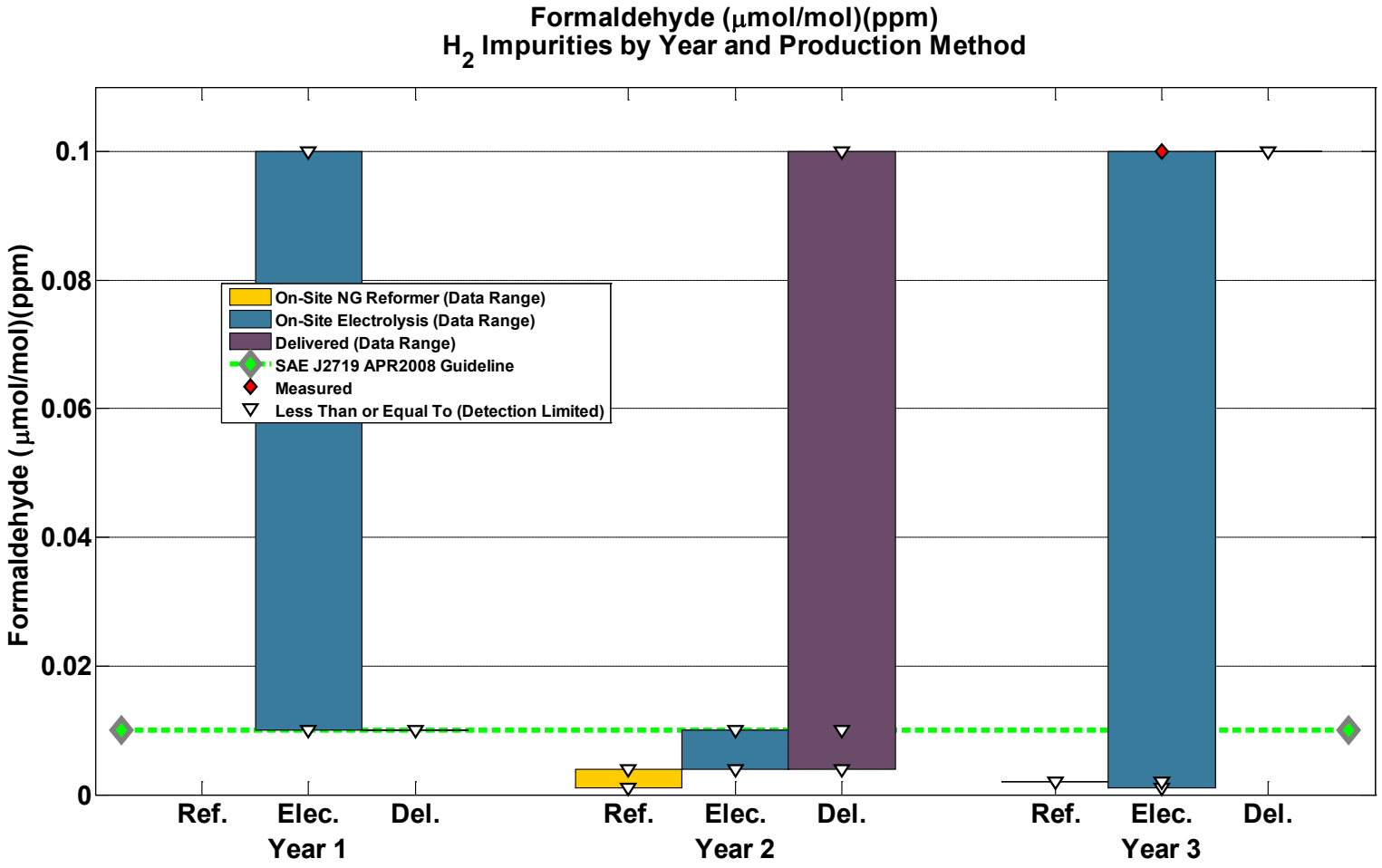
CDP#28 Supplemental: Hydrogen Impurities by Year and Production Method



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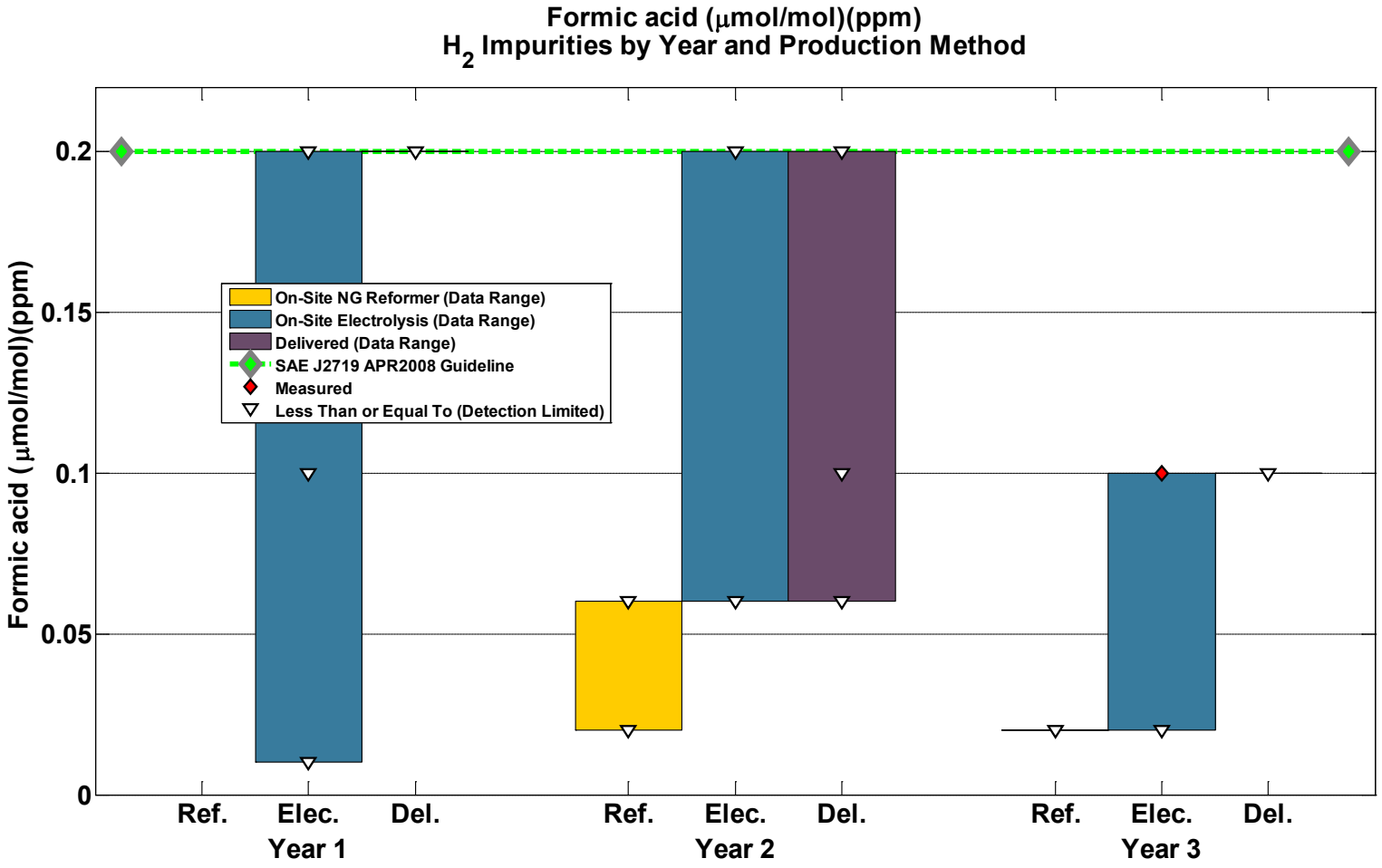
CDP#28 Supplemental: Hydrogen Impurities by Year and Production Method



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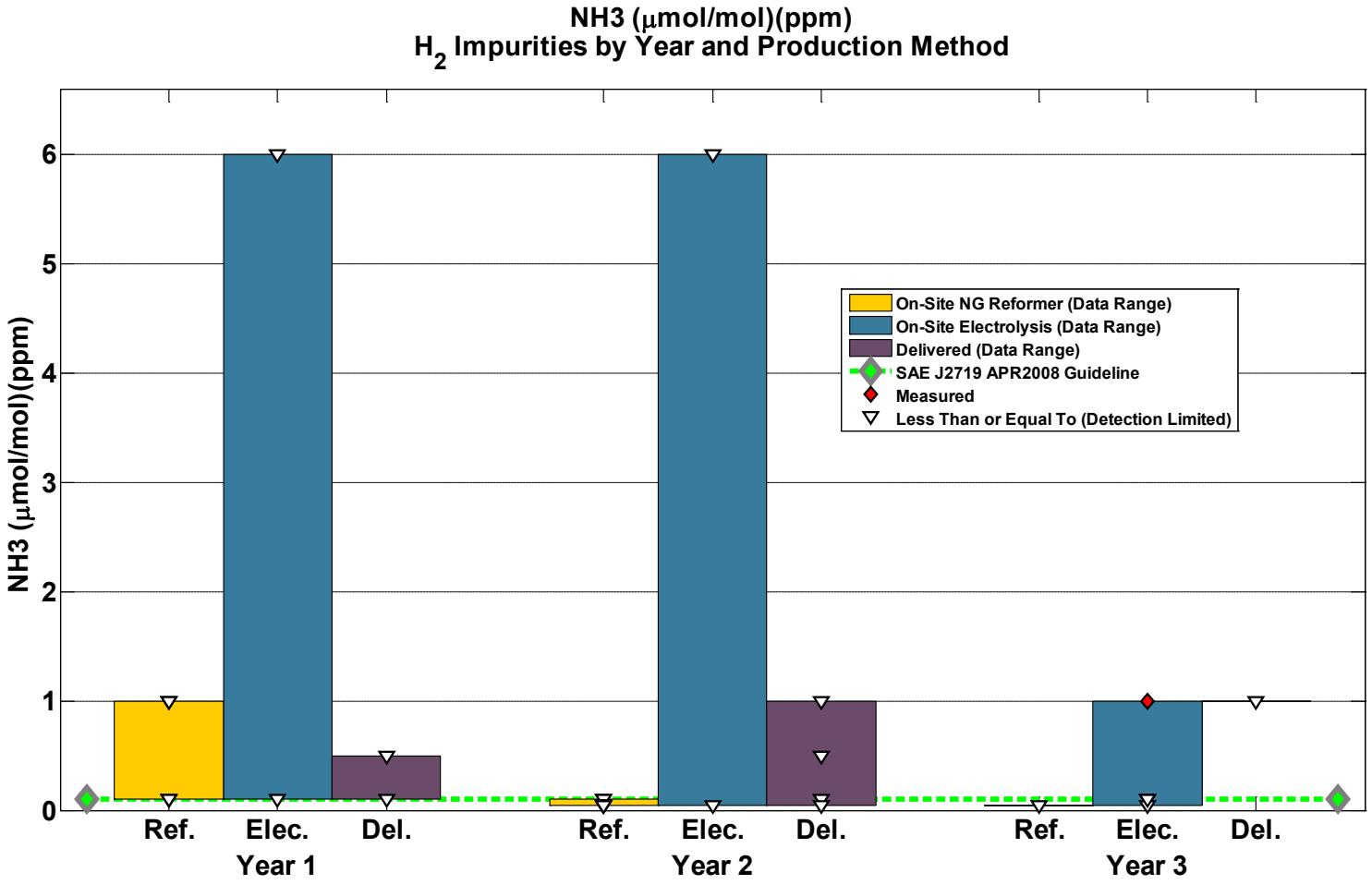

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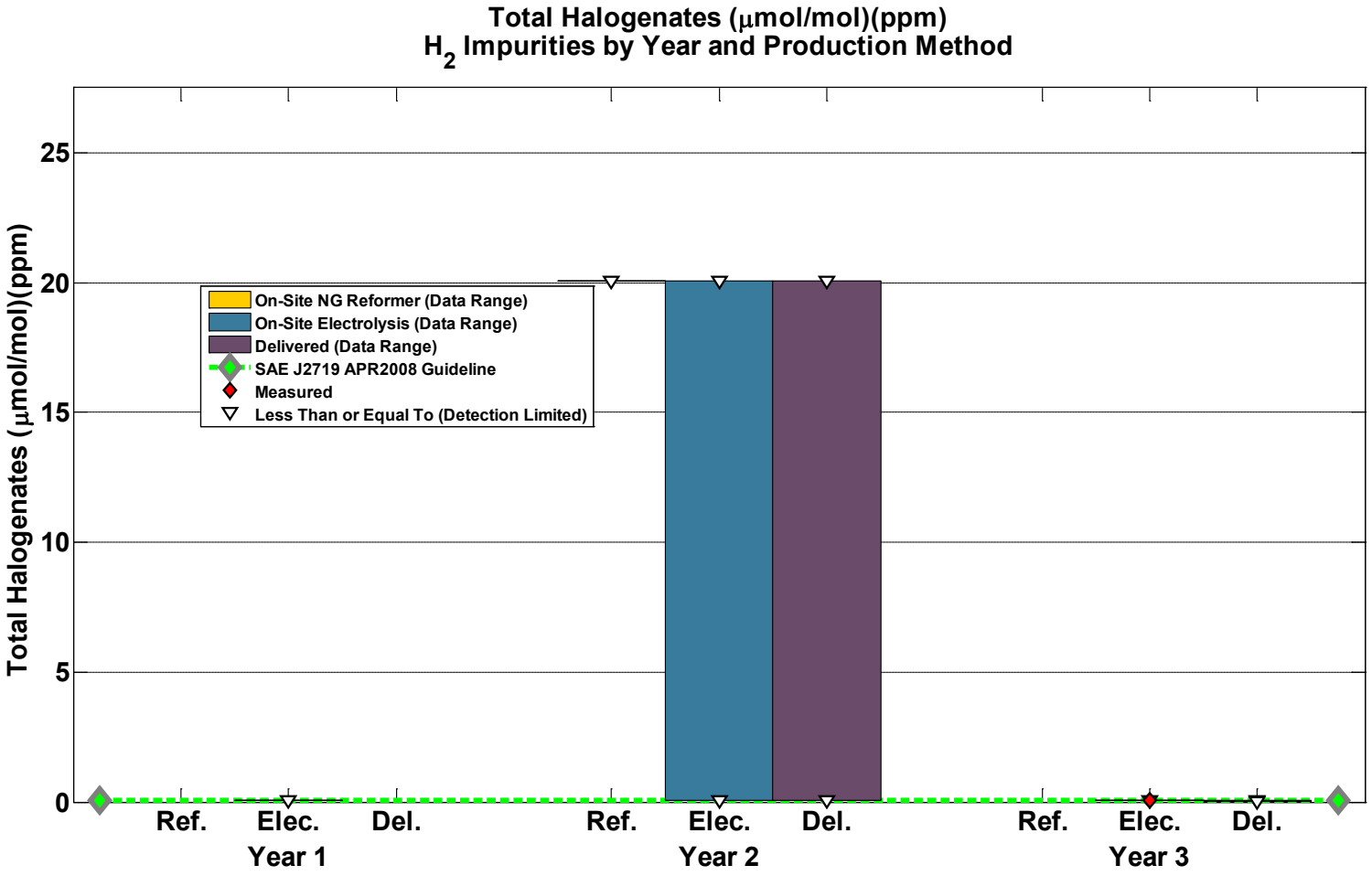

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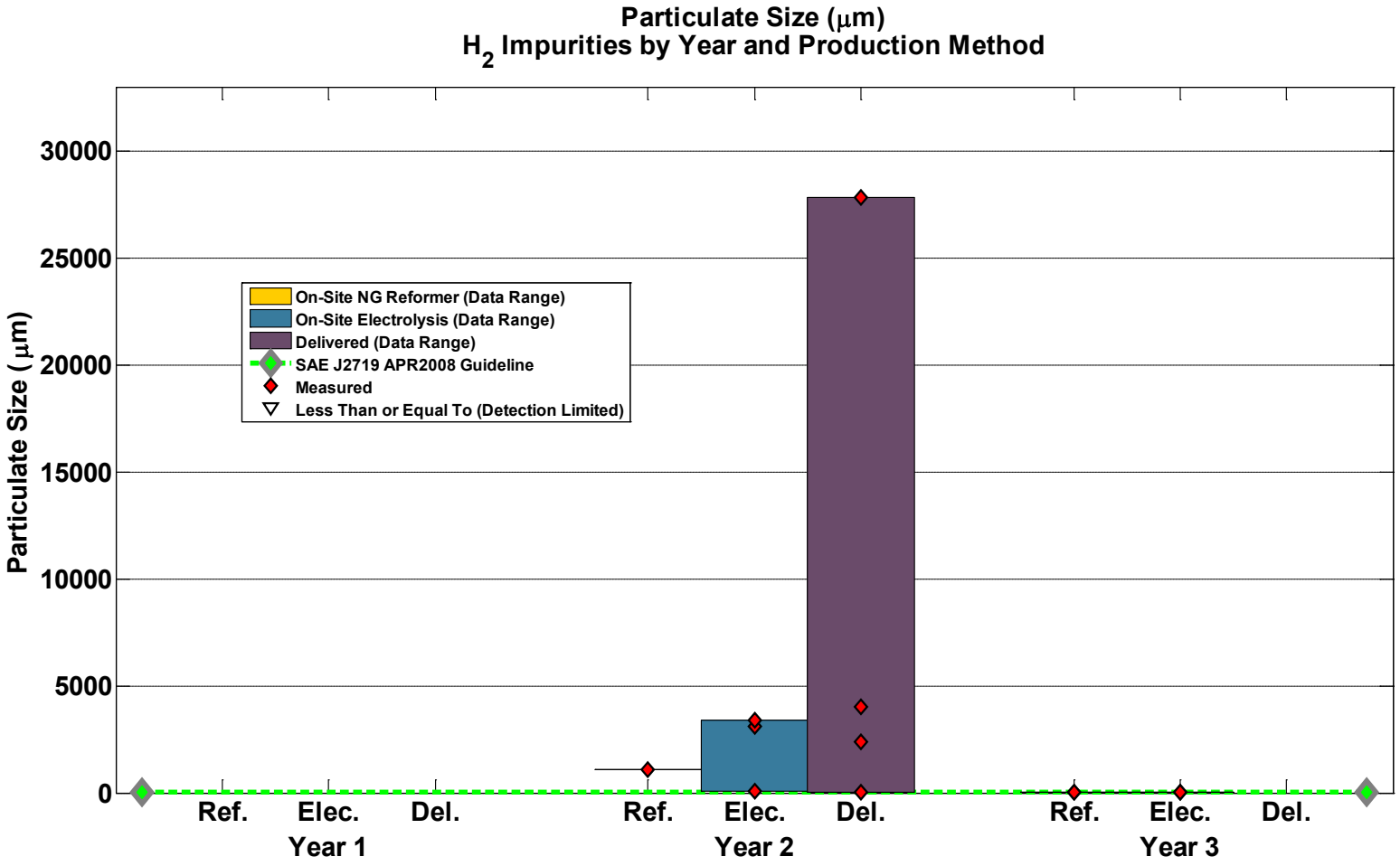

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Year 1 is 2005Q3-2006Q2, Year 2 is 2006Q3-2007Q2, and Year 3 is 2007Q3-2008Q2

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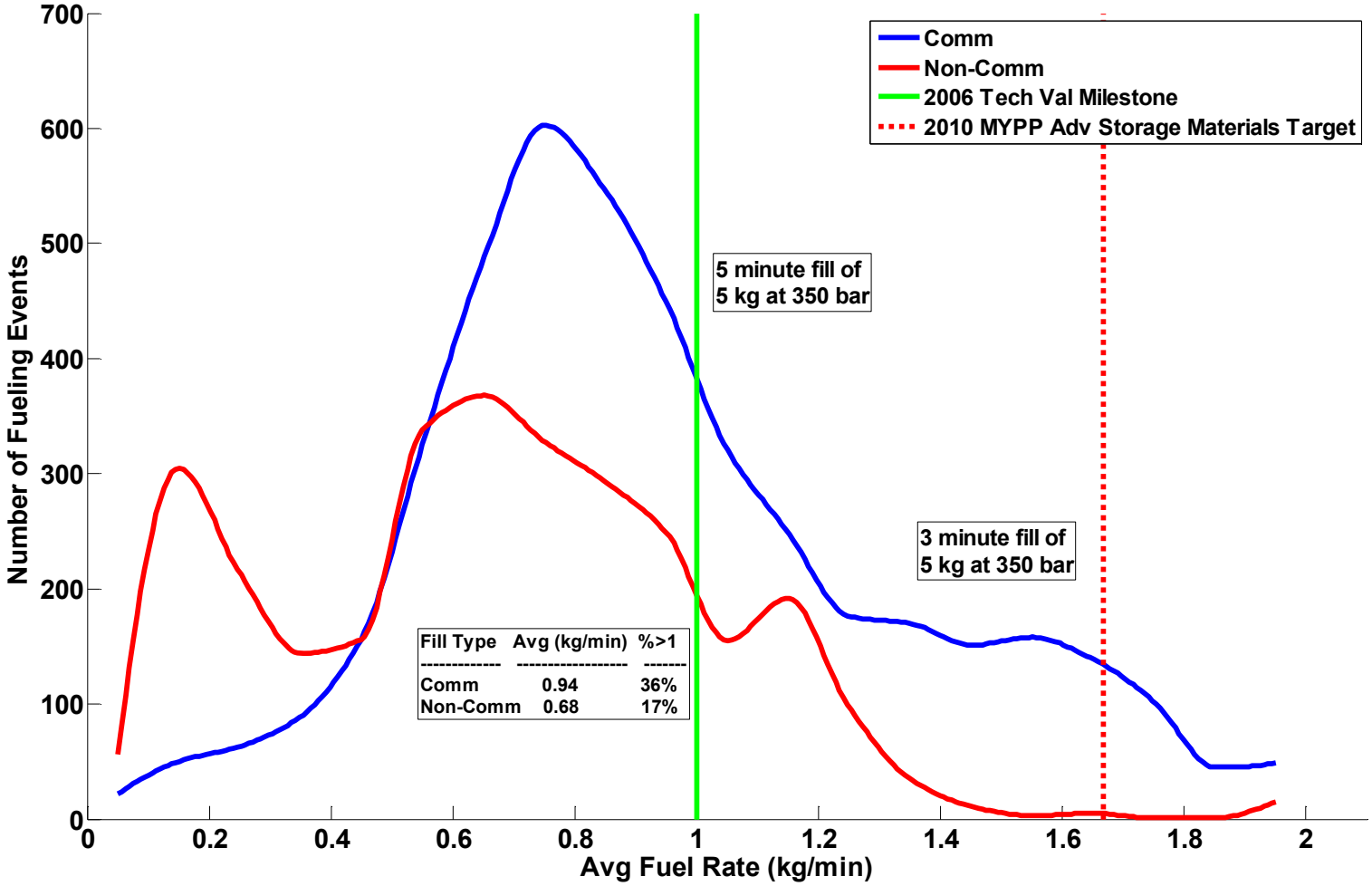
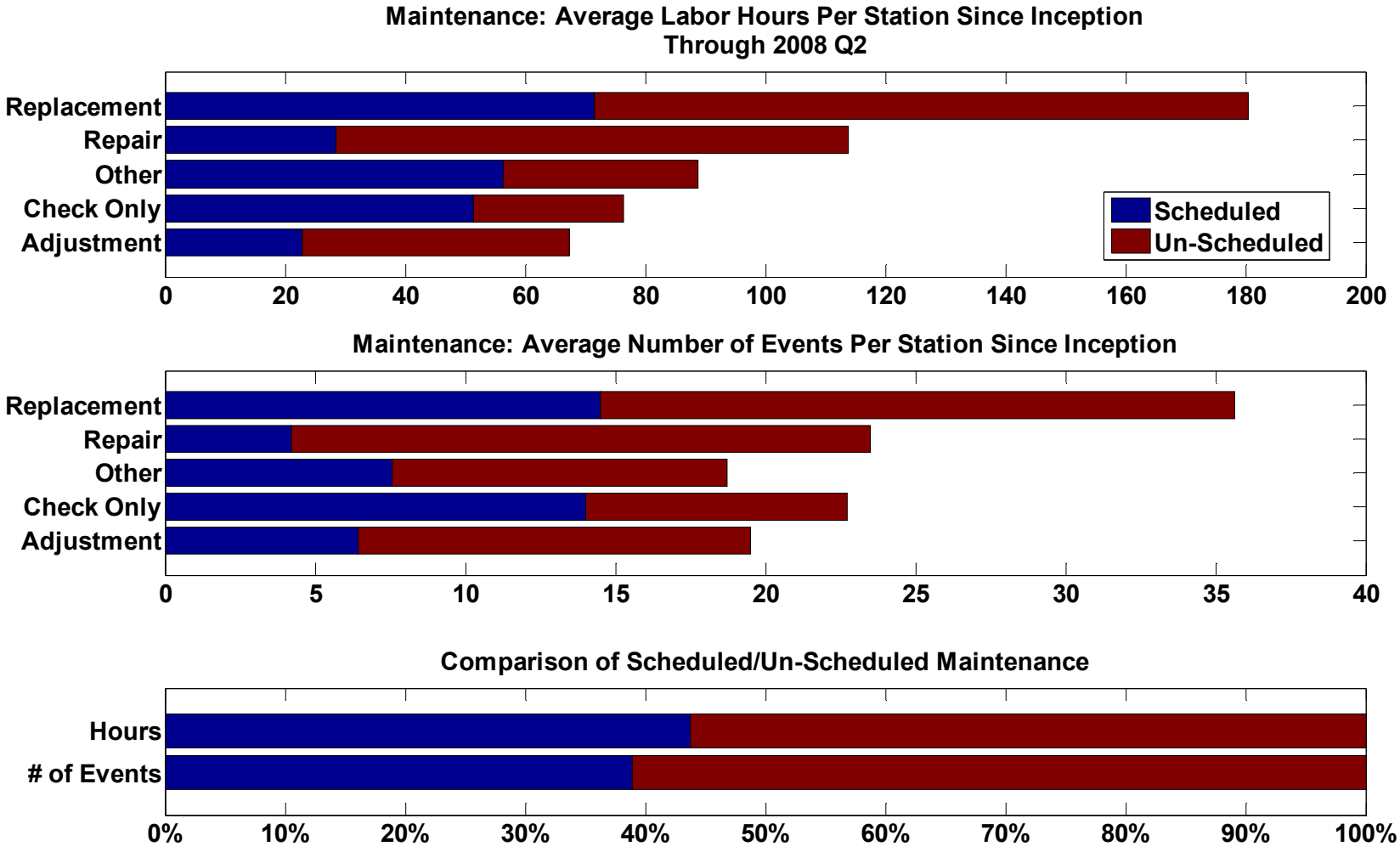
CDP#29: Fueling Rates – Communication and Non-Communication Fills



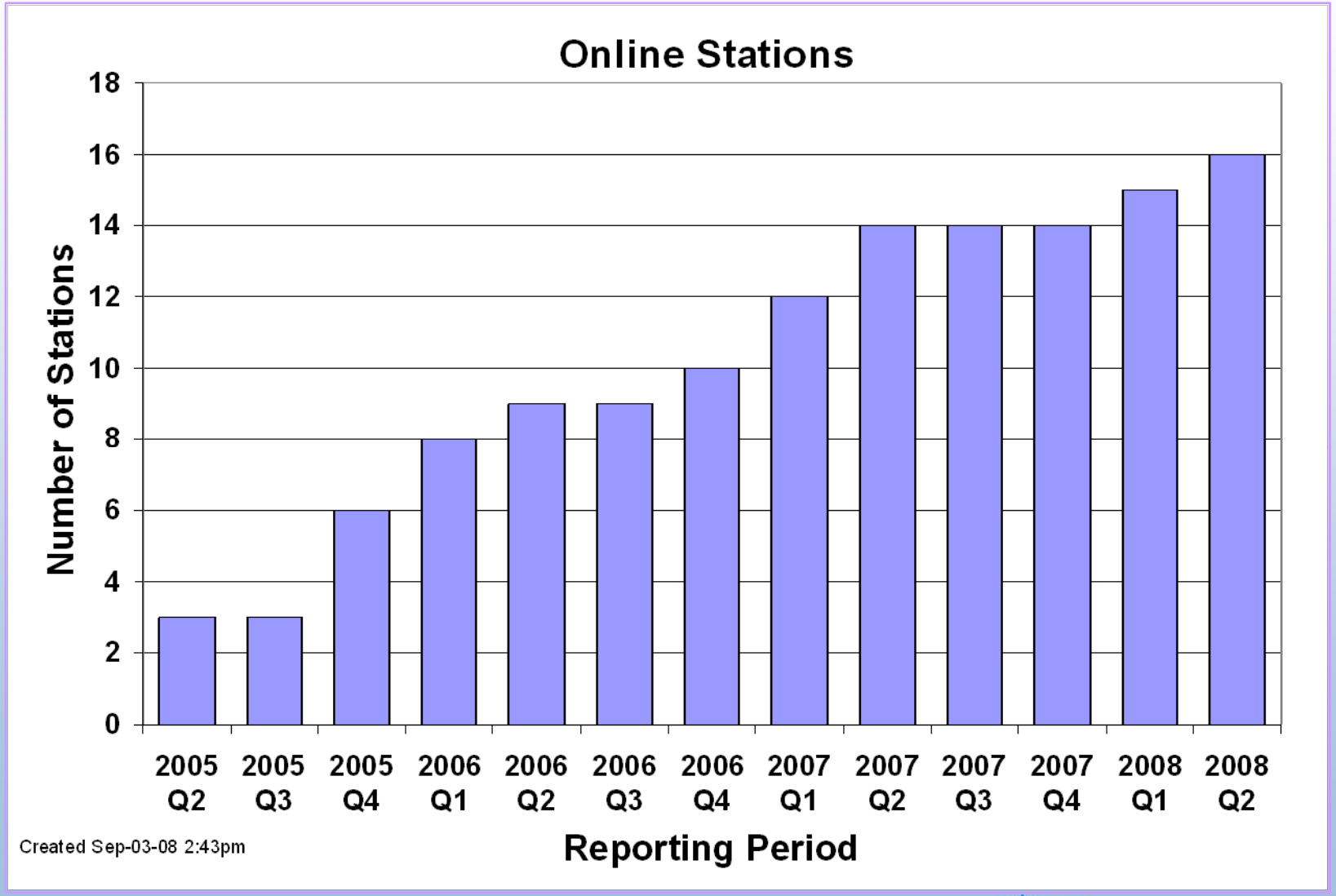
Created: Sep-02-08 4:59 PM

CDP#30: Infrastructure Maintenance

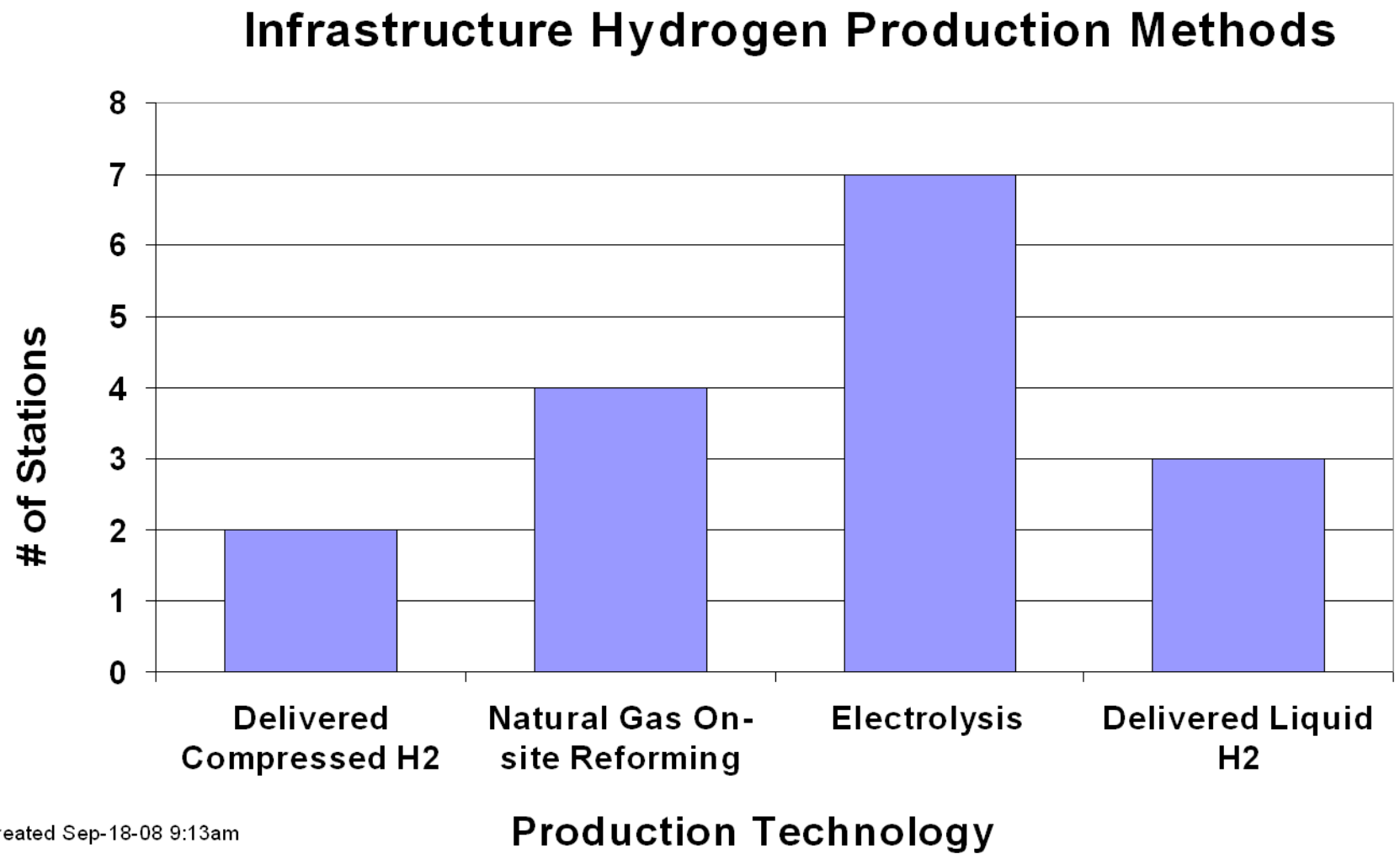


Created: Aug-08-08 4:37 PM

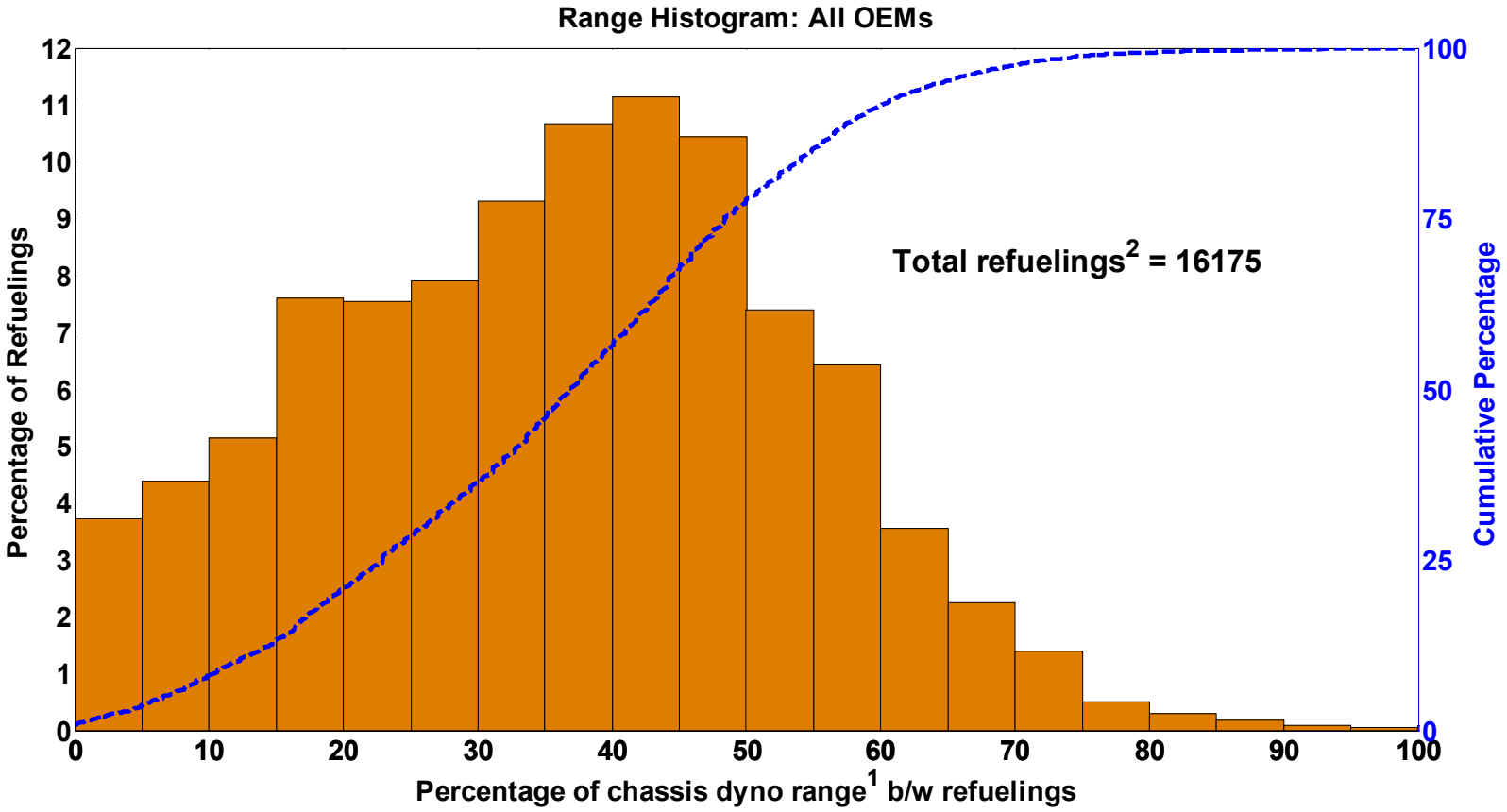
CDP#31: Number of Reporting Stations



CDP#32: Infrastructure Hydrogen Production Methods



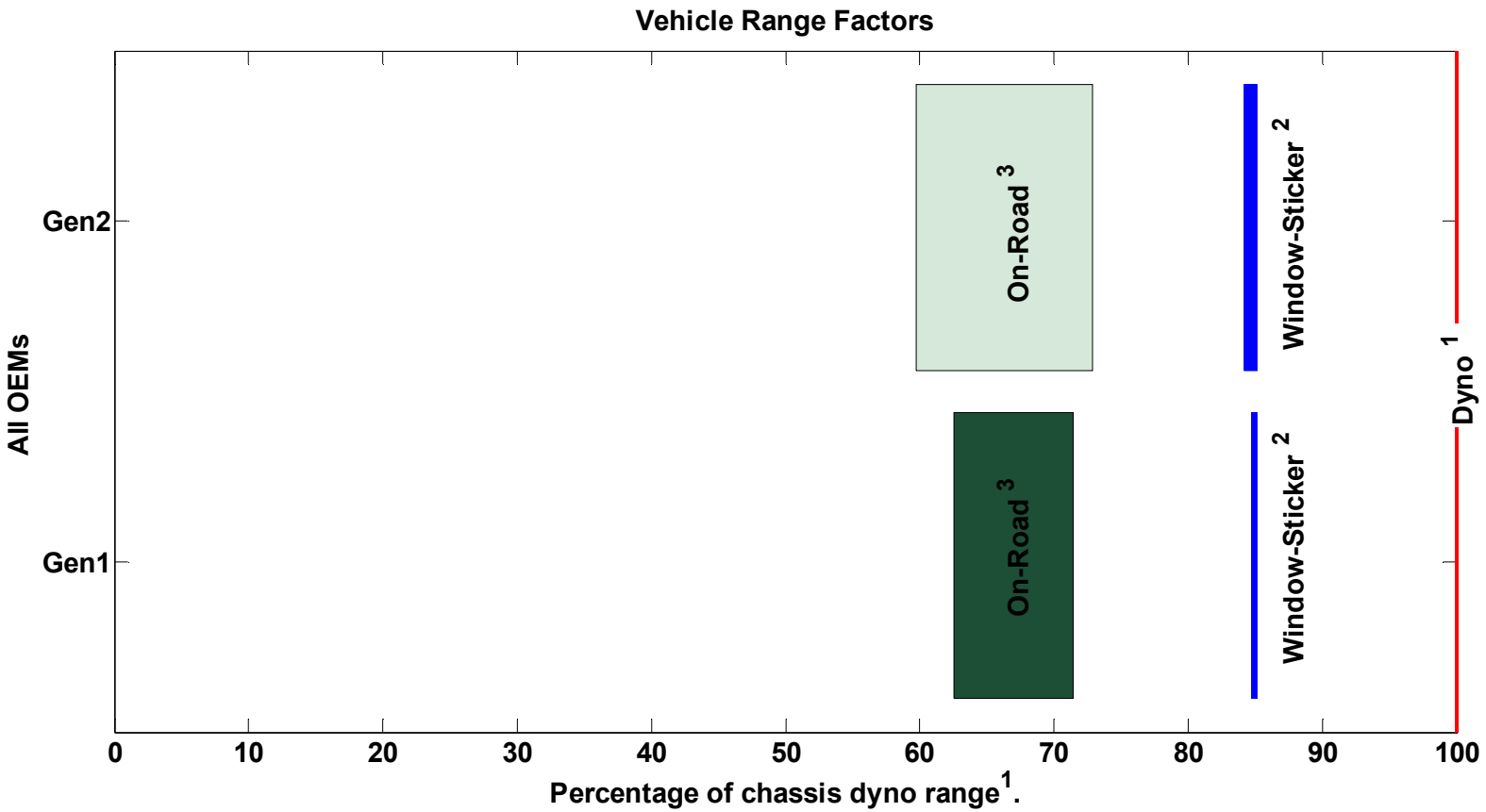
CDP#33: Percentage of Theoretical Range Traveled Between Refuelings



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: Sep-22-08 11:51 AM

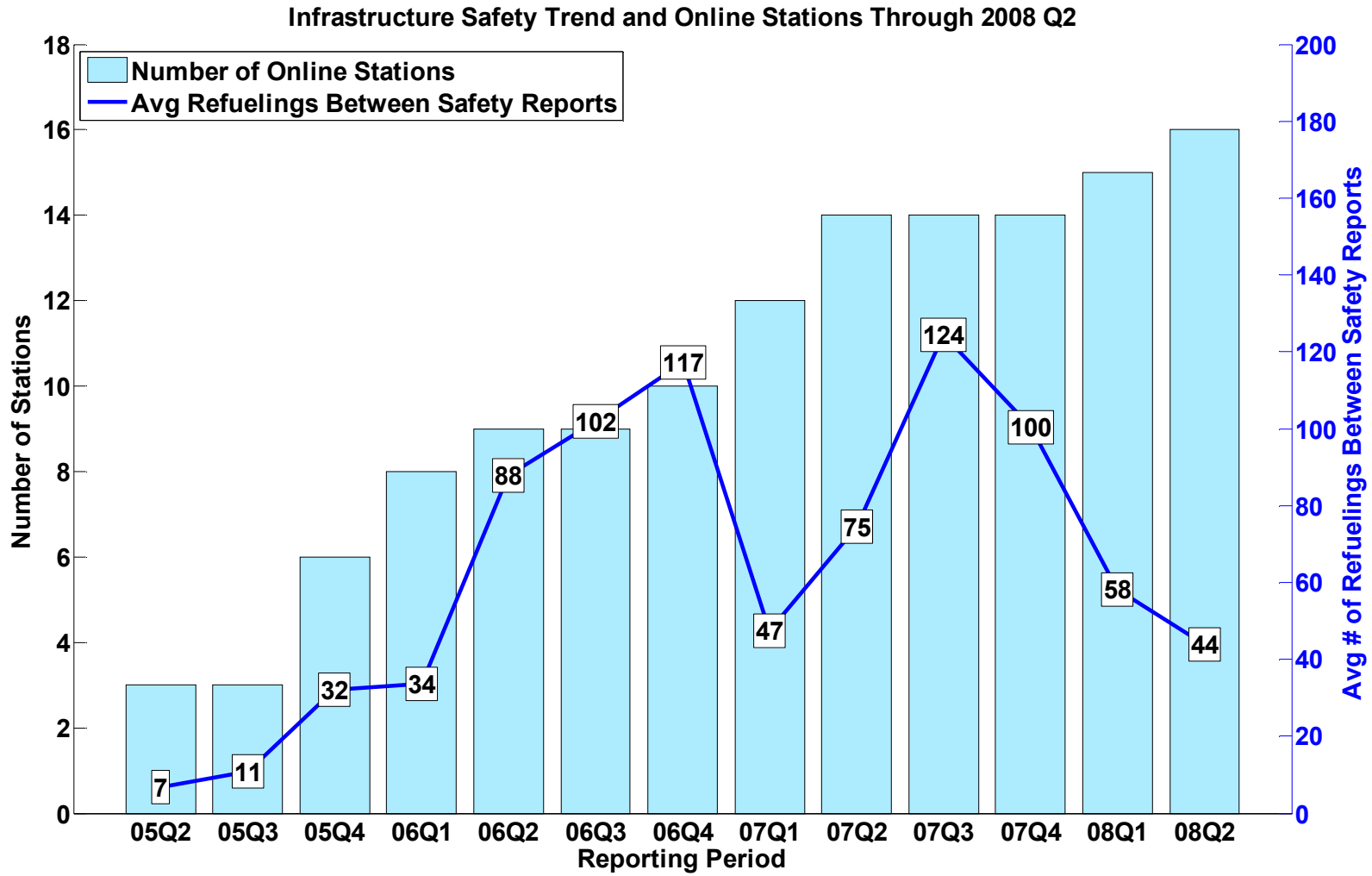
CDP#34: Effective Vehicle Range



1. Calculated using the combined City/Hwy fuel economy from dyno testing (non-adjusted) and usable fuel on board.
2. Applying window-sticker correction factors for fuel economy: 0.78 x Hwy and 0.9 x City.
3. Using fuel economy from on-road data (excluding trips > 1 mile, consistent with other data products).

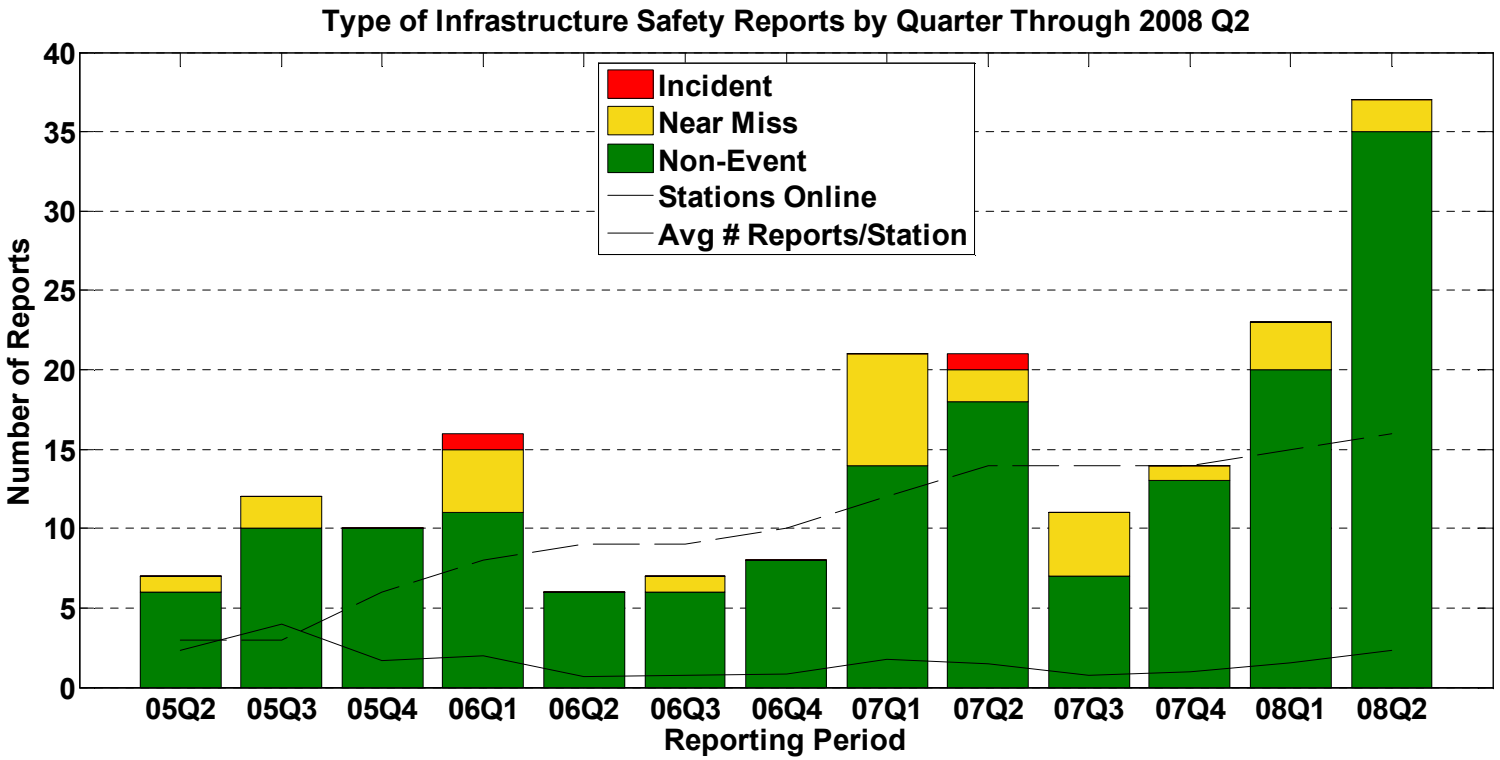
Created: Sep-22-08 11:52 AM

CDP#35: Average Refuelings Between Infrastructure Safety Reports



Created: Sep-02-08 5:02 PM

CDP#36: Type of Infrastructure Safety Report By Quarter



An INCIDENT is an event that results in:

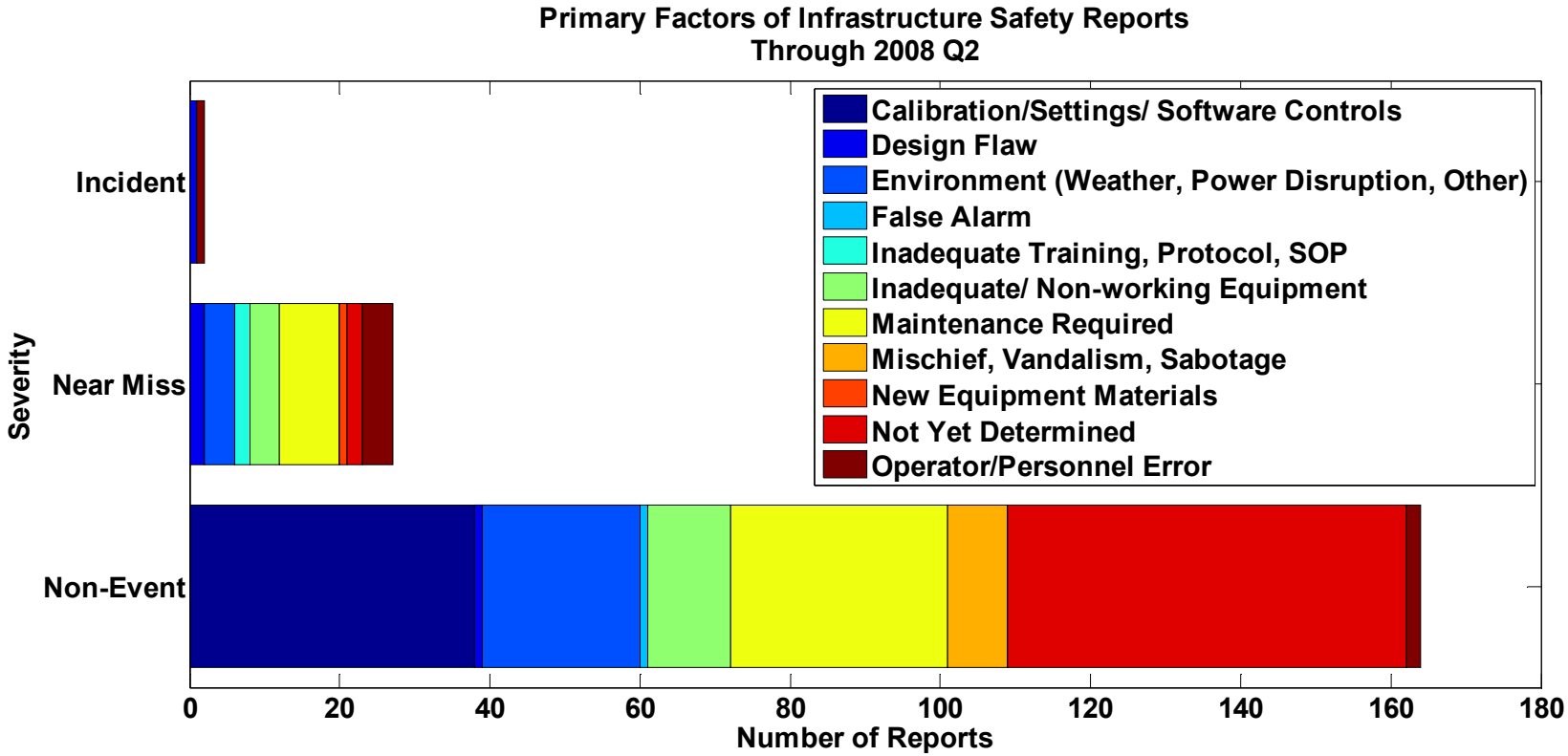
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing 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: Sep-02-08 5:02 PM

CDP#37: Primary Factors of Infrastructure Safety Reports



An INCIDENT is an event that results in:

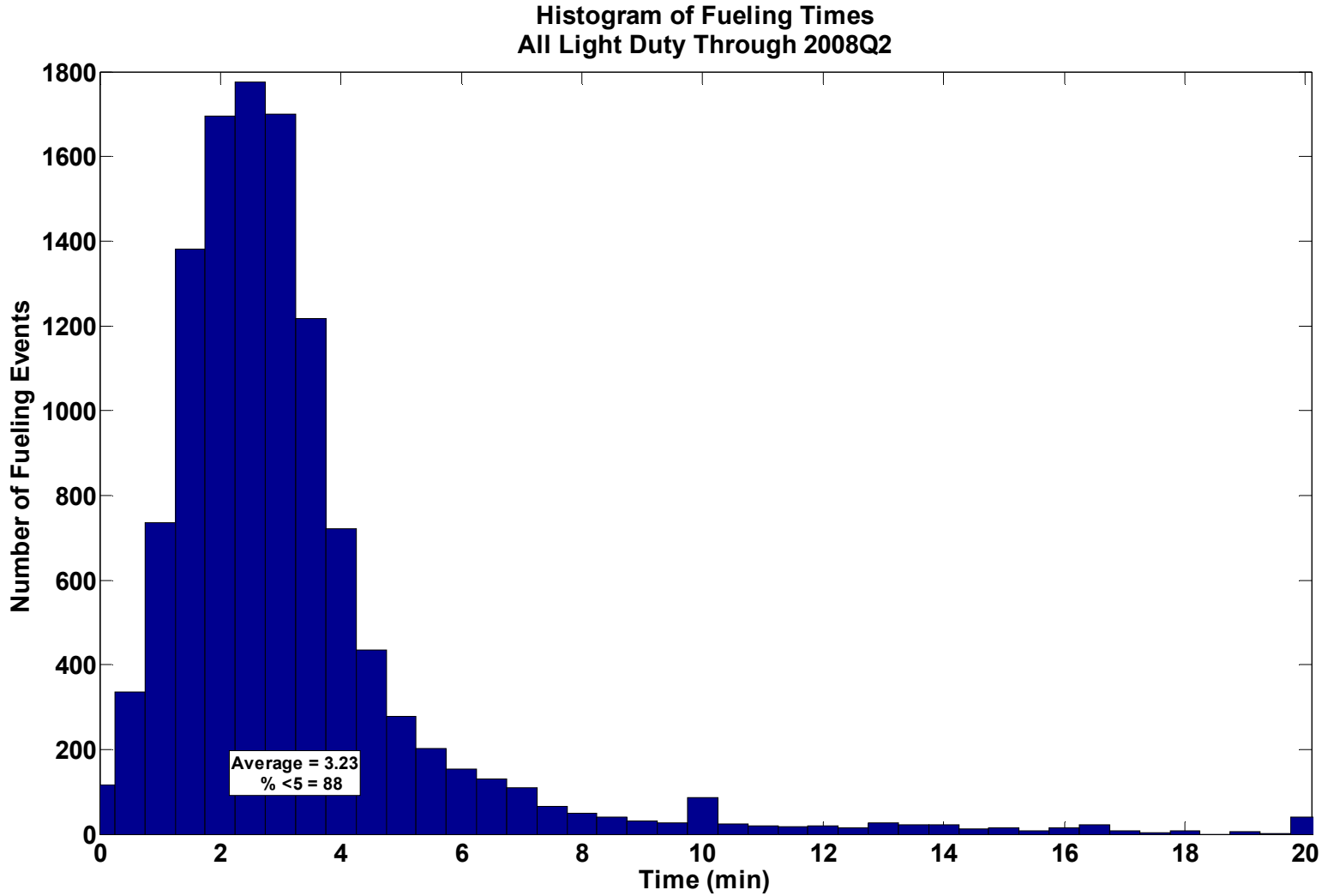
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
- release of any volatile, hydrogen containing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

A NEAR-MISS is:

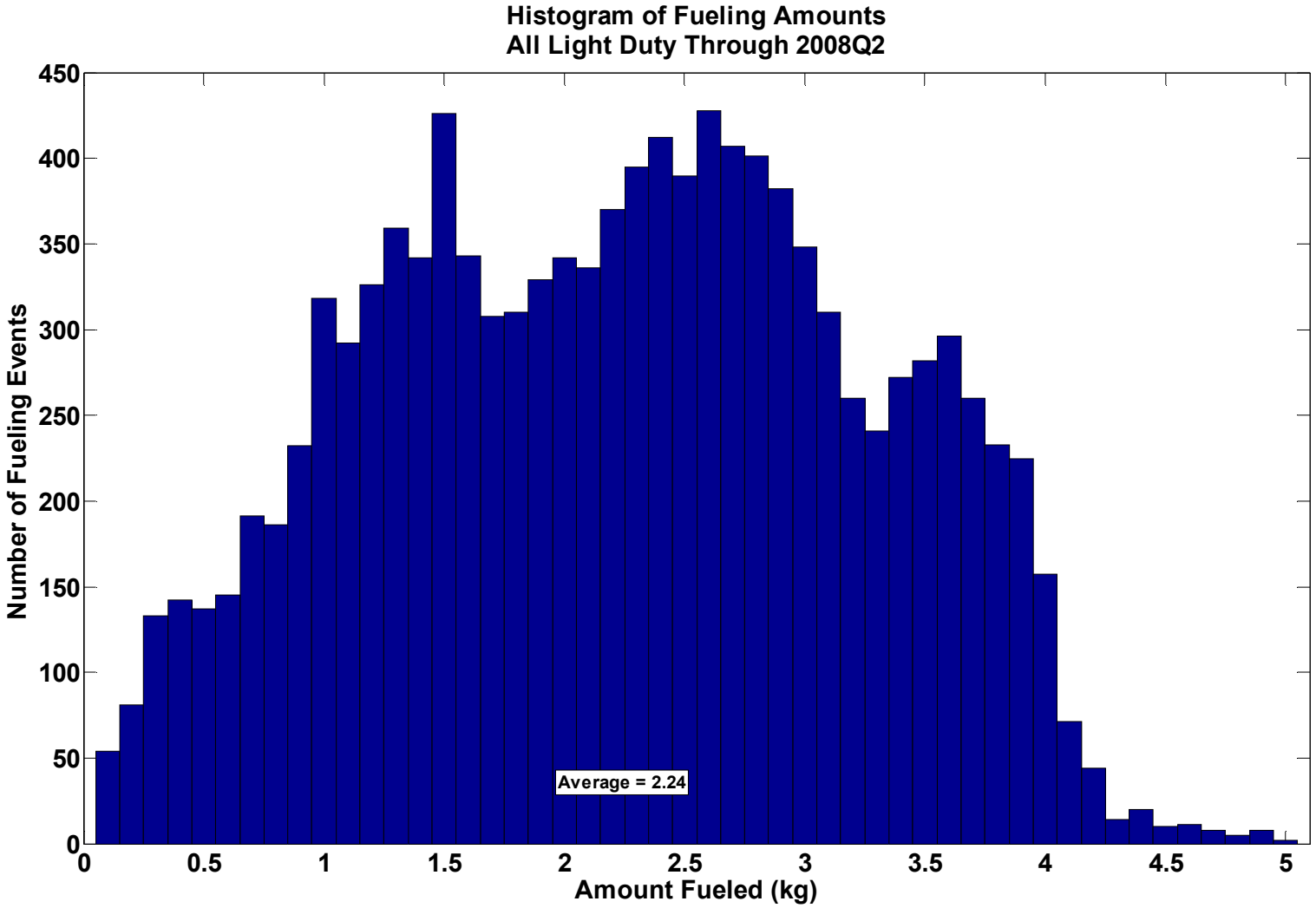
- an event that under slightly different circumstances could have become an incident
- unplanned H2 release insufficient to sustain a flame

Created: Sep-02-08 5:01 PM

CDP#38: Refueling Times

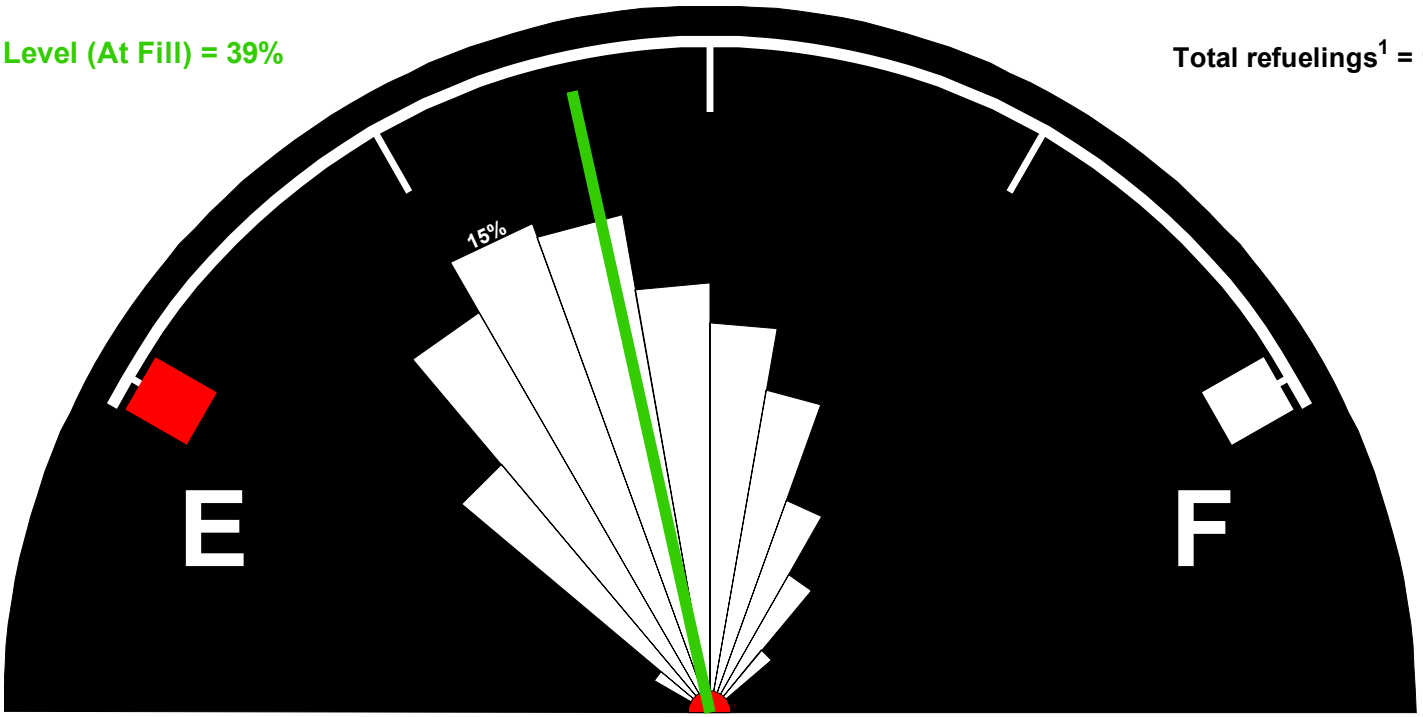


CDP#39: Refueling Amounts



Created: Sep-02-08 4:21 PM

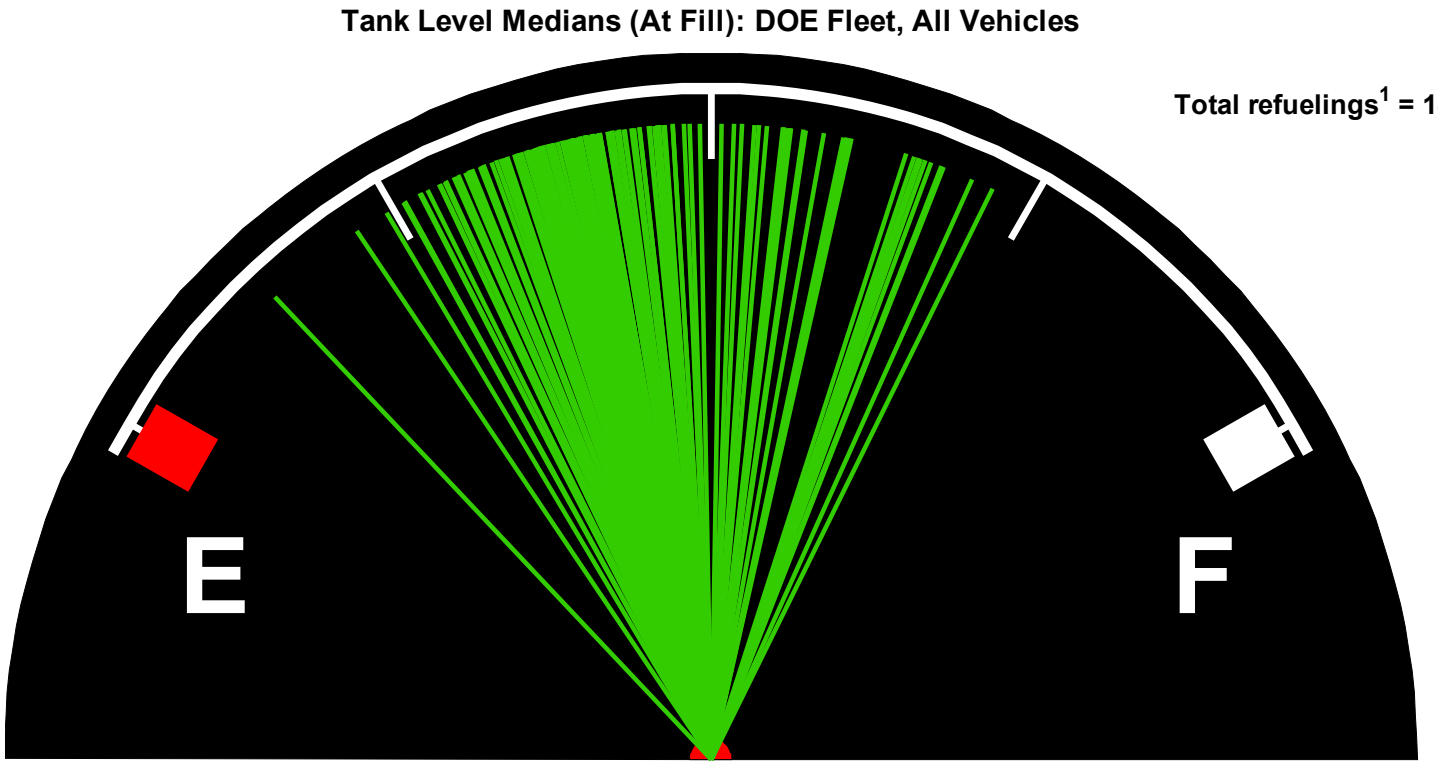
CDP#40: H2 Tank Level at Refueling



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: Sep-19-08 10:35 AM

CDP#41: Refueling Tank Levels - Medians



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.

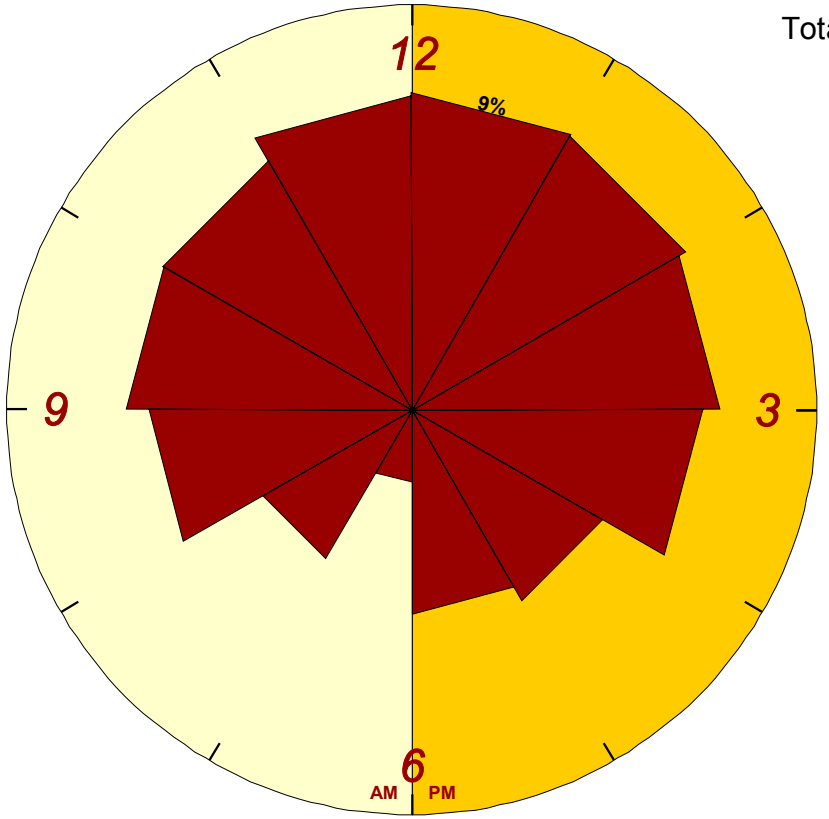
Created: Sep-19-08 10:35 AM

CDP#42: Refueling by Time of Day

Refueling by Time of Day: DOE Fleet

% of fills b/t 6 AM & 6 PM: 90.4%

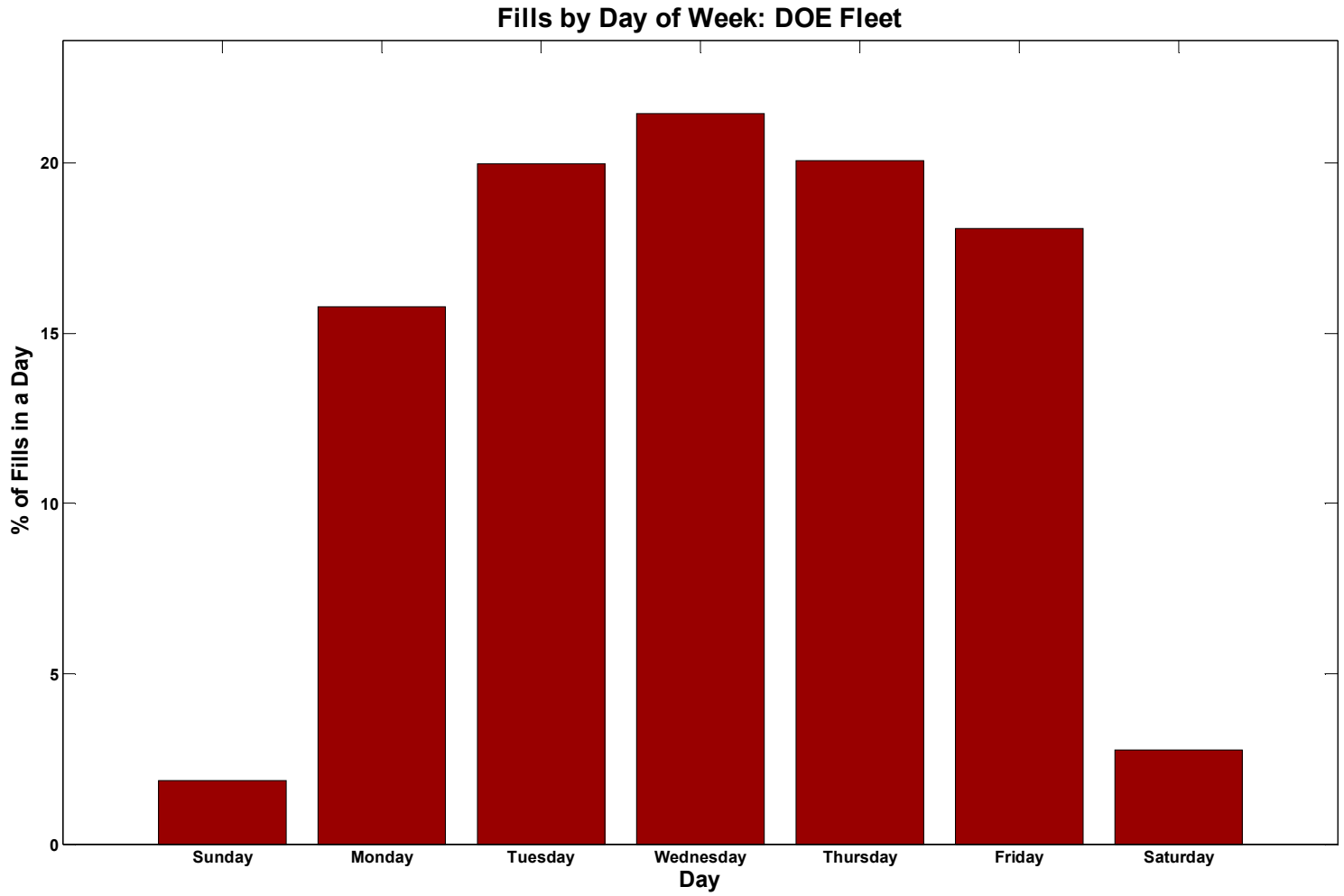
Total Fill[3] Events = 15158



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: Sep-19-08 10:35 AM

CDP#43: Refueling by Day of Week



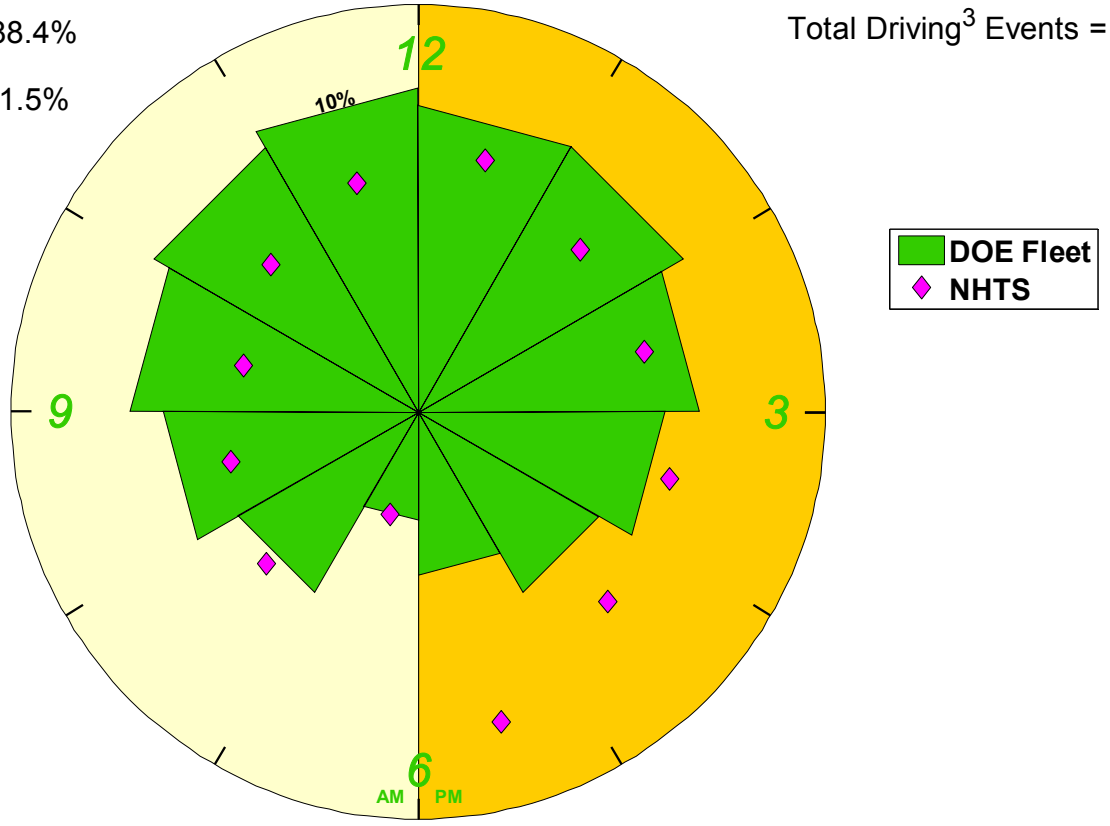
Created: Sep-19-08 10:35 AM

CDP#44: Driving Start Time – Day

Driving Start Time - Day: DOE Fleet

% of driving trips b/t 6 AM & 6 PM: 88.4%

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



Total Driving[3] Events = 181174

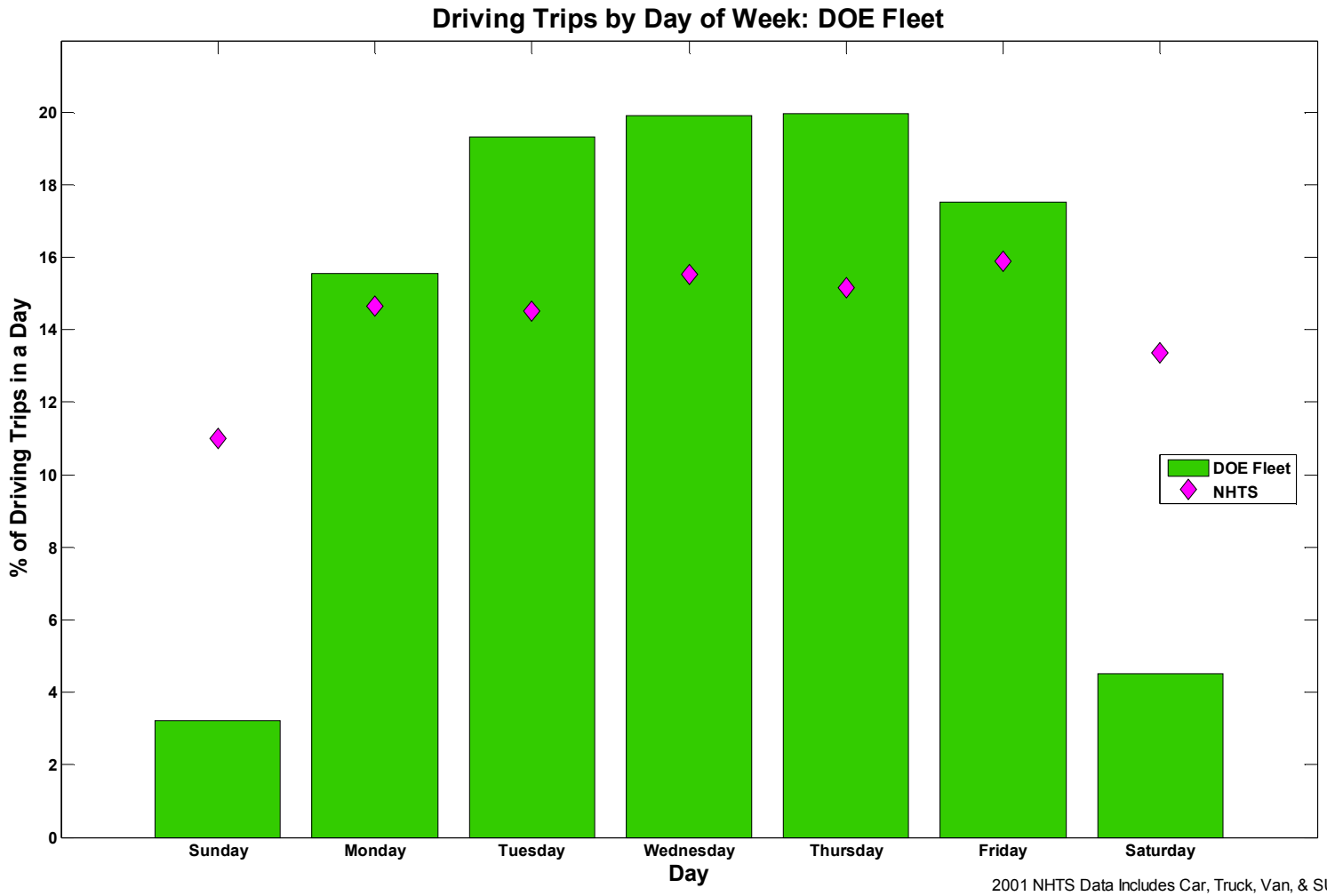
1. Driving trips between 6 AM & 6 PM
2. The outer arc is set at 12 % total Driving.
3. Some events not recorded/detected due to data noise or incompleteness.

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

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

Created: Aug-29-08 9:49 AM

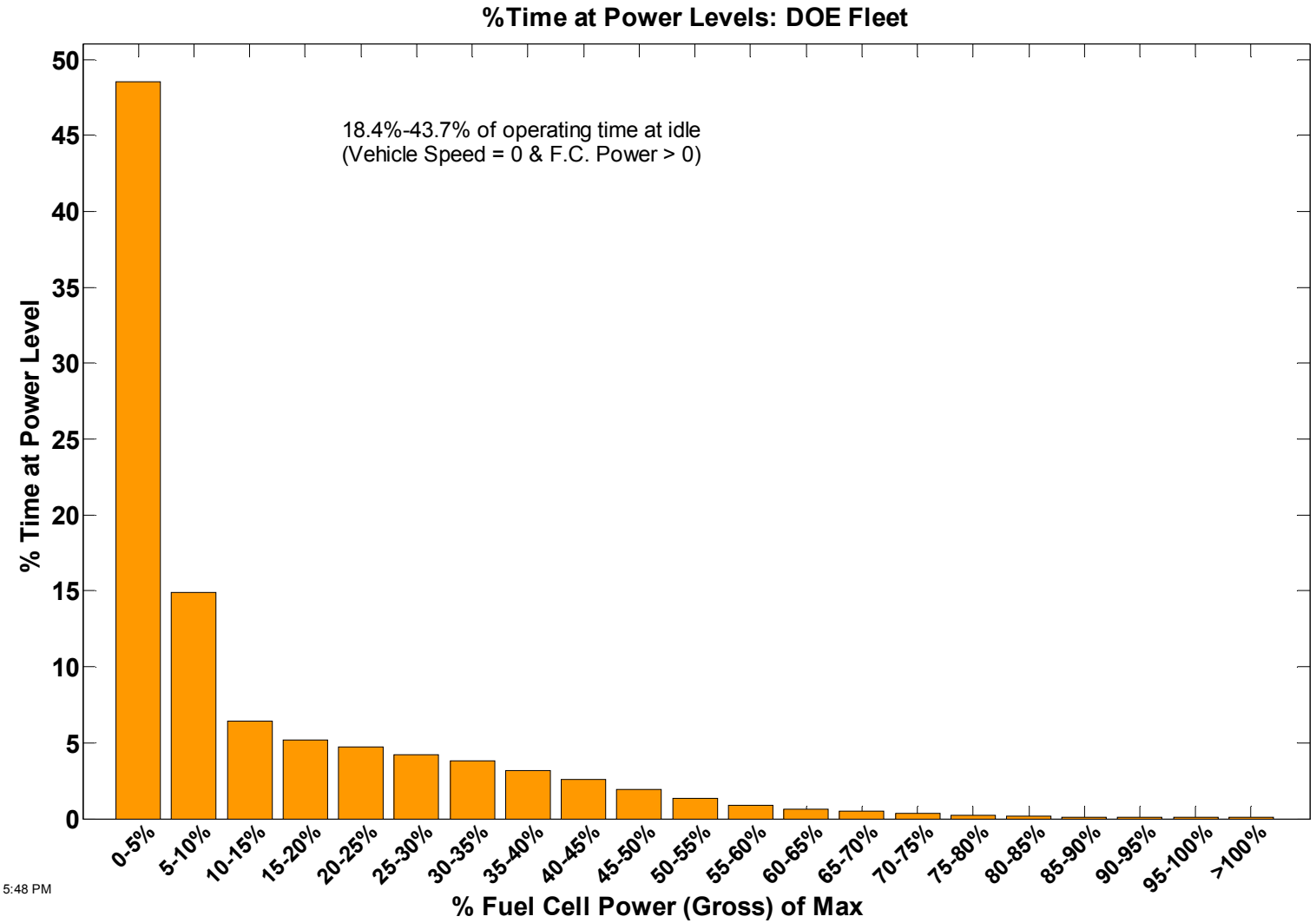
CDP#45: Driving by Day of Week



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

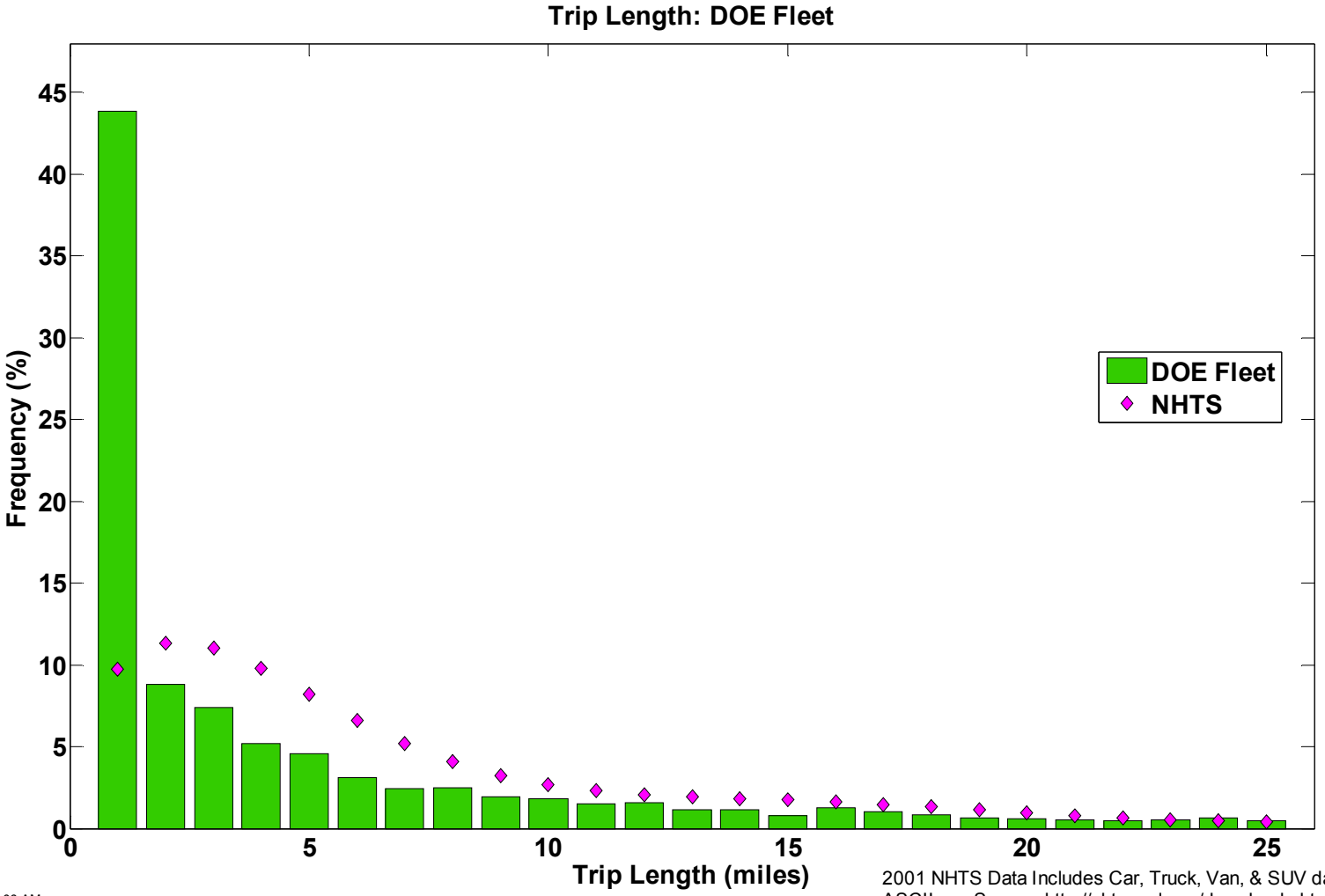
Created: Aug-29-08 9:49 AM

CDP#46: Fuel Cell System Operating Power



Created: Aug-28-08 5:48 PM

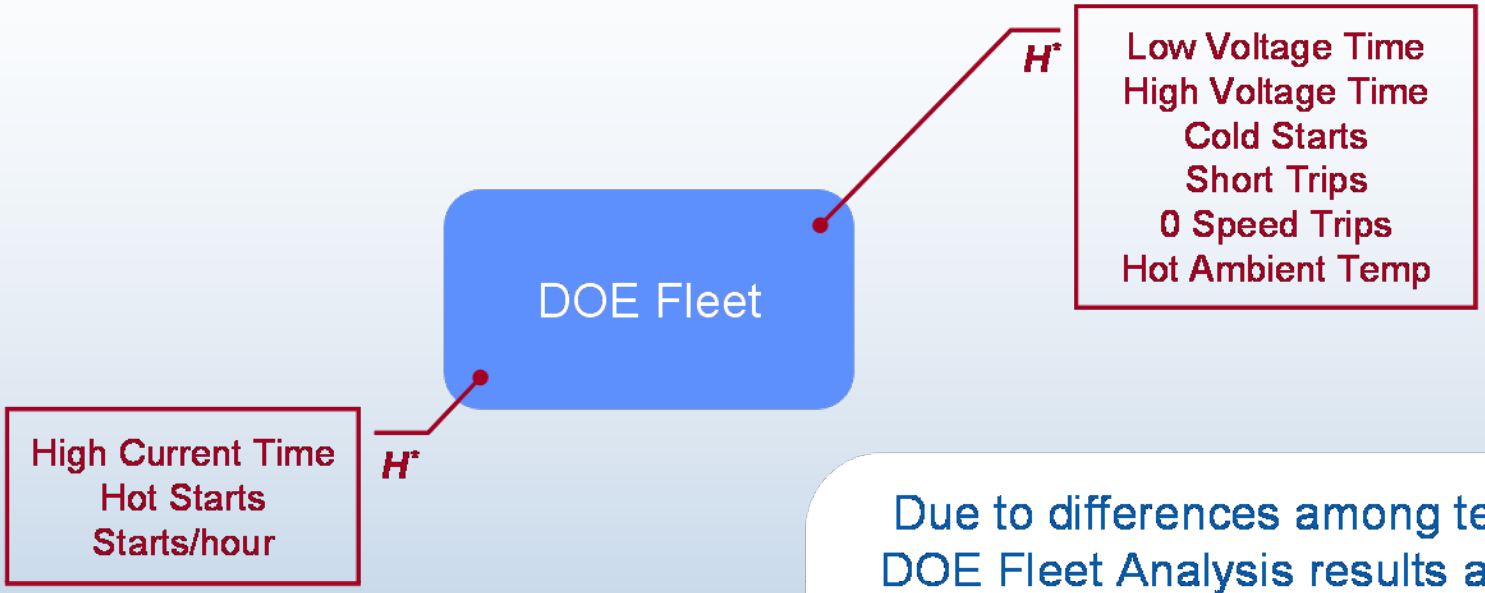
CDP#47: Trip Length



Created: Sep-03-08 11:06 AM

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



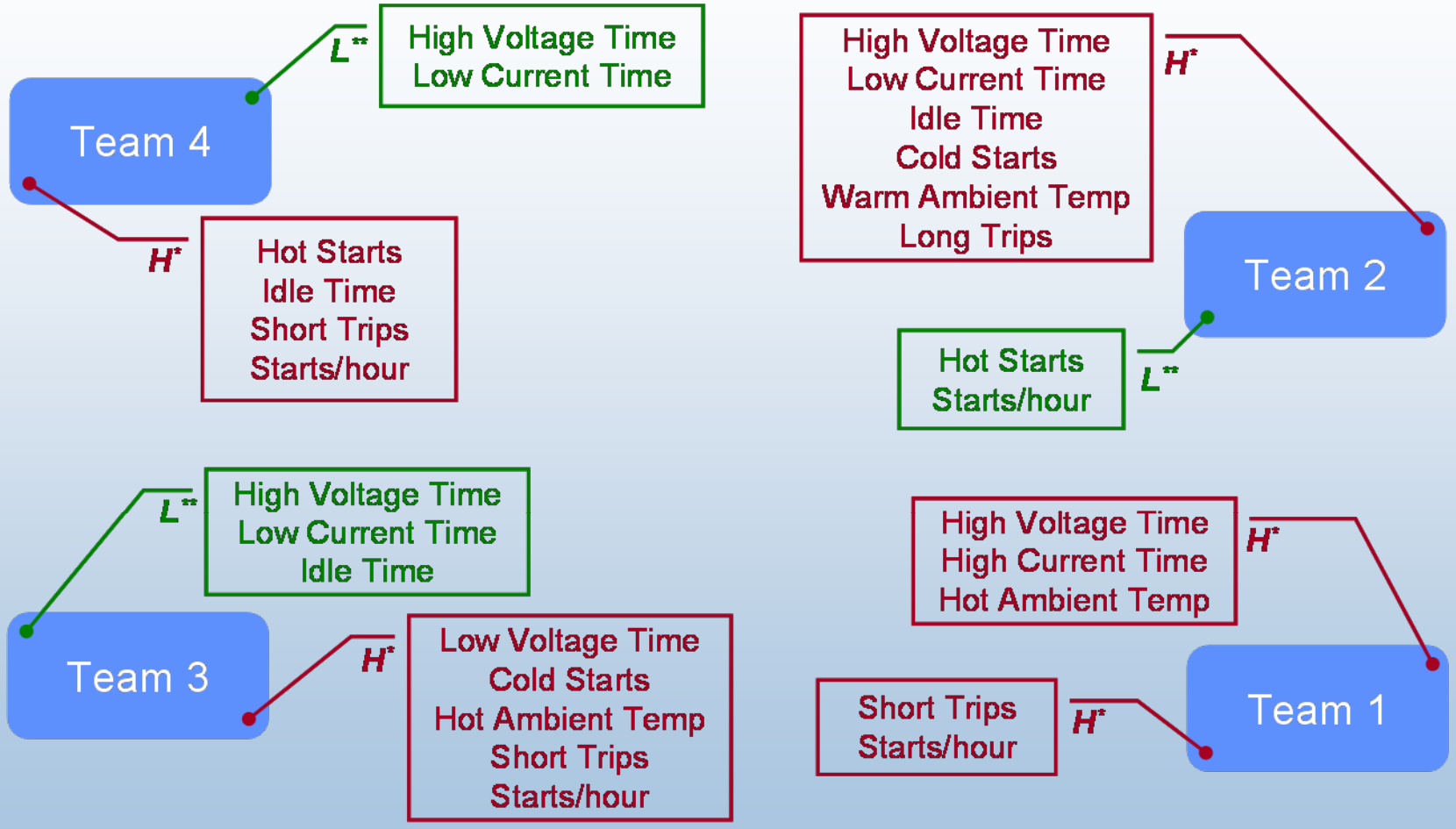
Due to differences among teams, the DOE Fleet Analysis results are spread out and concrete conclusions are difficult to draw.

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.
2) Teams' PLS models have a high percentage of explained decay rate variance, but the models are not robust and results are scattered.

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

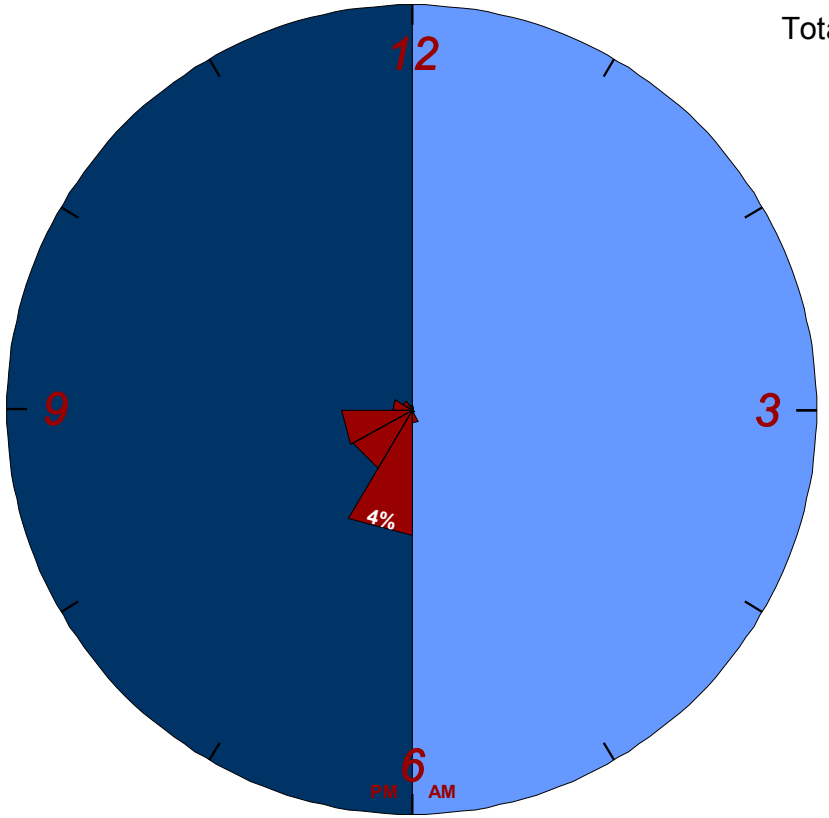
Created: Feb-27-08 12:17 PM

CDP#50: Refueling by Time of Night

Refueling by Time of Night: DOE Fleet

% of fills b/t 6 PM & 6 AM: 9.6%

Total Fill[3] Events = 15158



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.

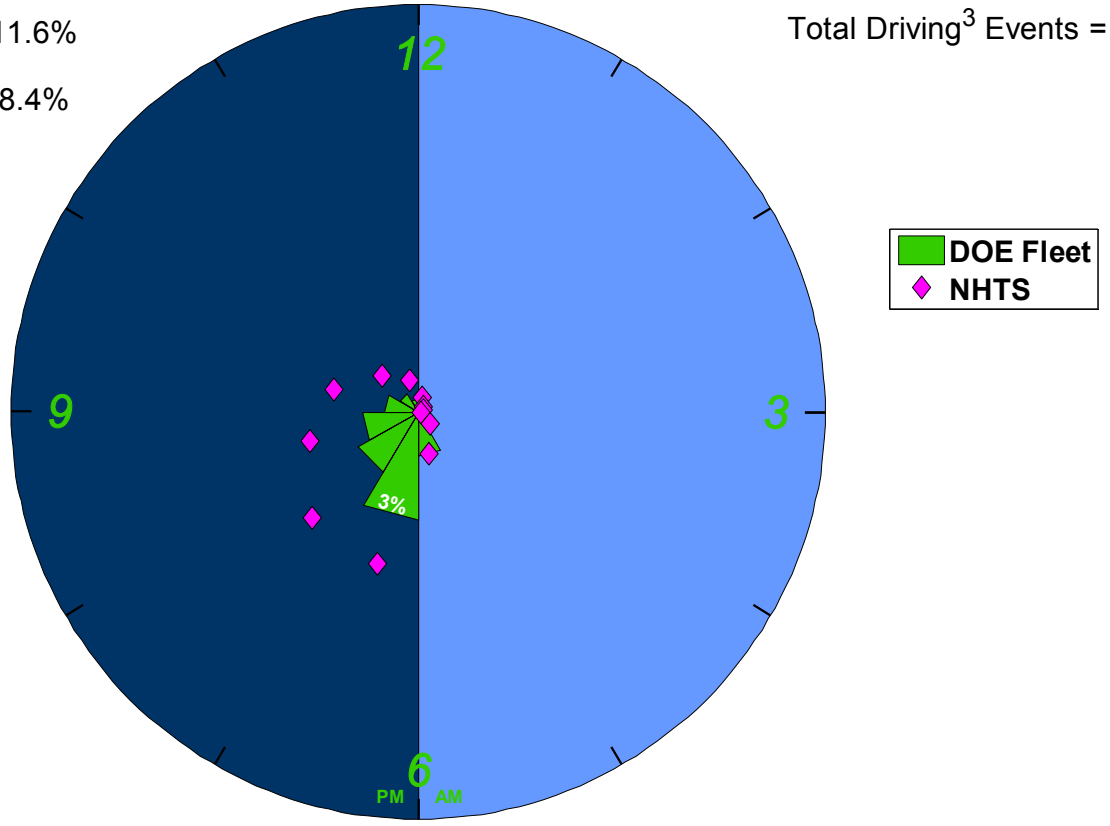
Created: Sep-19-08 10:35 AM

CDP#51: Driving Start Time – Night

Driving Start Time - Night: DOE Fleet

% of driving trips b/t 6 PM & 6 AM: 11.6%

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



Total Driving[3] Events = 181174

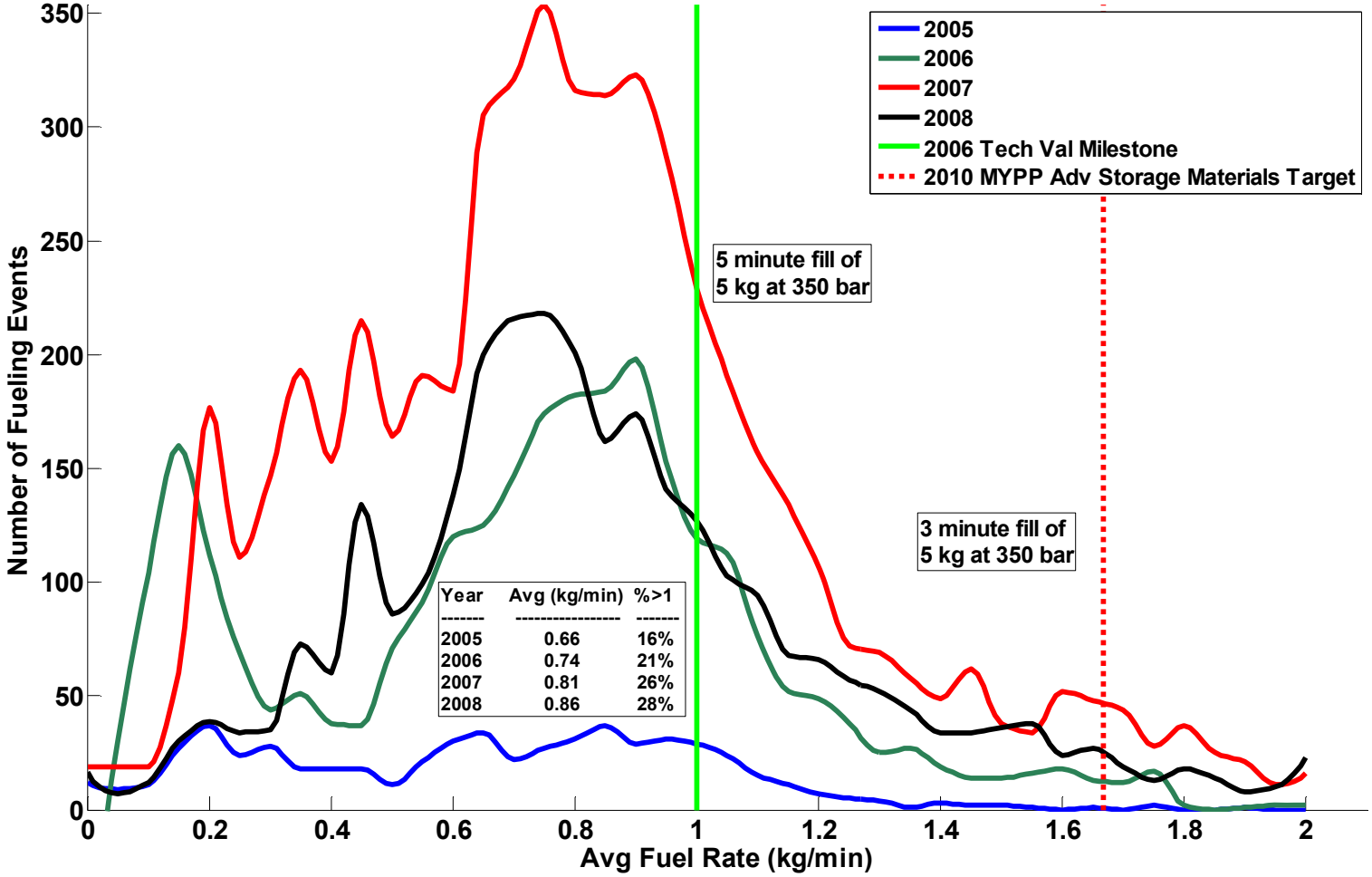
1. Driving trips between 6 PM & 6 AM
2. The outer arc is set at 12 % total Driving.
3. Some events not recorded/detected due to data noise or incompleteness.

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

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

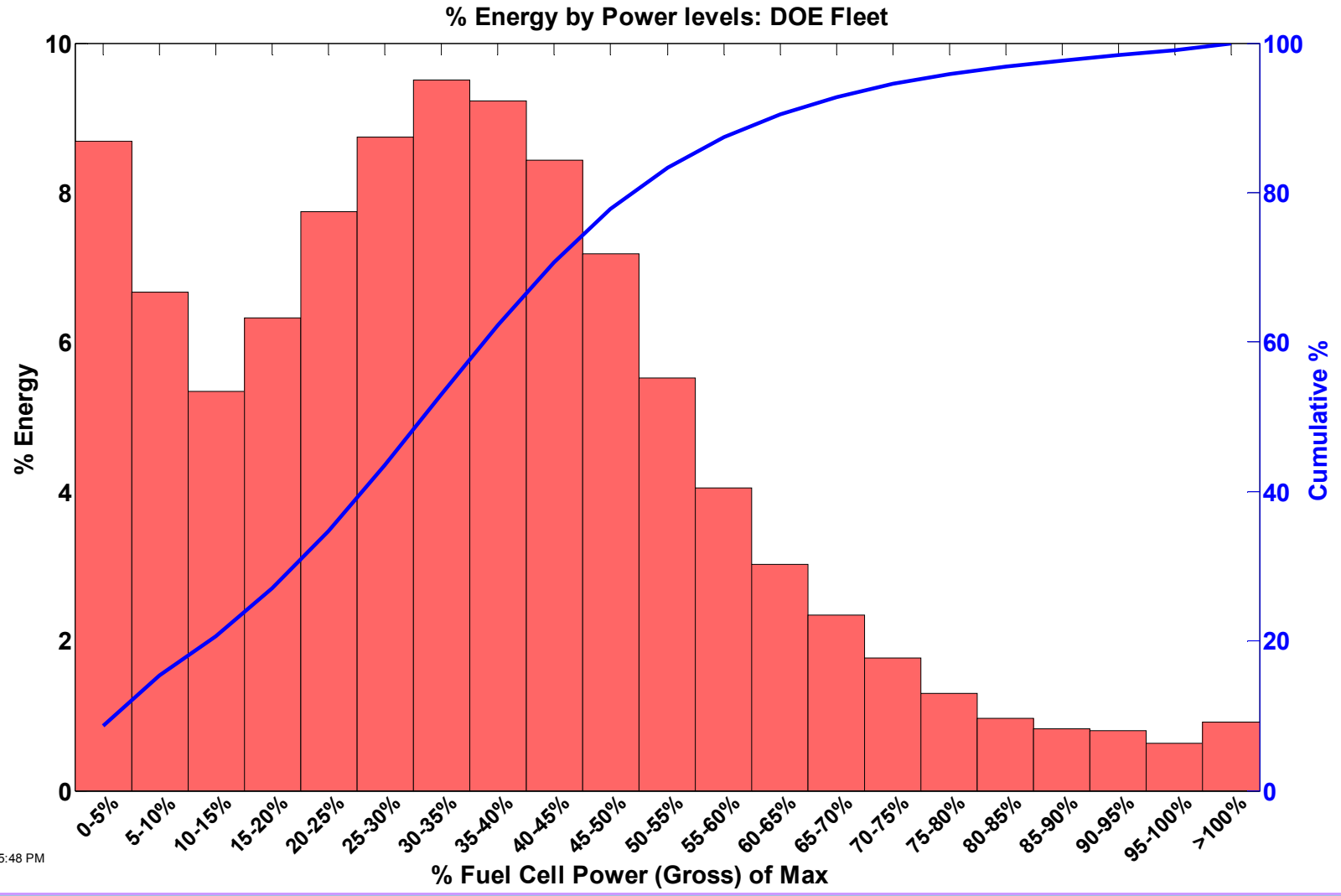
Created: Aug-29-08 9:49 AM

CDP#52: Refueling Data by Year



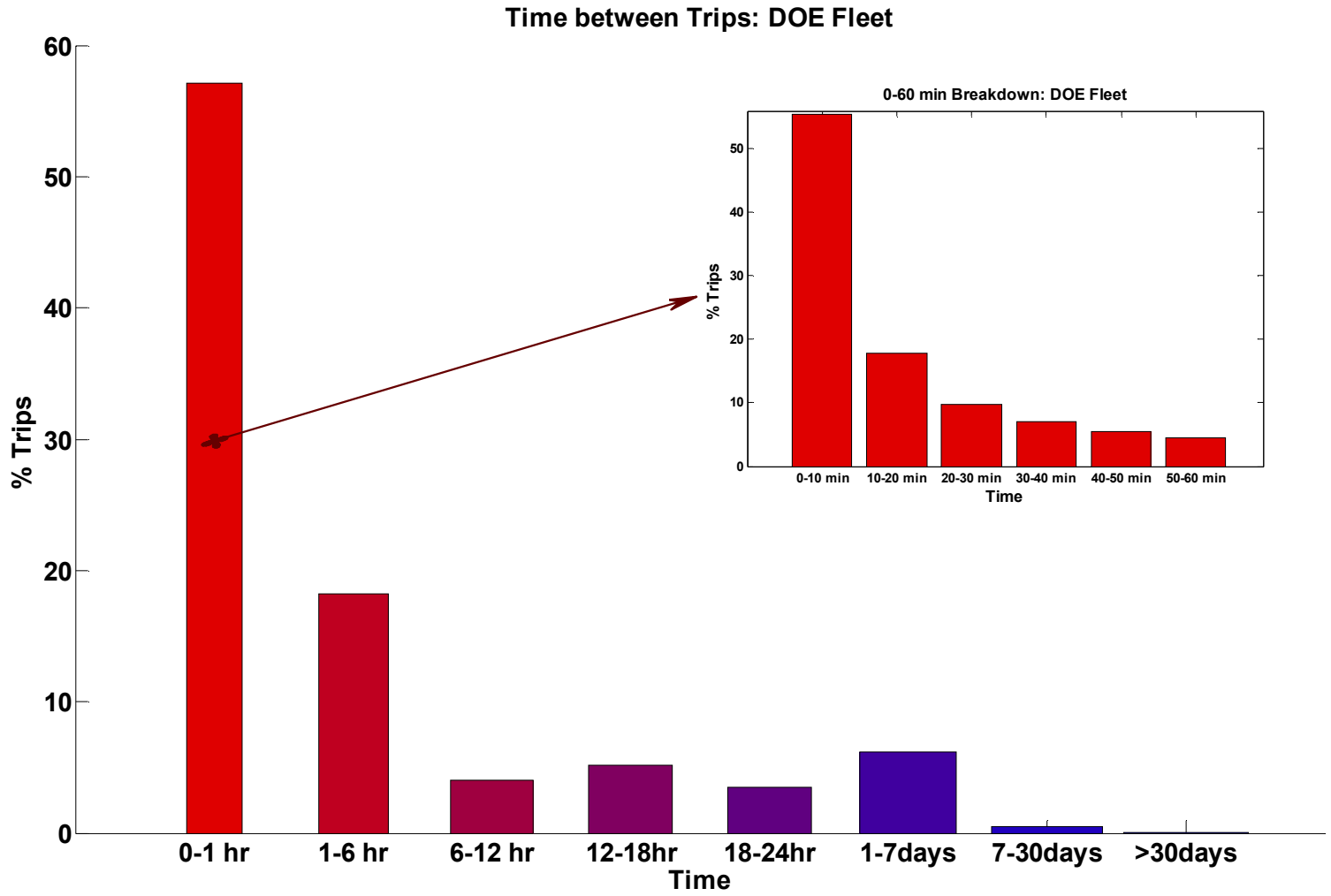
Created: Sep-02-08 4:21 PM

CDP#53: Fuel Cell System Energy within Power Levels



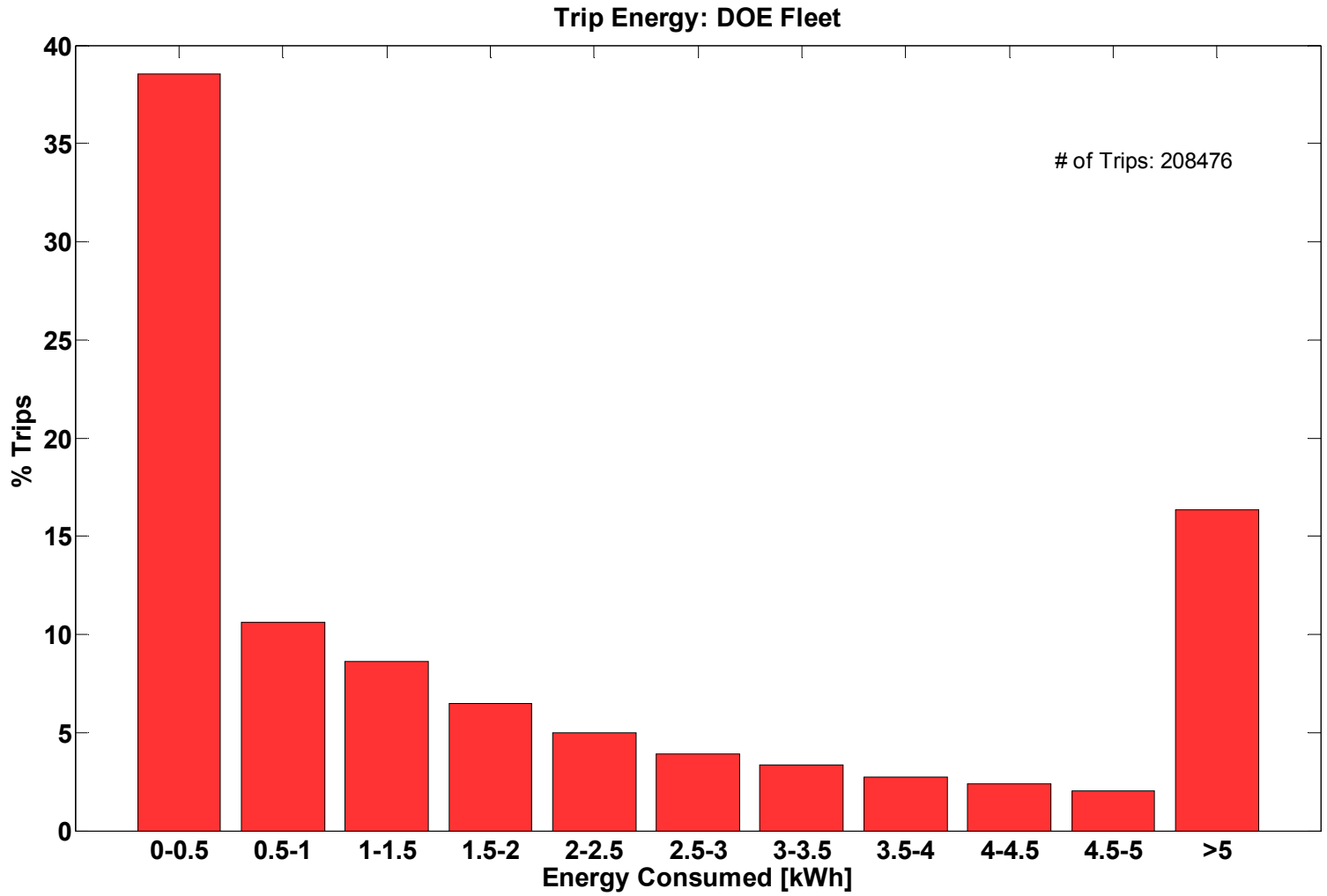
Created: Aug-28-08 5:48 PM

CDP#54: Time Between Trips



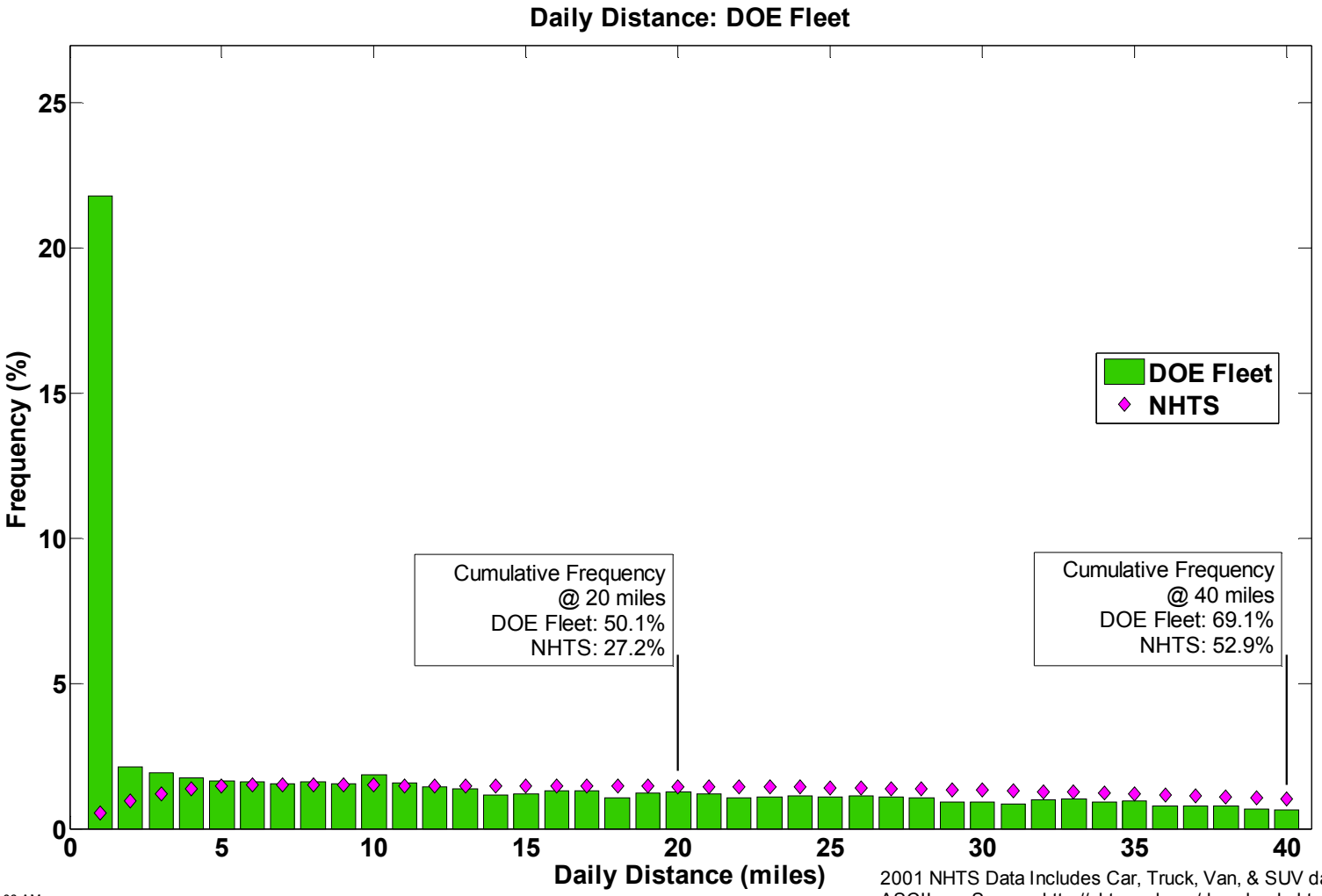
Created: Sep-03-08 11:06 AM

CDP#55: Fuel Cell System Energy



Created: Aug-28-08 5:48 PM

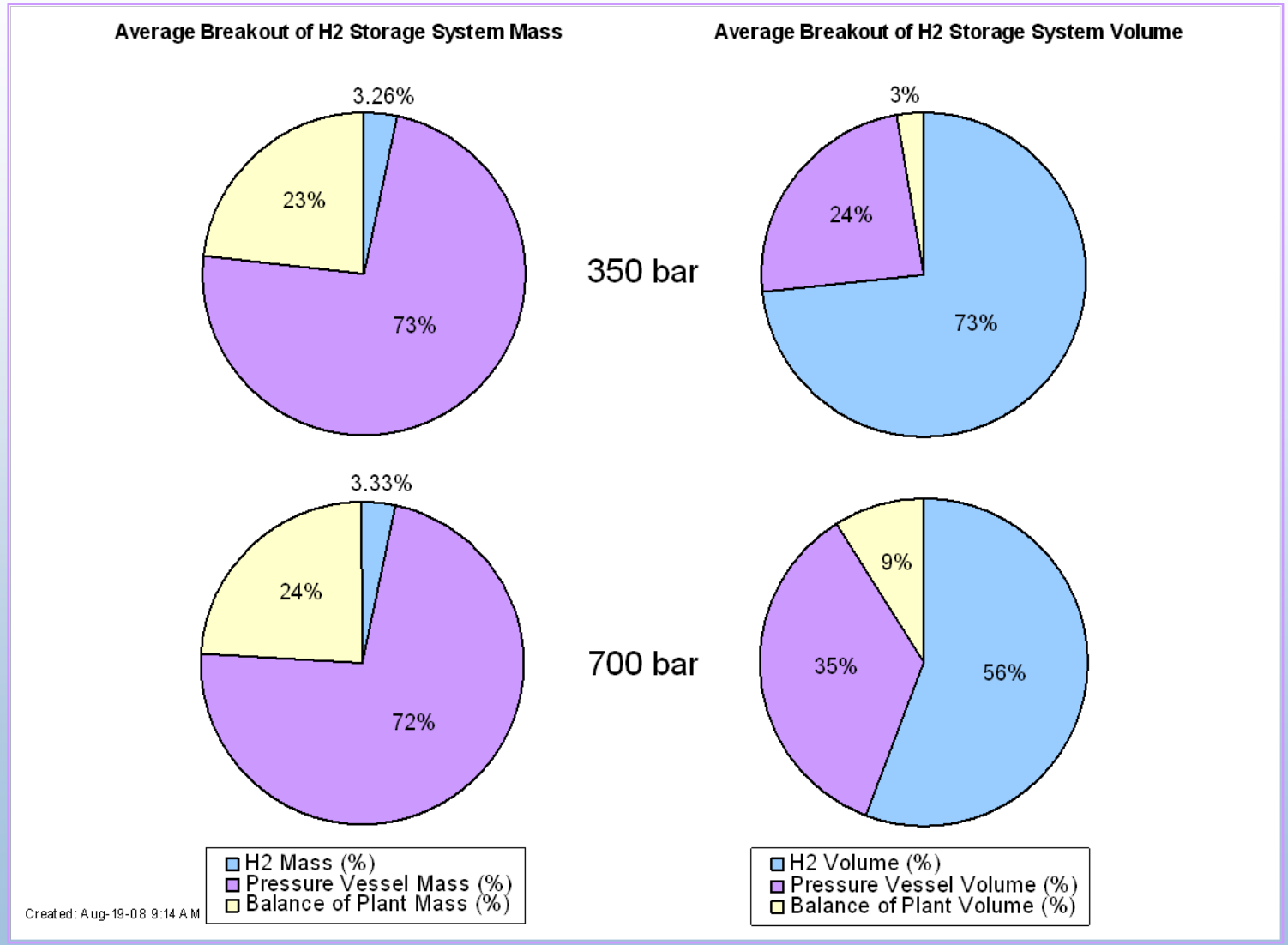
CDP#56: Daily Driving Distance



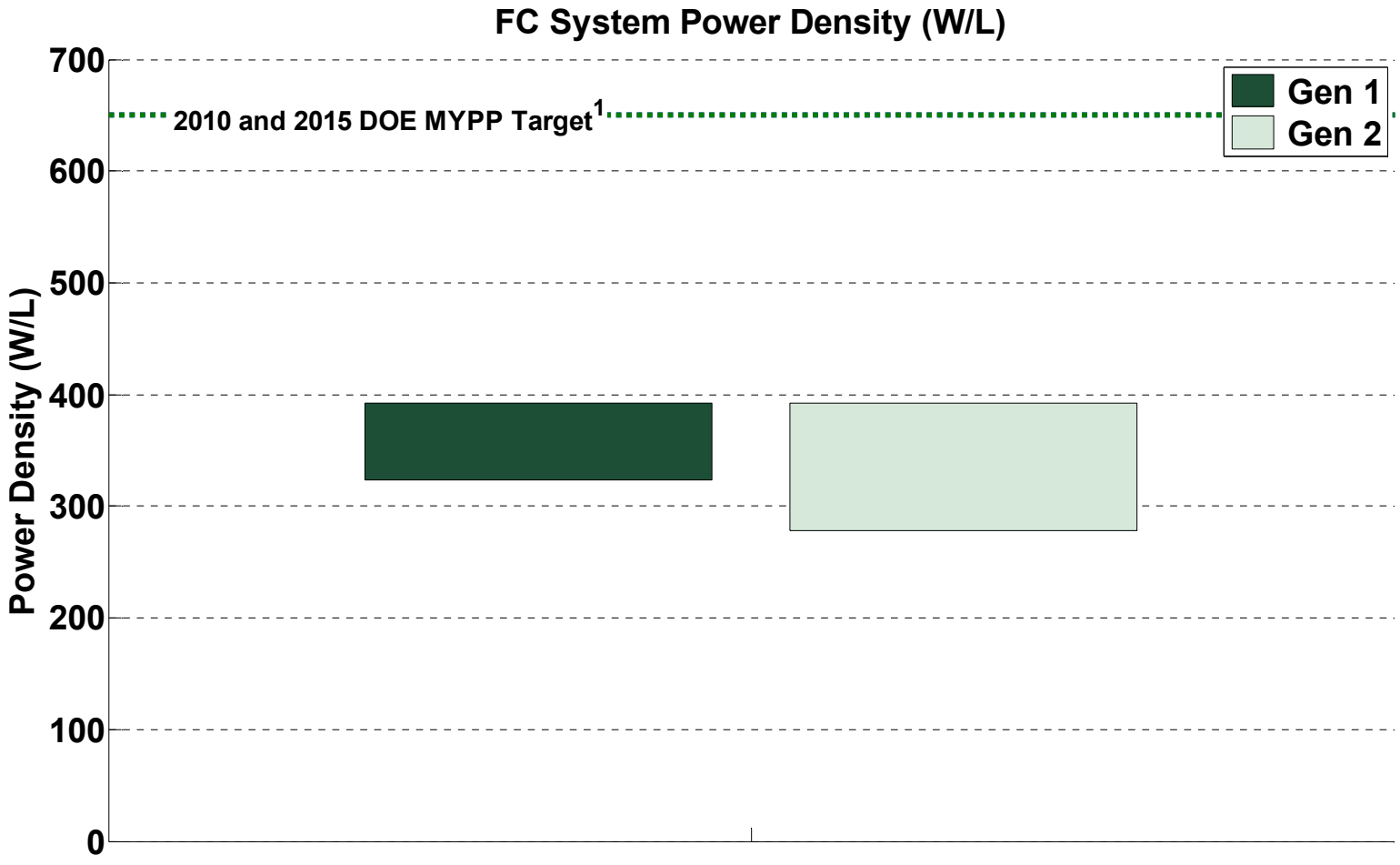
Created: Sep-03-08 11:06 AM

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



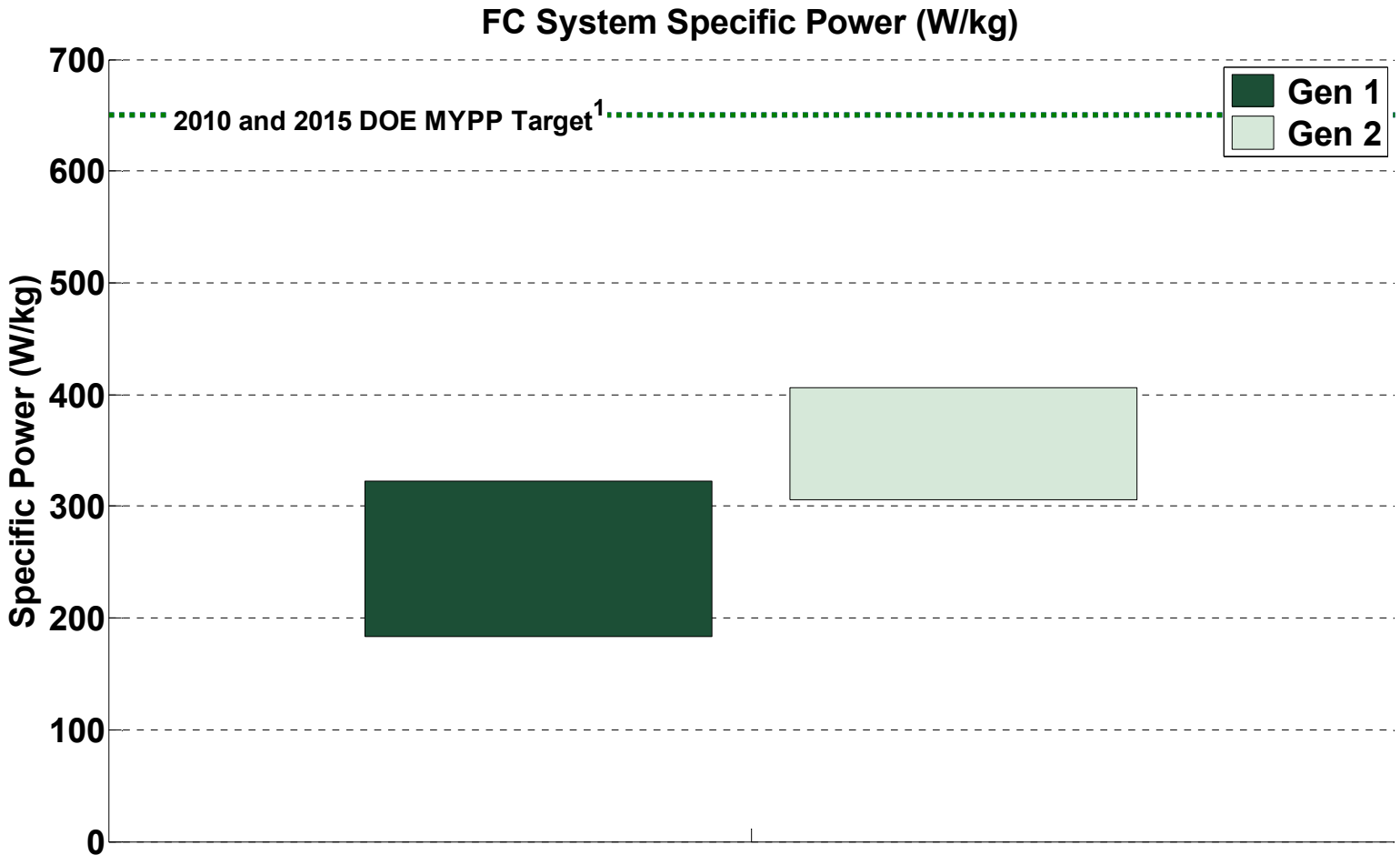
CDP#58: Fuel Cell System Power Density



Created: Sep-17-08 10:29 AM

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

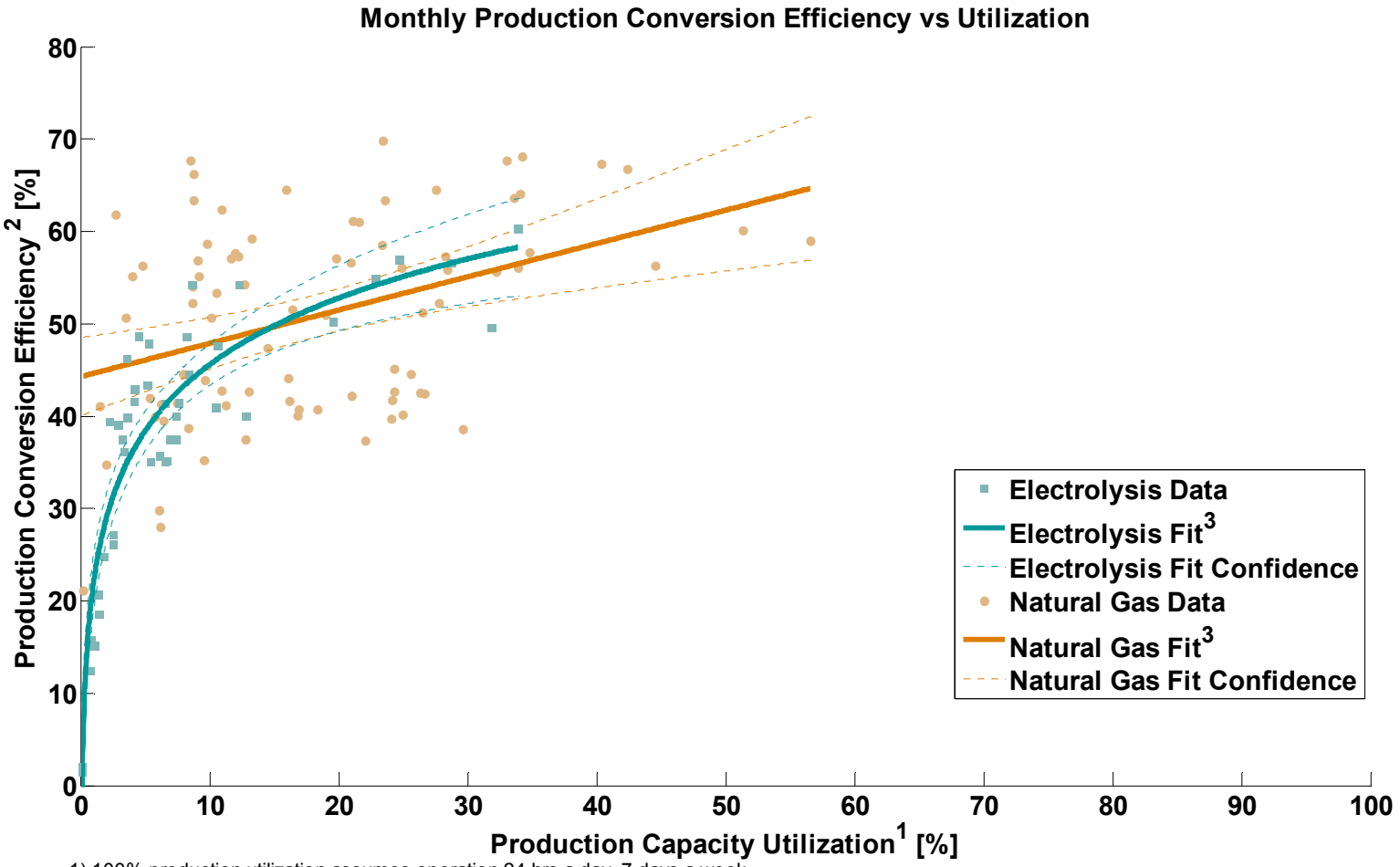
CDP#59: Fuel Cell System Specific Power



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



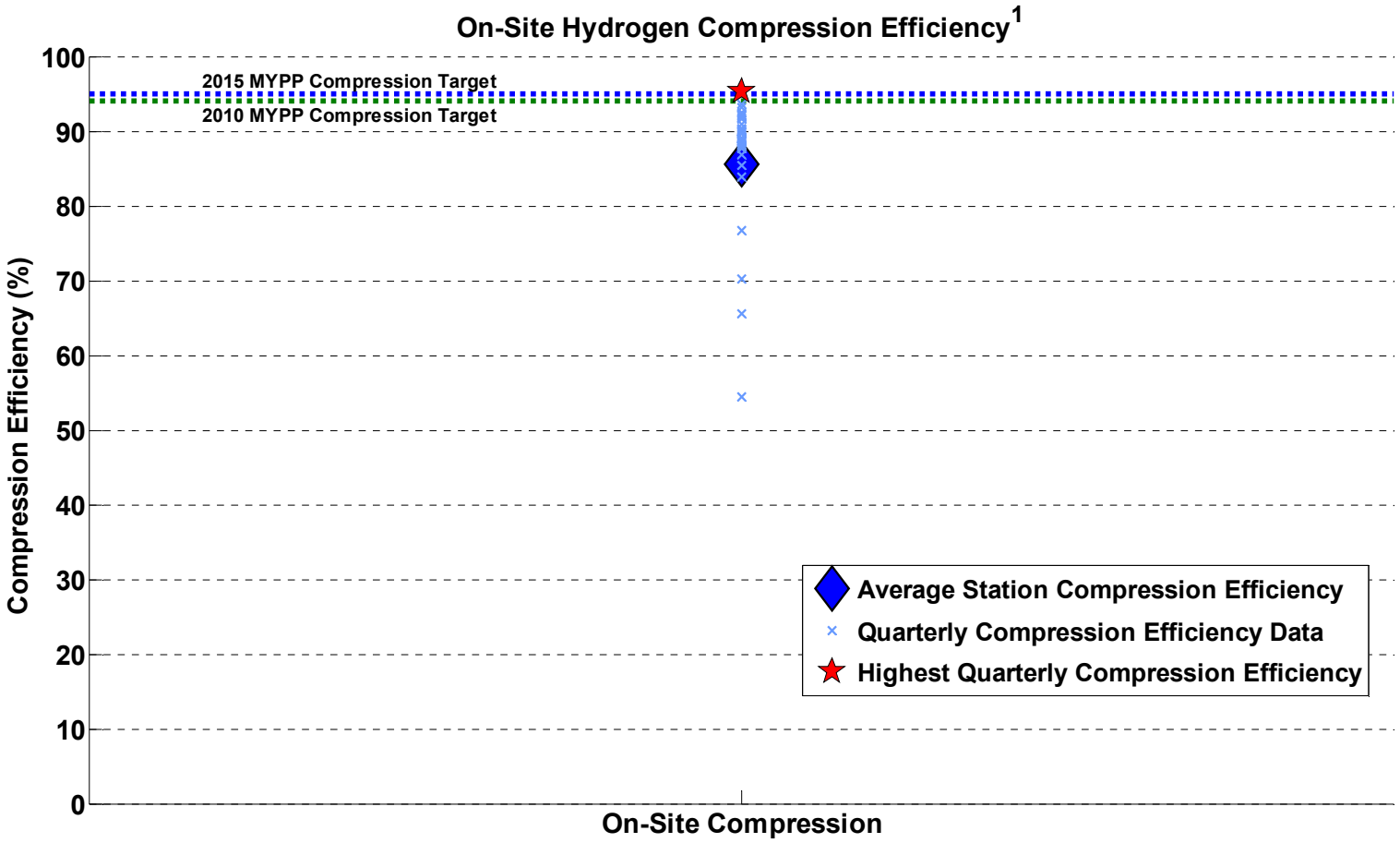
1) 100% production utilization assumes operation 24 hrs a day, 7 days a week

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 = 0.81) & low correlation with natural gas data (R^2 = 0.058)

Created: Sep-24-08 4:15 PM

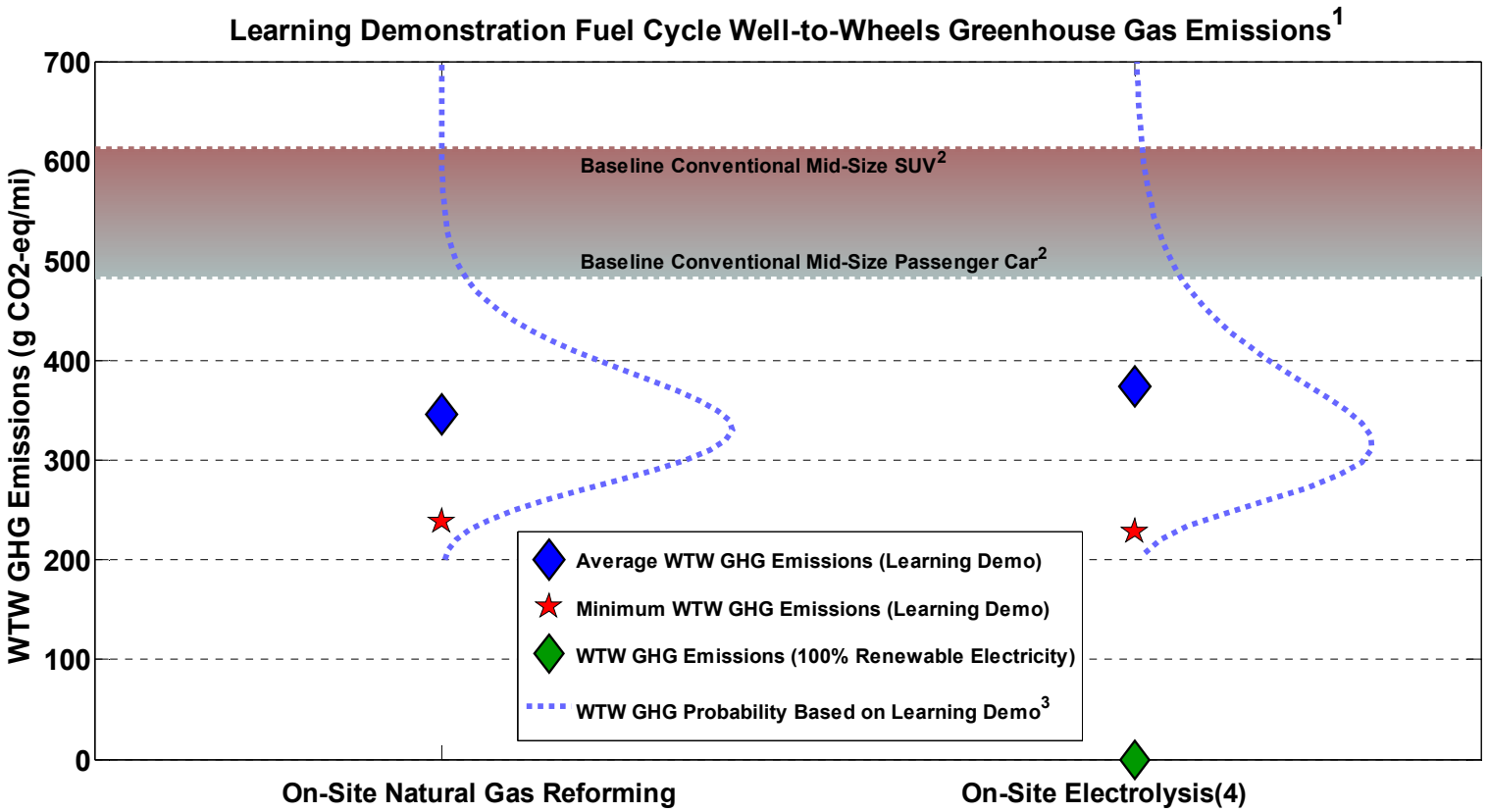
CDP#61: Refueling Station Compressor Efficiency



[1]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: Sep-03-08 4:45 PM

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 1296 g/mile.

Created: Sep-24-08 4:19 PM

REPORT DOCUMENTATION PAGE

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OMB No. 0704-0188

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October 2008	Technical Report	

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
K. Wipke, S. Sprik, J. Kurtz, and T. Ramsden

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13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
Graphs of composite data products produced by DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation project through September 2008.

15. SUBJECT TERMS
hydrogen; hydrogen demonstration; hydrogen validation

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPONE NUMBER (*Include area code)*
Unclassified	Unclassified	Unclassified	UL		