



# Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

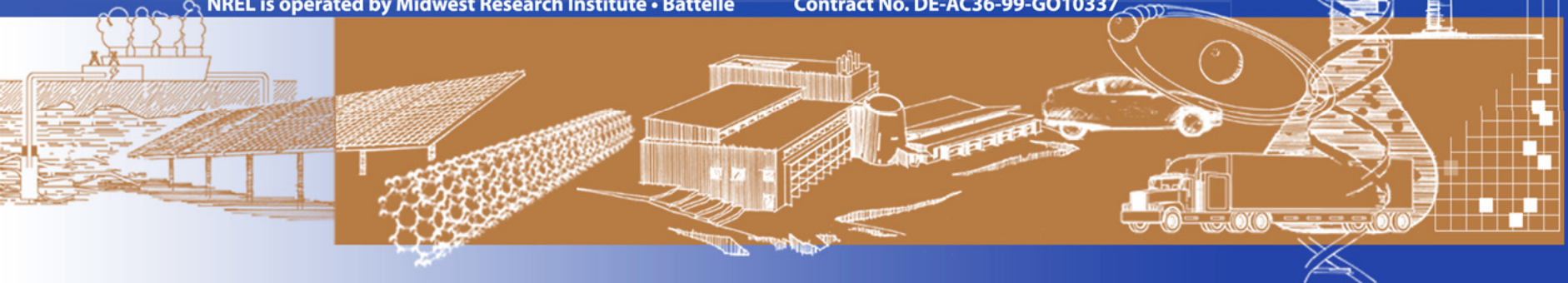
Spring 2007 Composite Data Products  
March 8, 2007

K. Wipke, S. Sprik, H. Thomas, and C. Welch

*Technical Report*  
NREL/TP-560-41413  
April 2007

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# **Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project**

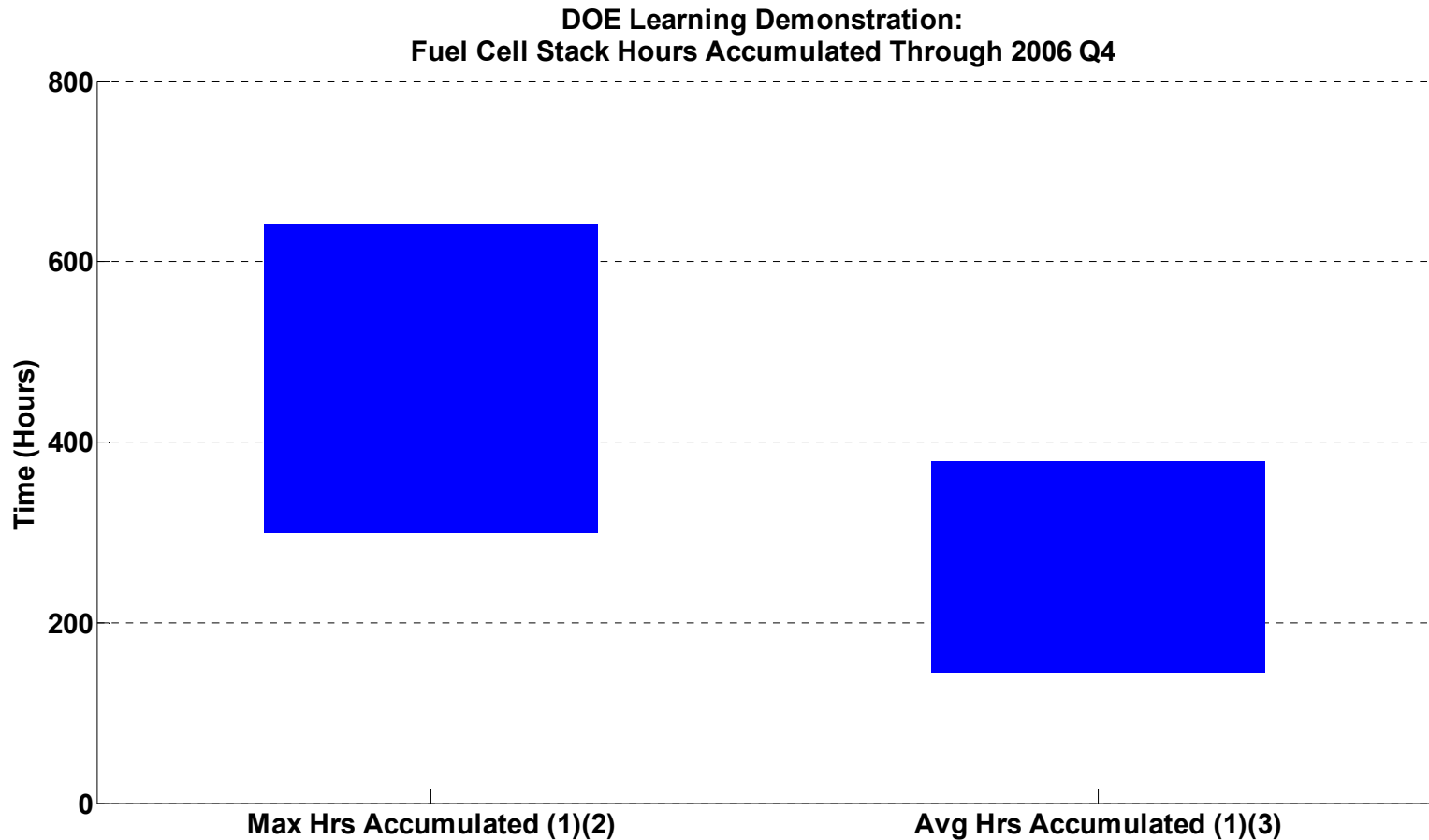
***Spring 2007***

***Composite Data Products***

***3/8/07***

Keith Wipke, Sam Sprik, Holly Thomas, Cory Welch

# CDP#1A: Learning Demo Fuel Cell Stack Hours Accumulated Through 2006 Q4



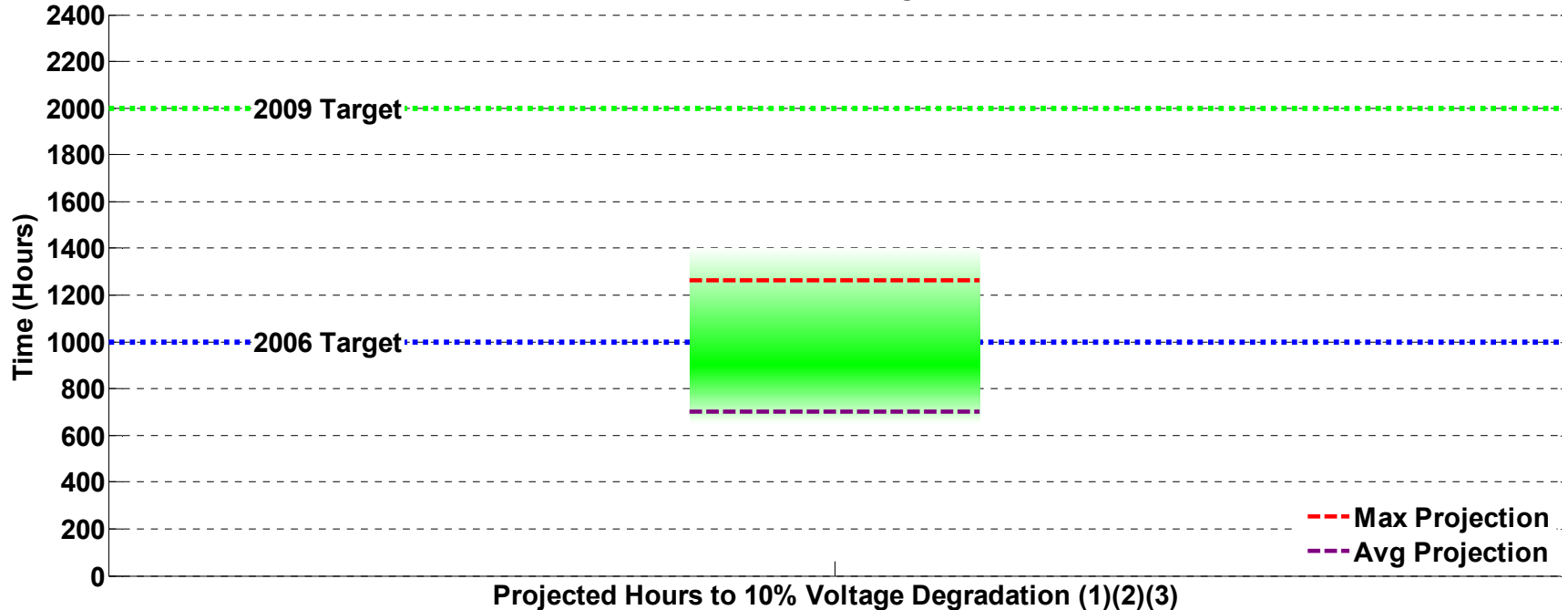
(1) Range bars created using one data point for each OEM.

(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.

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

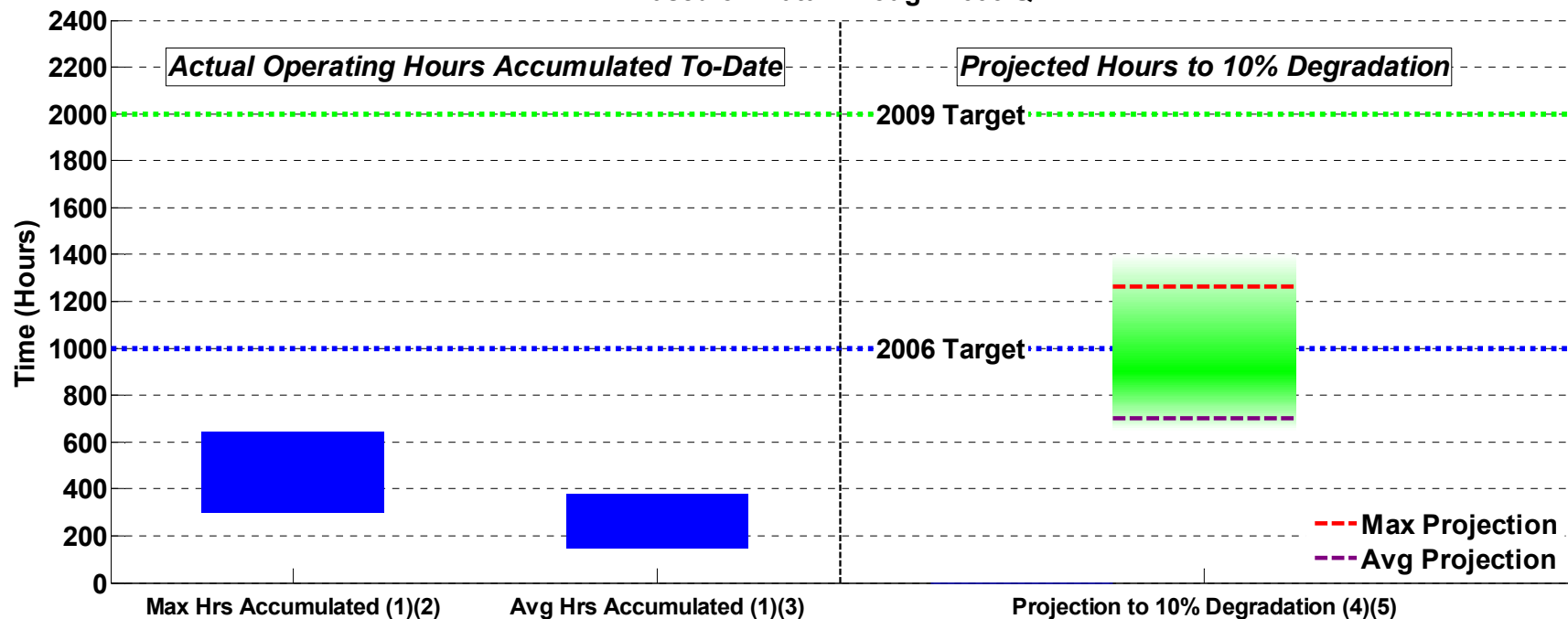
DOE Learning Demonstration Fuel Cell Stack Durability:  
Based on Data Through 2006 Q4



- (1) 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.
- (2) 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 due to data and methodology limitations. Projections will change as additional data are accumulated.
- (3) Projections based on limited accumulated stack hours to date. Average stack hours accumulated to-date range between 145 and 379. Maximum stack hours accumulated to-date range between 300 and 642.

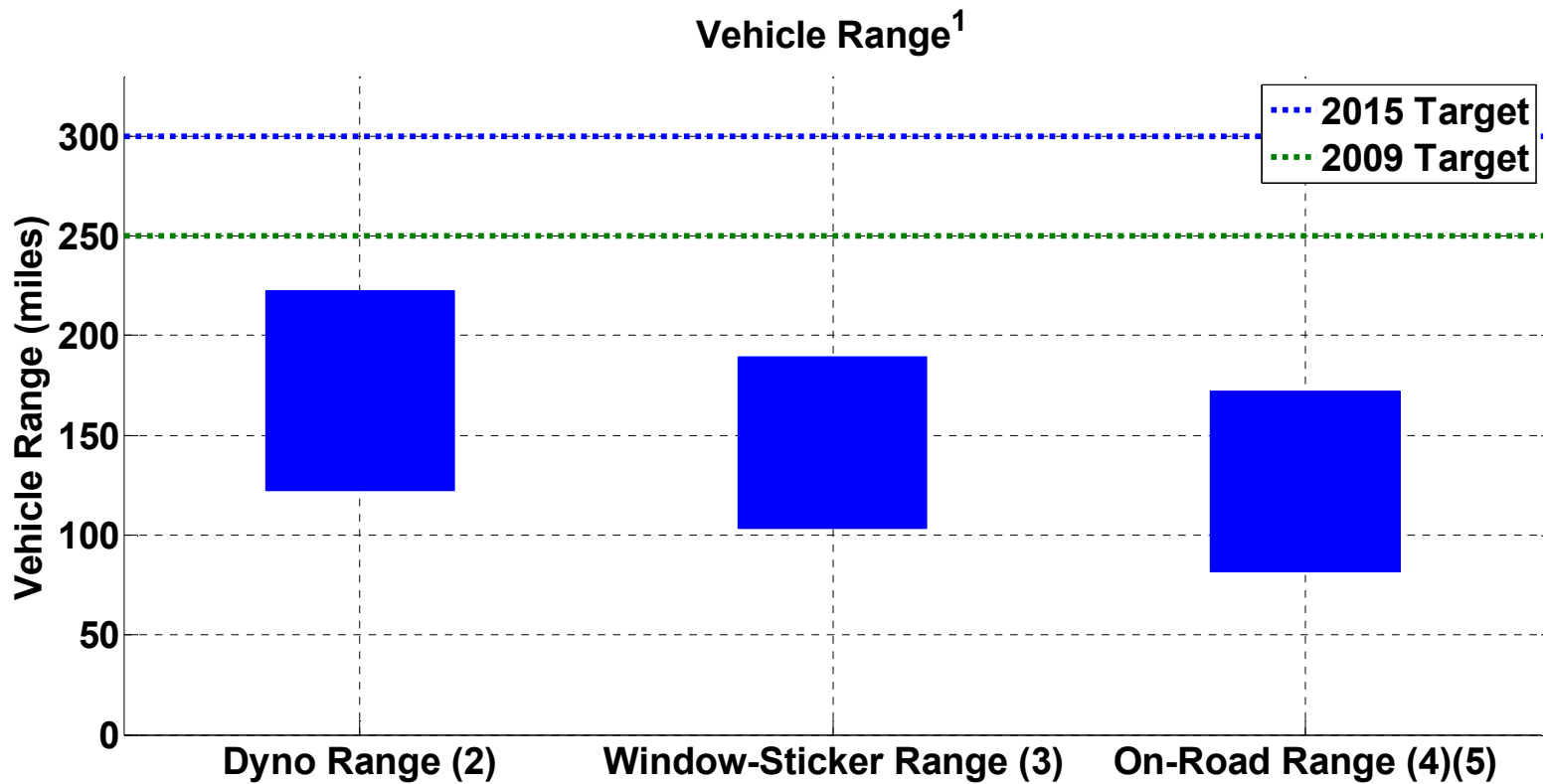
# CDP#1C: Hours Accumulated and Projected Hours to 10% Stack Voltage Degradation

DOE Learning Demonstration Fuel Cell Stack Durability:  
Based on Data Through 2006 Q4



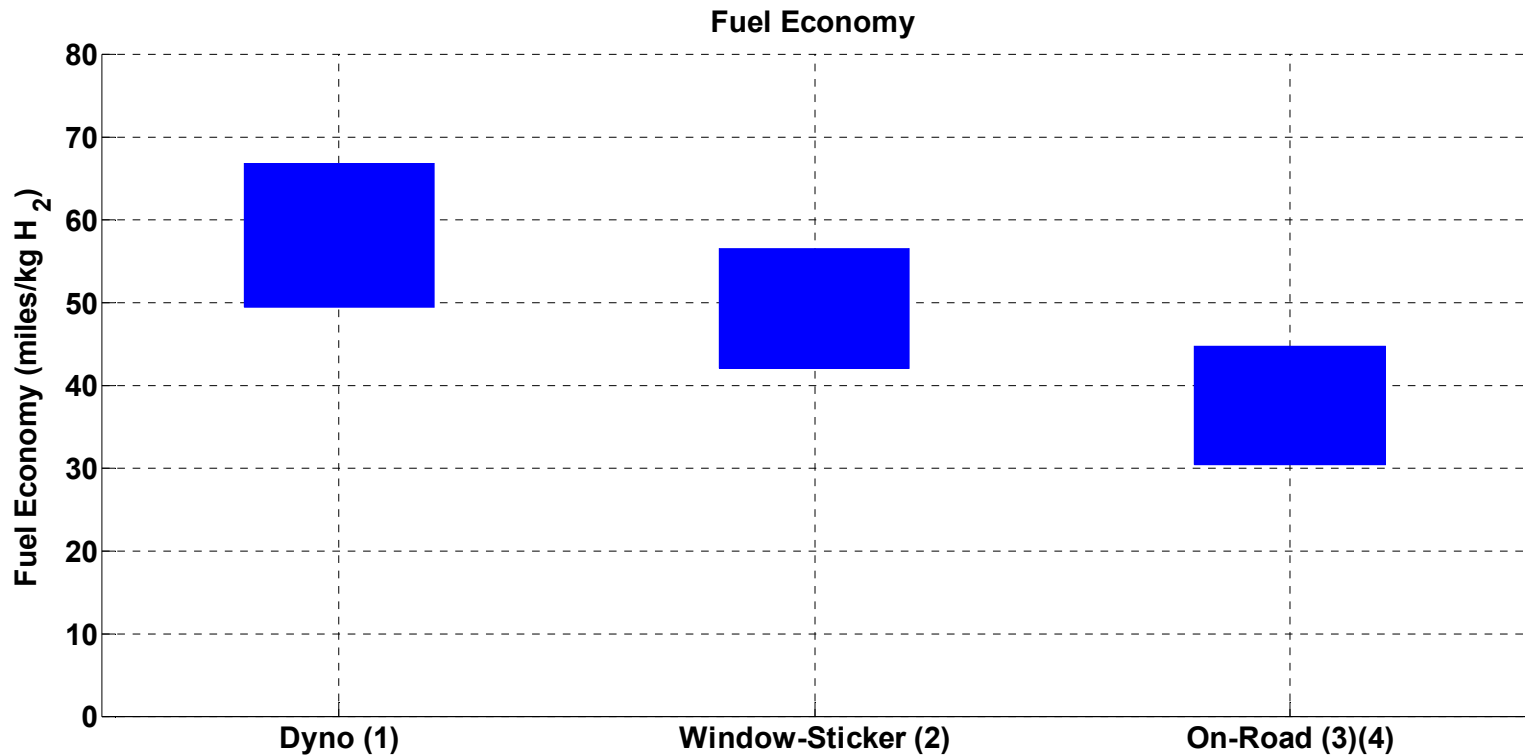
- (1) Range bars created using one data point for each OEM.
- (2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.
- (3) Range (highest and lowest) of the average operating hours accumulated to-date of all stacks in 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 due to data and methodology limitations. Projections will change as additional data are accumulated.

# 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.

# 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).

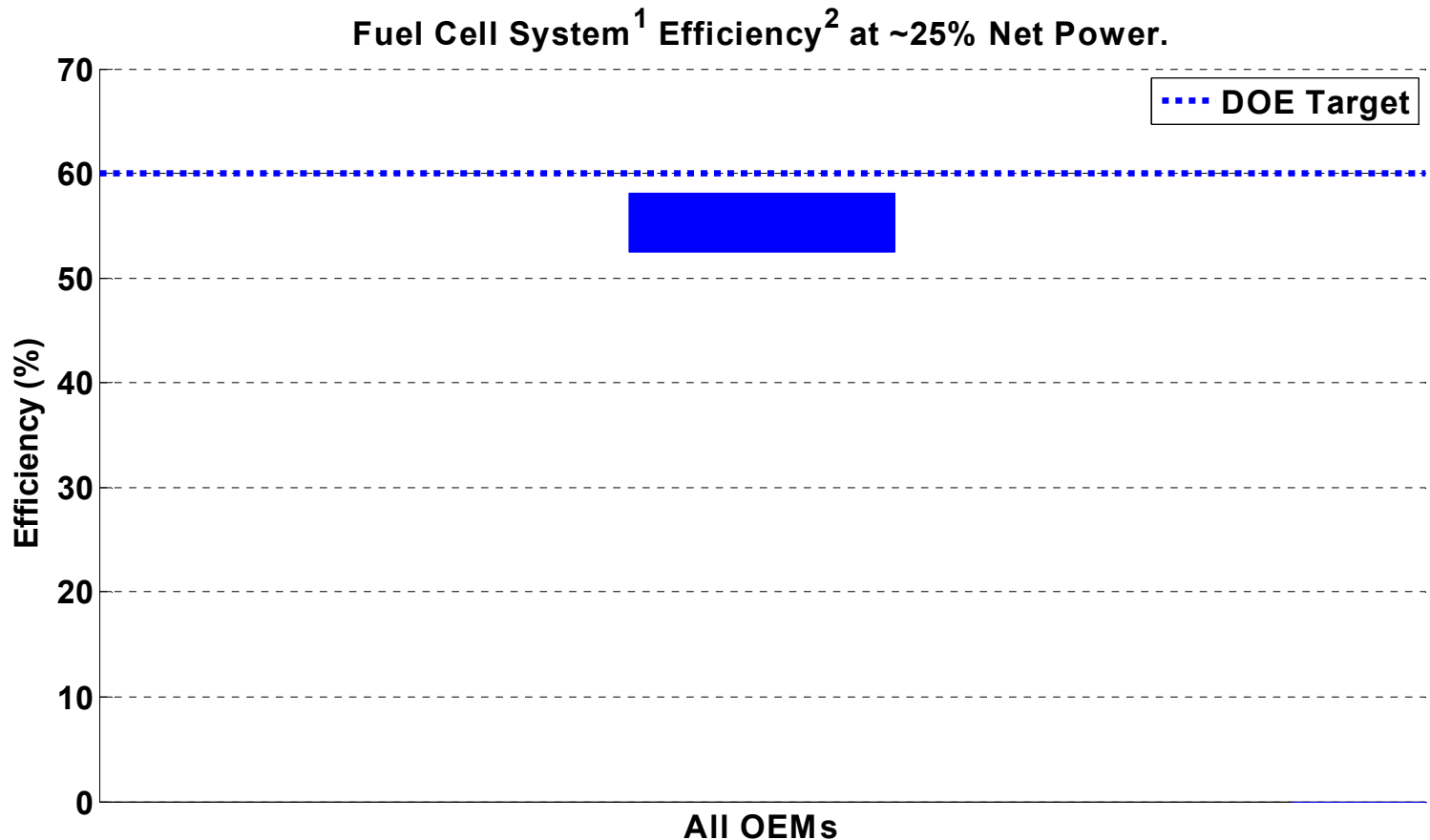
(3) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.

(4) Calculated from on-road fuel cell stack current or mass flow readings.

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# CDP#8: FC System Efficiency



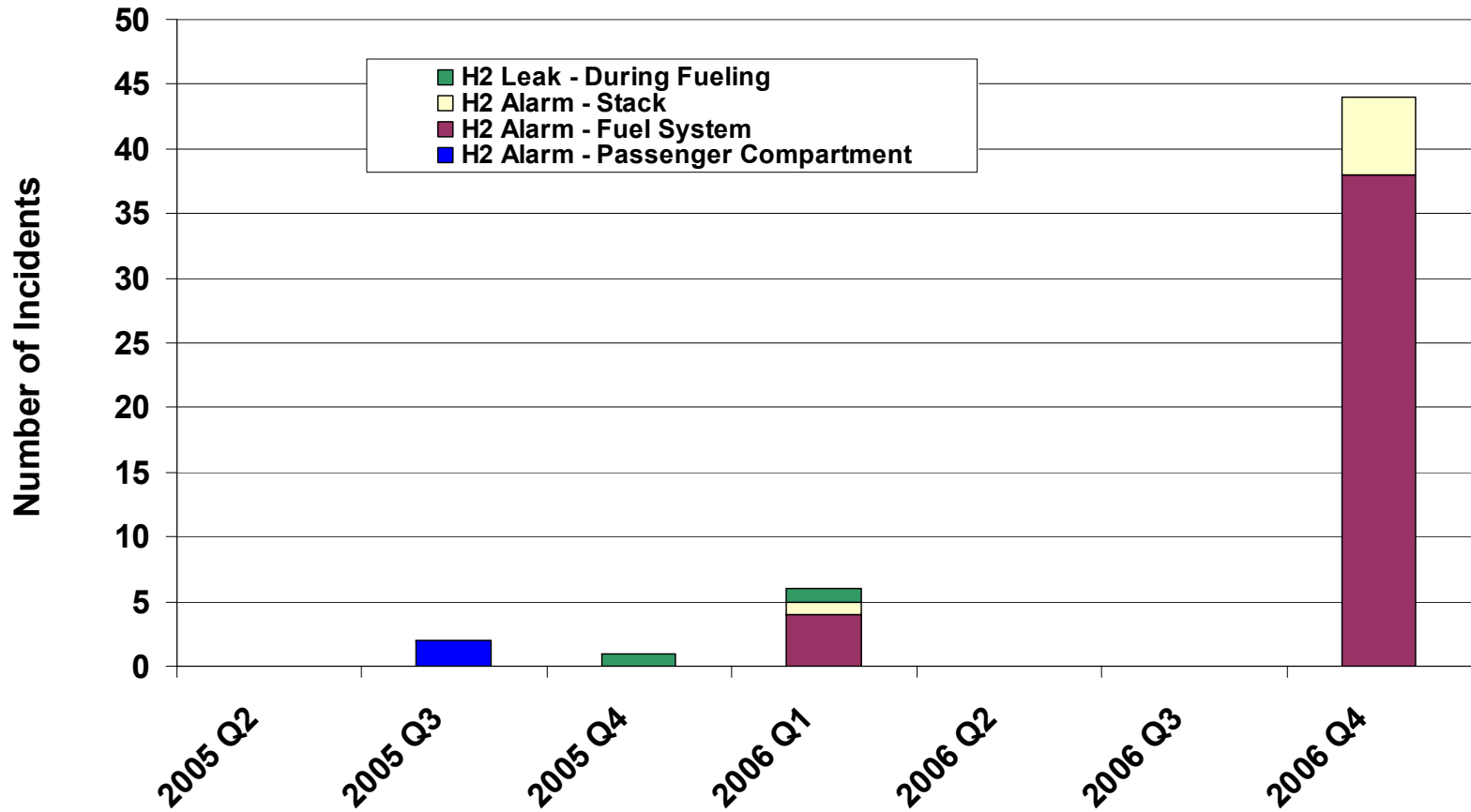
<sup>1</sup> Gross stack power minus fuel cell system auxiliaries, per DRAFT SAEJ2615.

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

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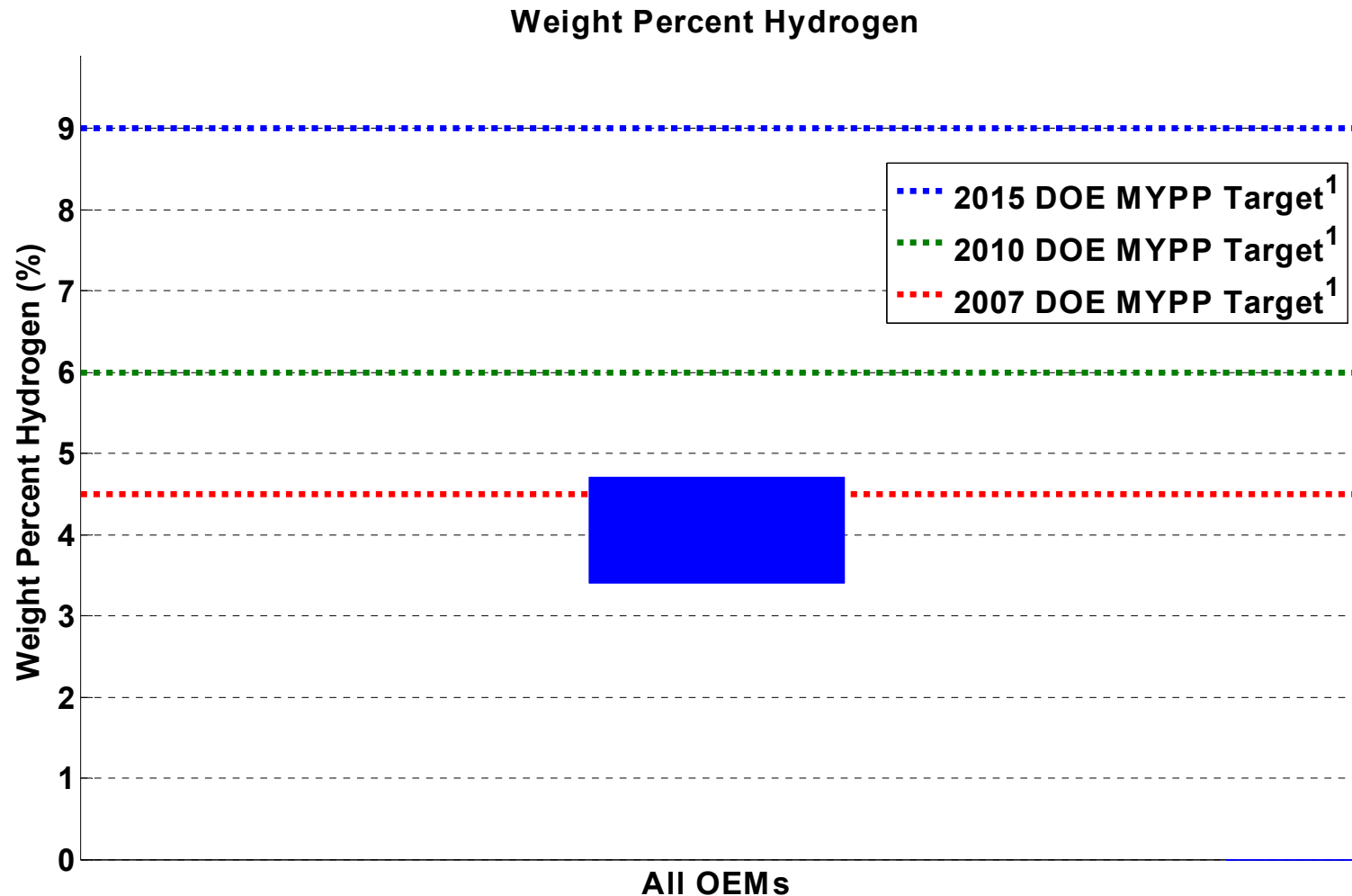
# CDP#9: Safety Incidents – Vehicles

## Safety Incidents - Vehicle Operation



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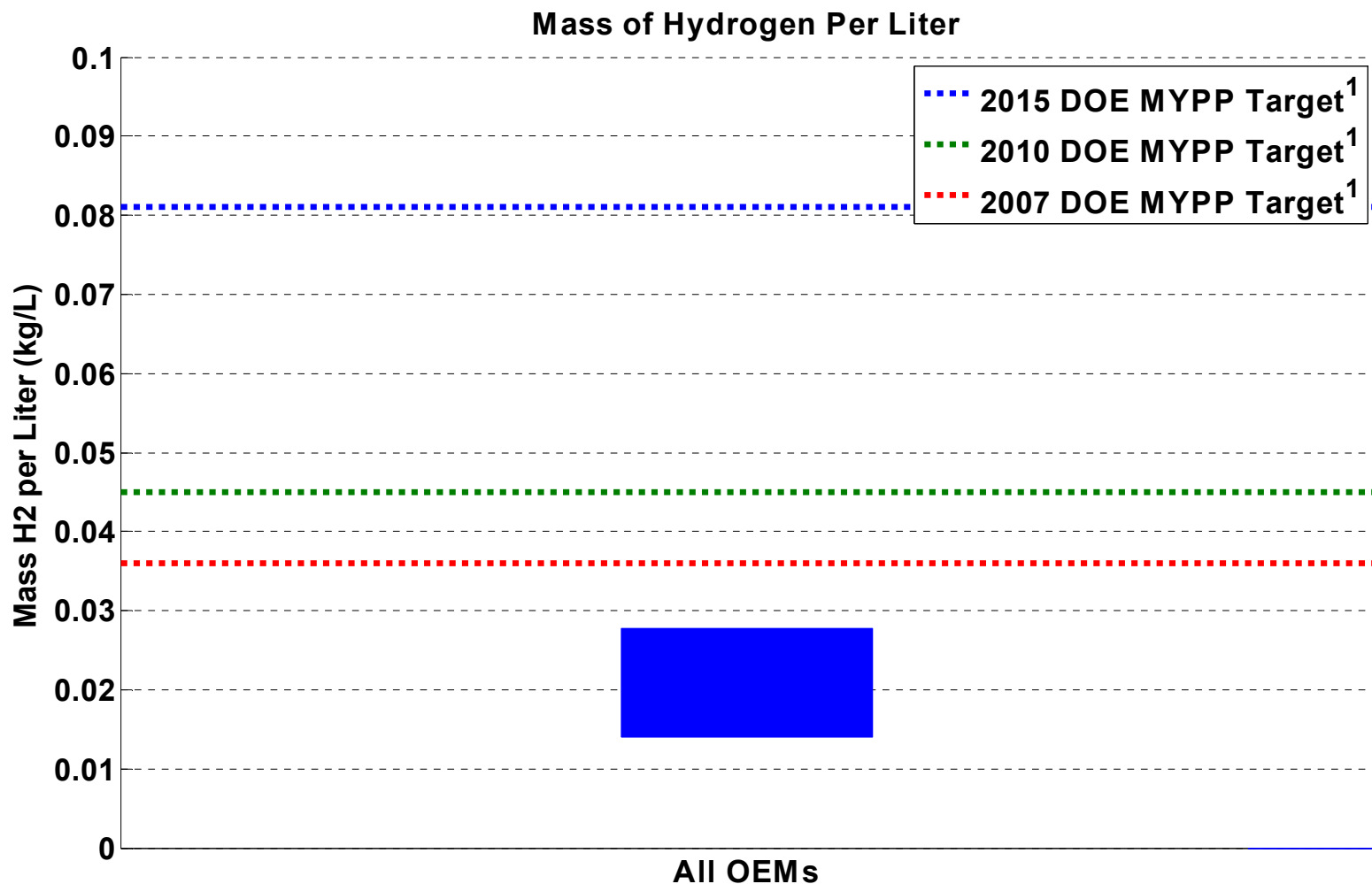
# CDP#10: Storage Weight % Hydrogen



Created: 23-Feb-2006

<sup>1</sup>Some near-term targets have been achieved with compressed and liquid tanks. Emphasis is on advanced materials-based technologies.

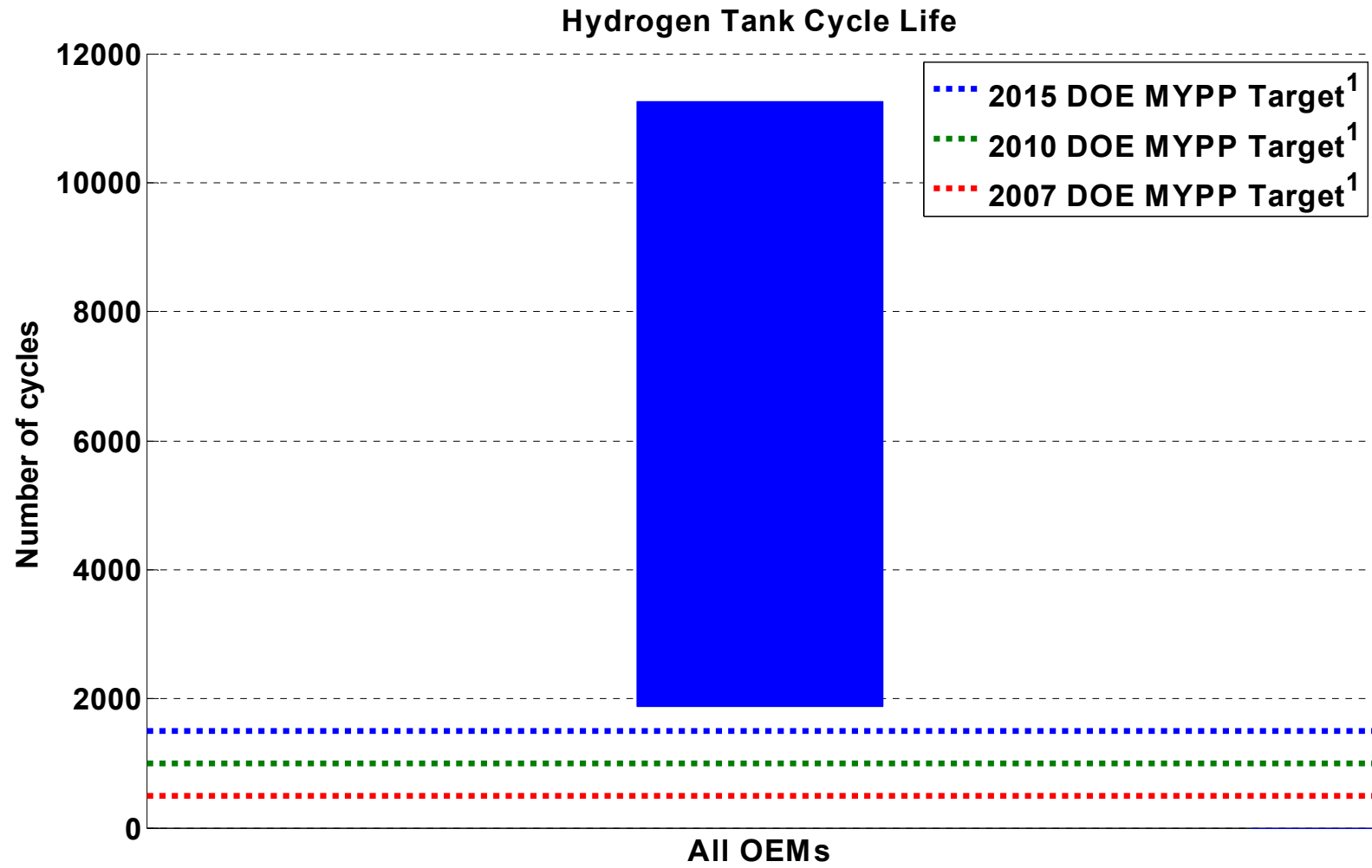
# CDP#11: Volumetric Capacity of H2 Storage



Created: 23-Feb-2006

<sup>1</sup>Emphasis is on advanced materials-based technologies.

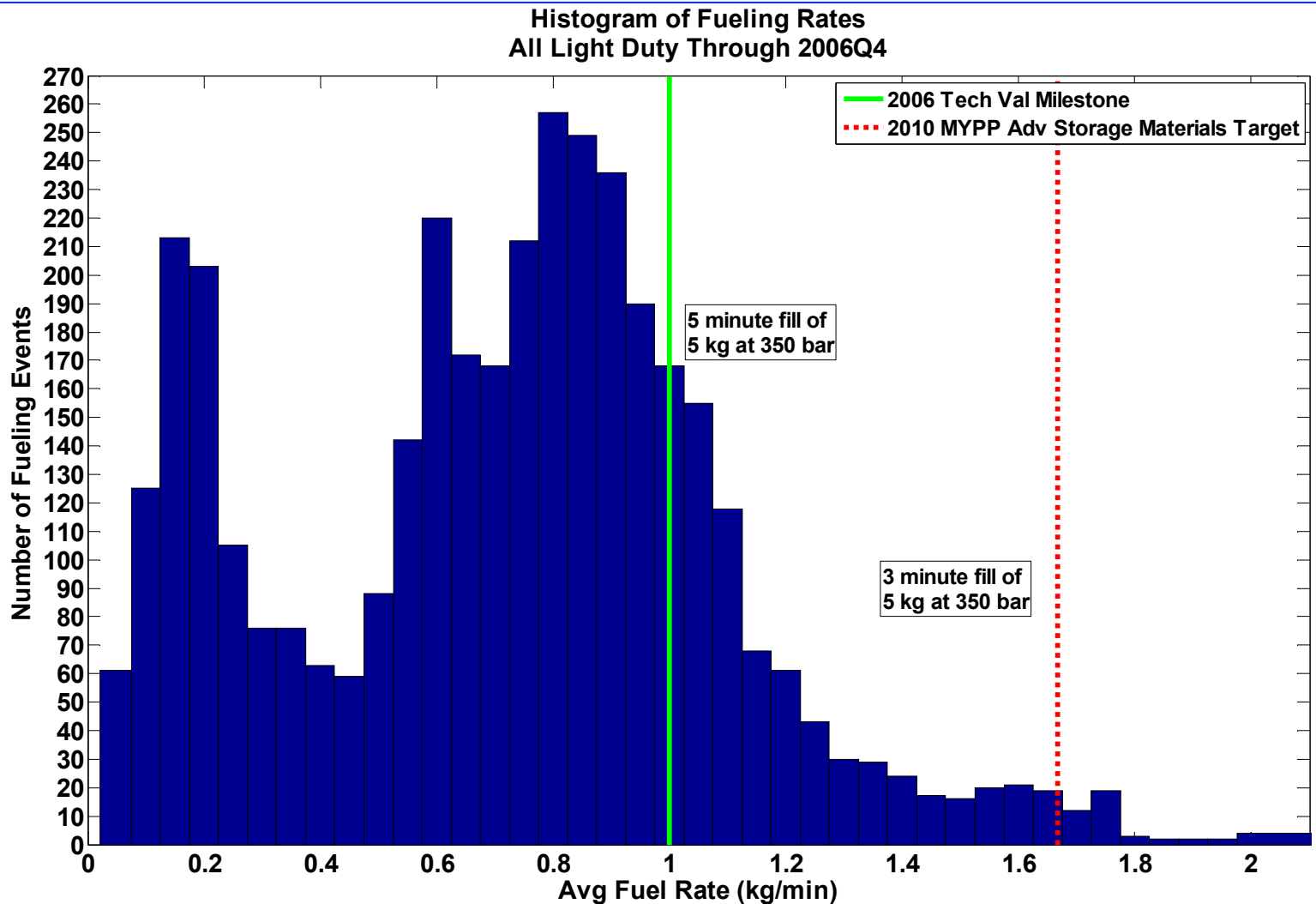
# CDP#12: Vehicle Hydrogen Tank Cycle Life



Created: 23-Feb-2006

<sup>1</sup>Some near-term targets have been achieved with compressed and liquid tanks. Emphasis is on advanced materials-based technologies.

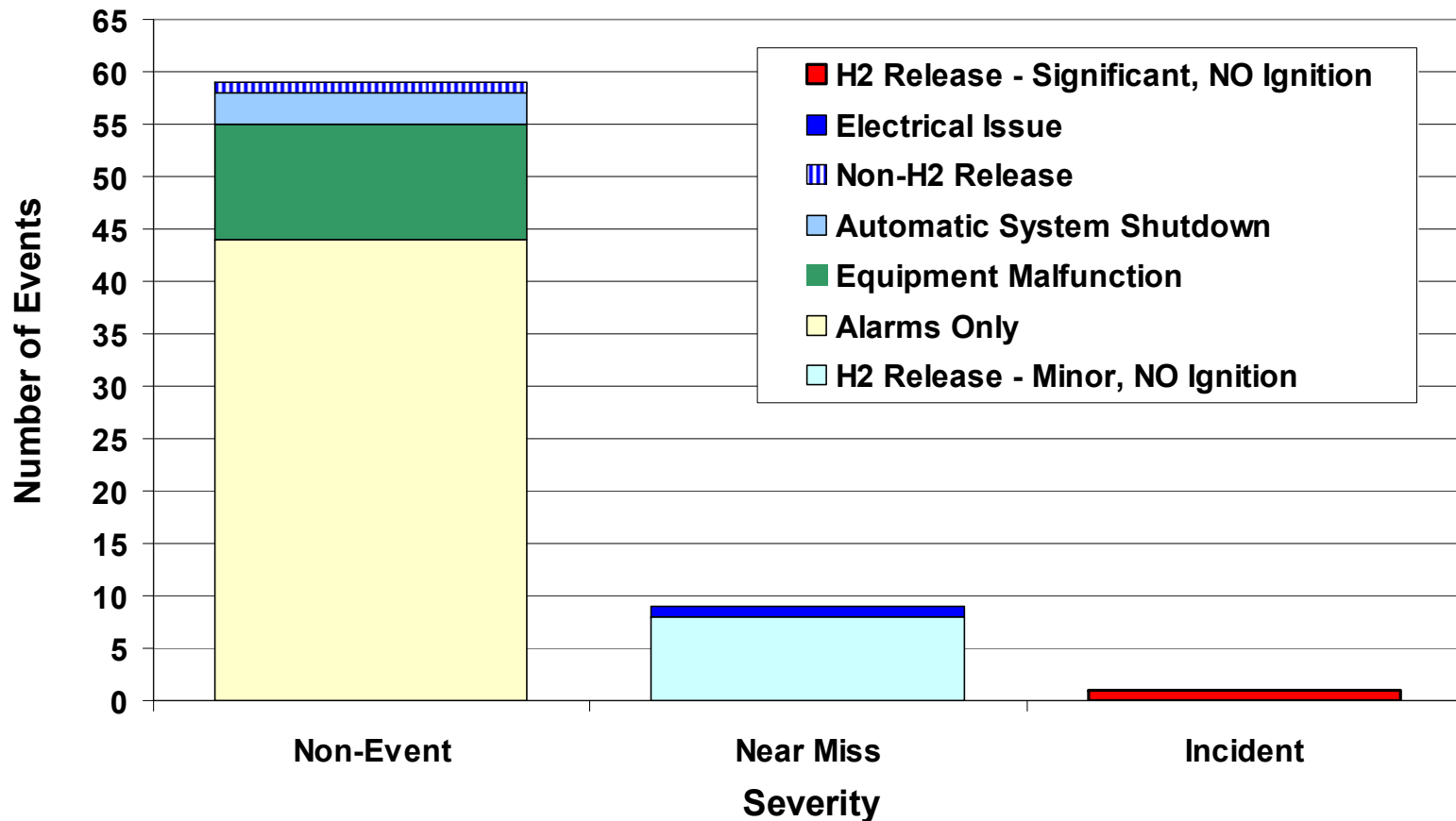
# CDP#18: Refueling Rates



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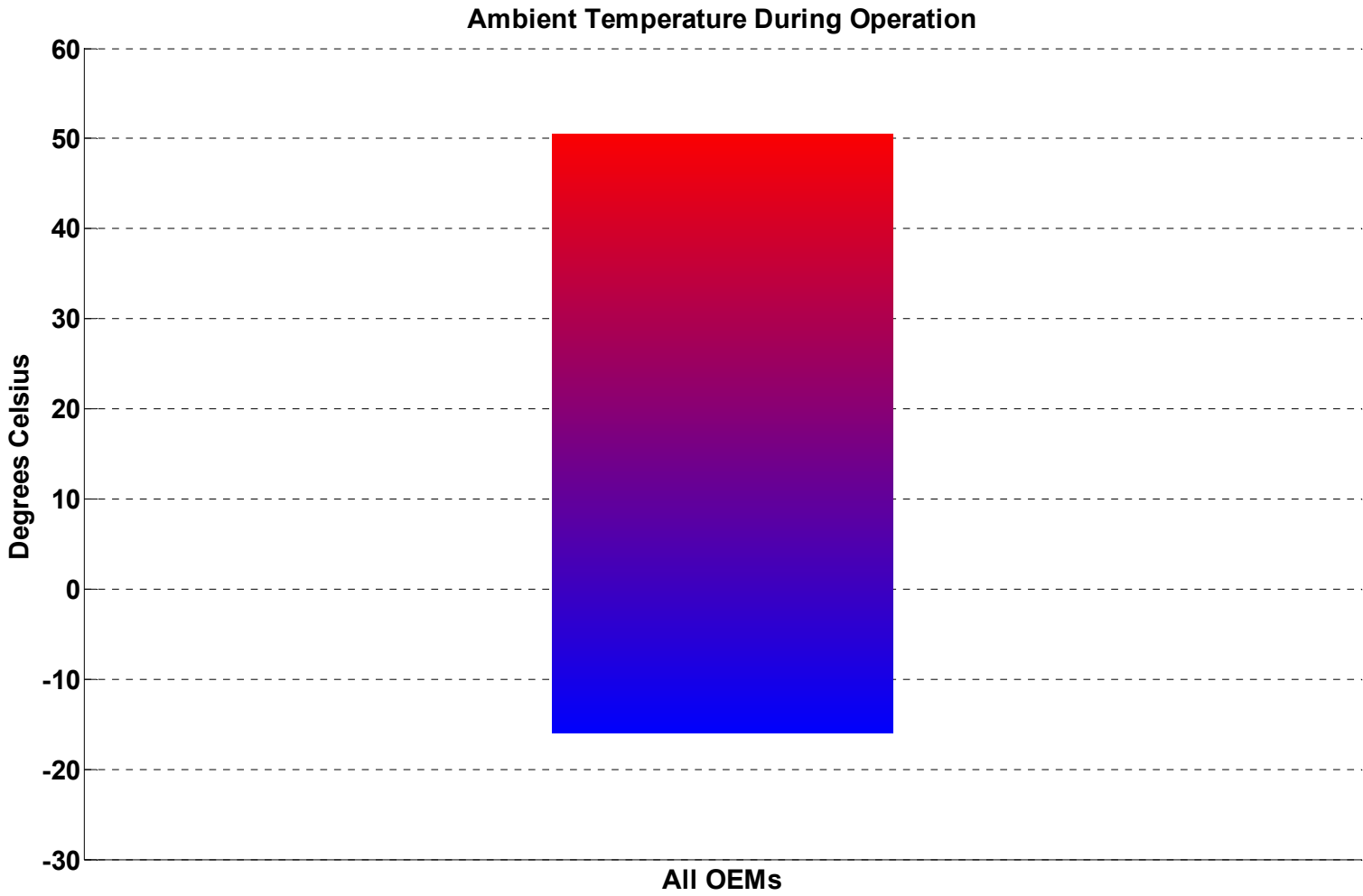
# CDP#20: Safety Incidents – Infrastructure

Total Infrastructure Safety Events by Severity and Event Type Through 2006 Q4



Created 07-Mar-2007

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

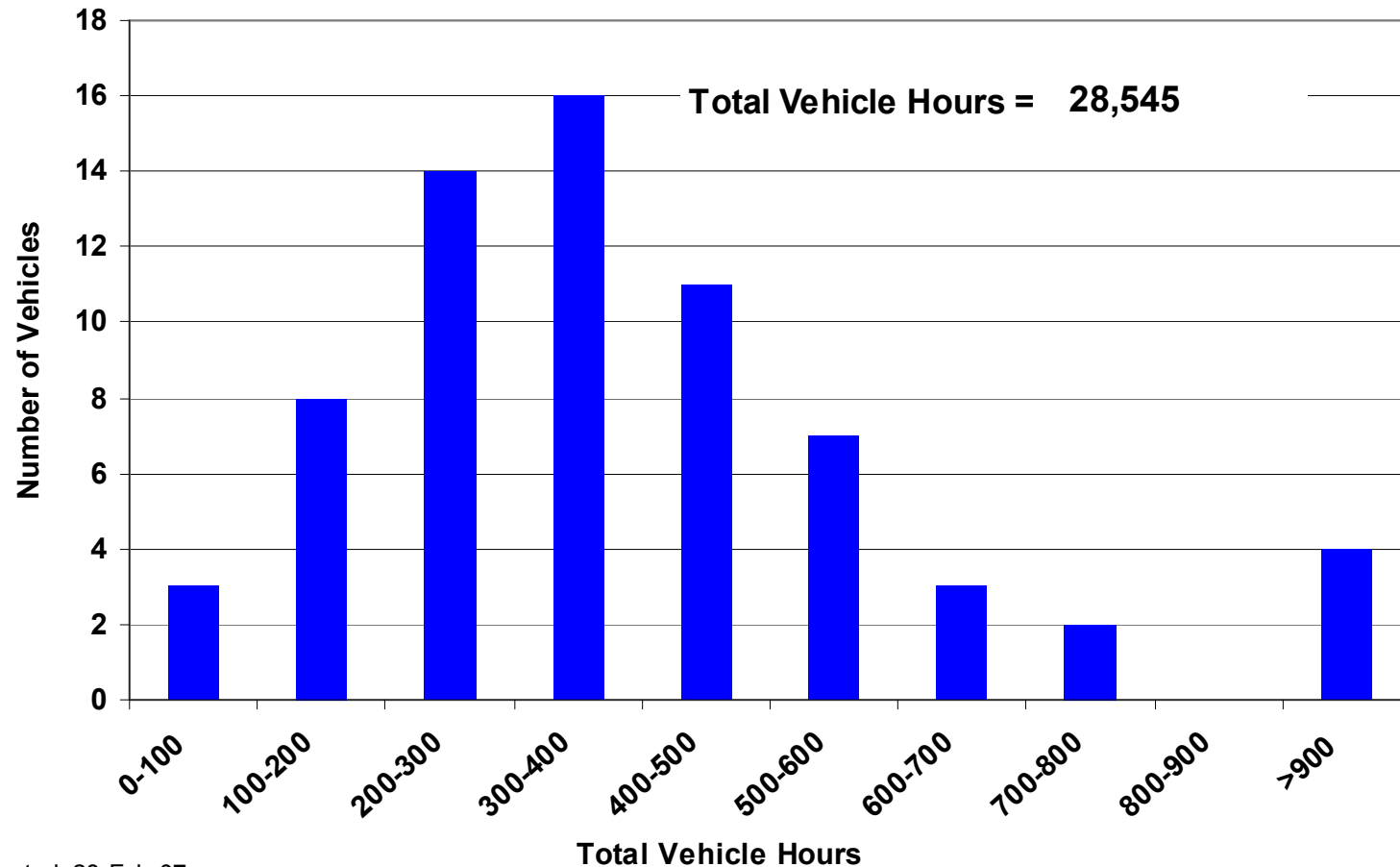


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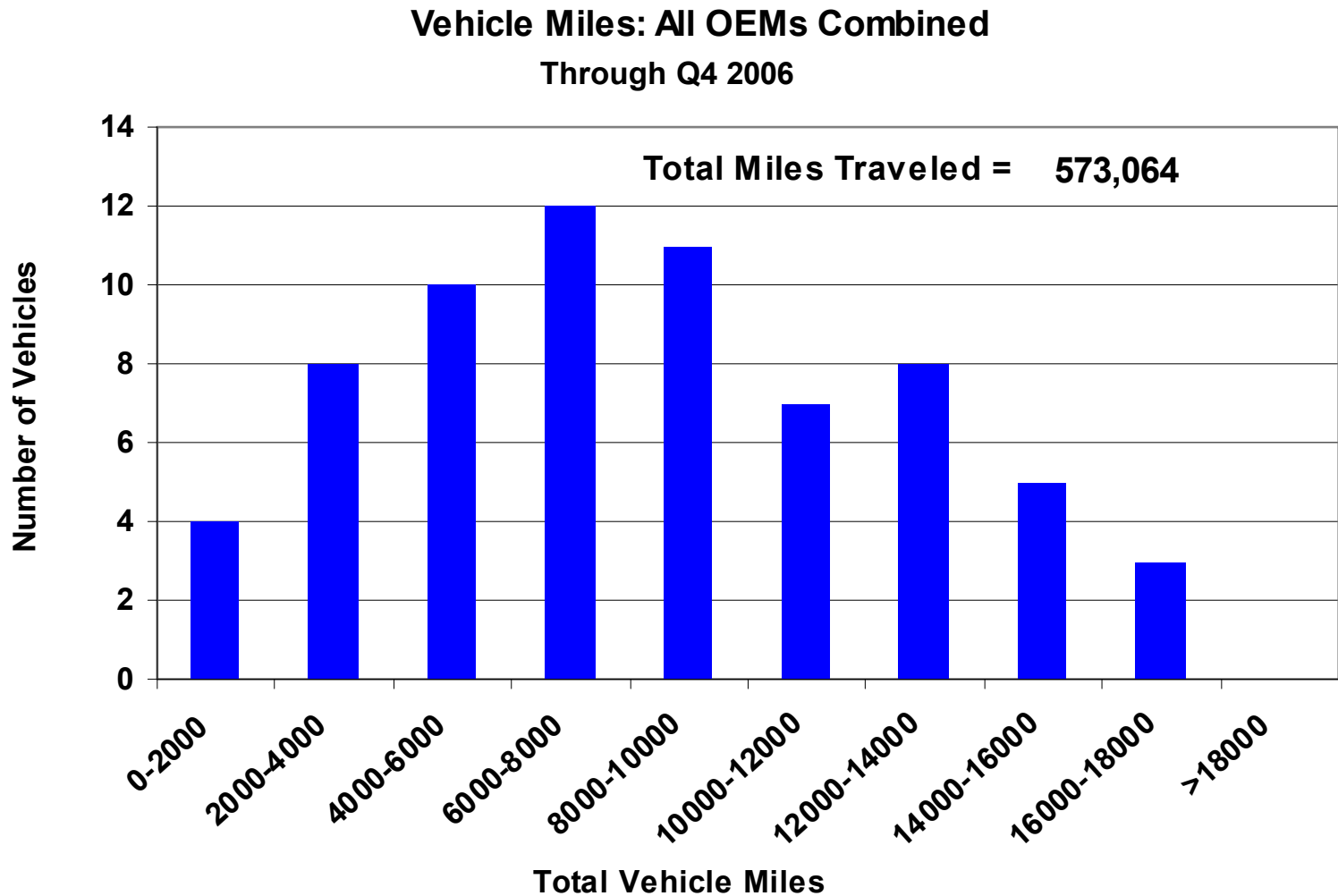
# CDP#22: Vehicle Operating Hours

Vehicle Hours: All OEMs Combined  
Through Q4 2006



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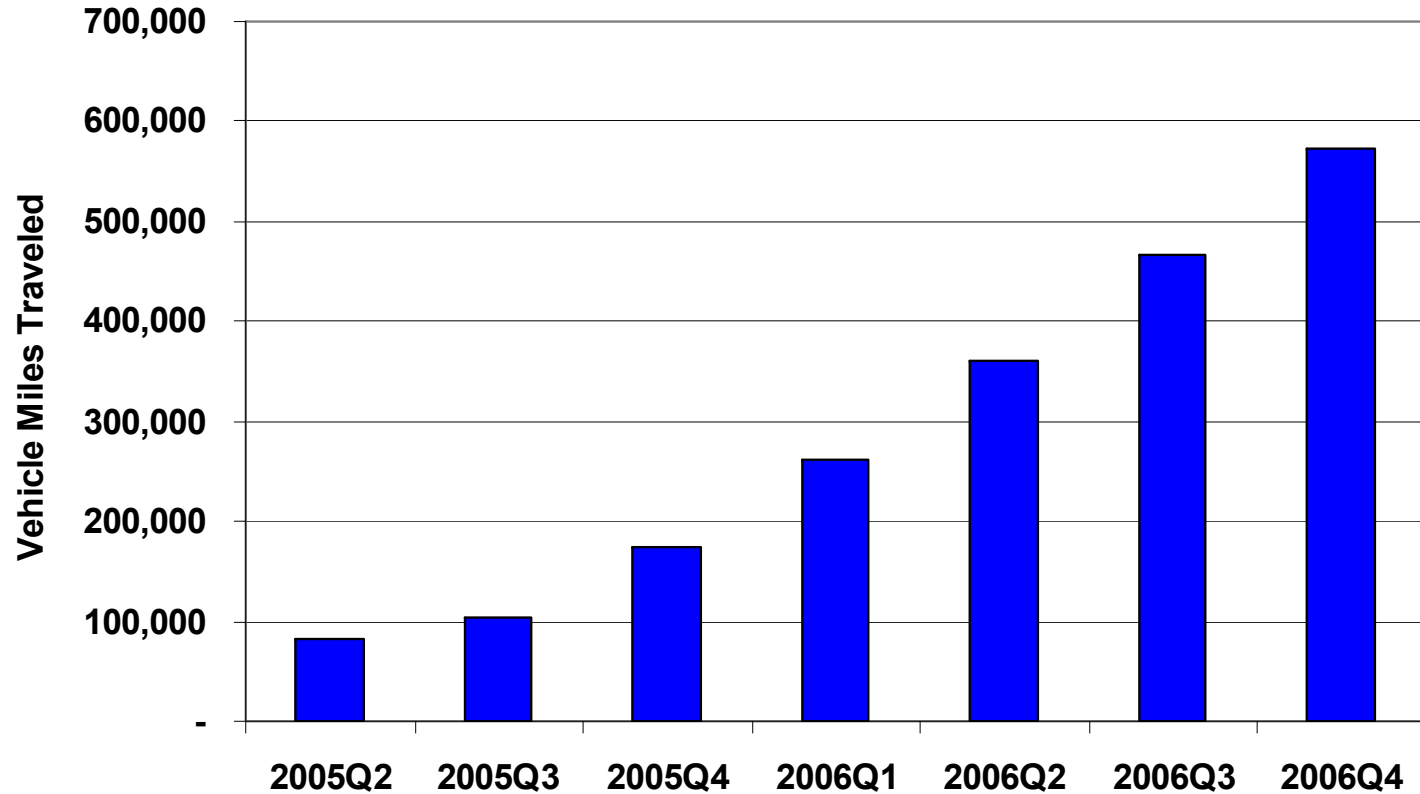
# CDP#23: Vehicles vs. Miles Traveled



Created: 28-Feb-07

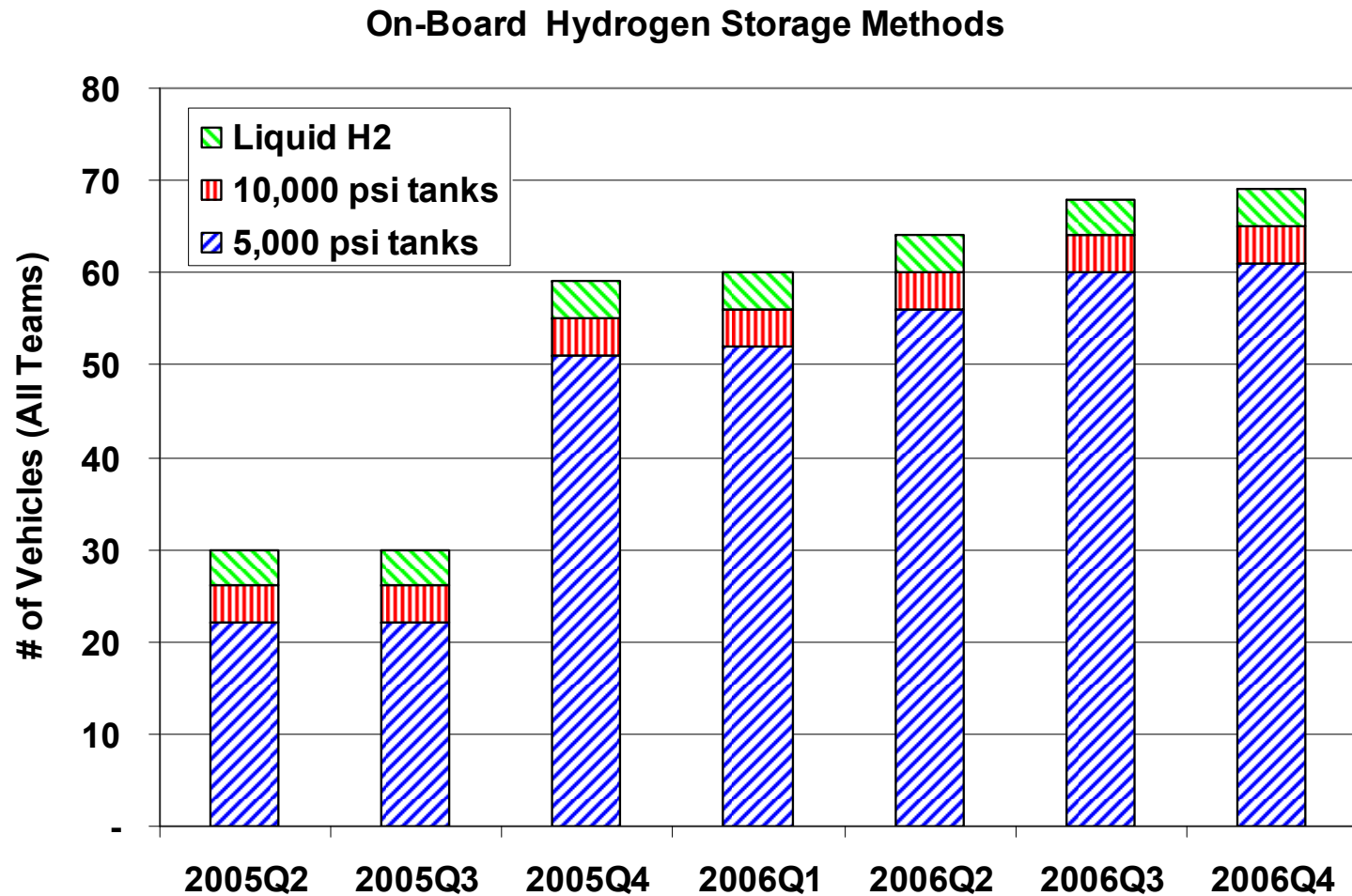
# CDP#24: Cumulative Vehicle Miles Traveled

Cumulative Vehicle Miles Traveled: All OEMs



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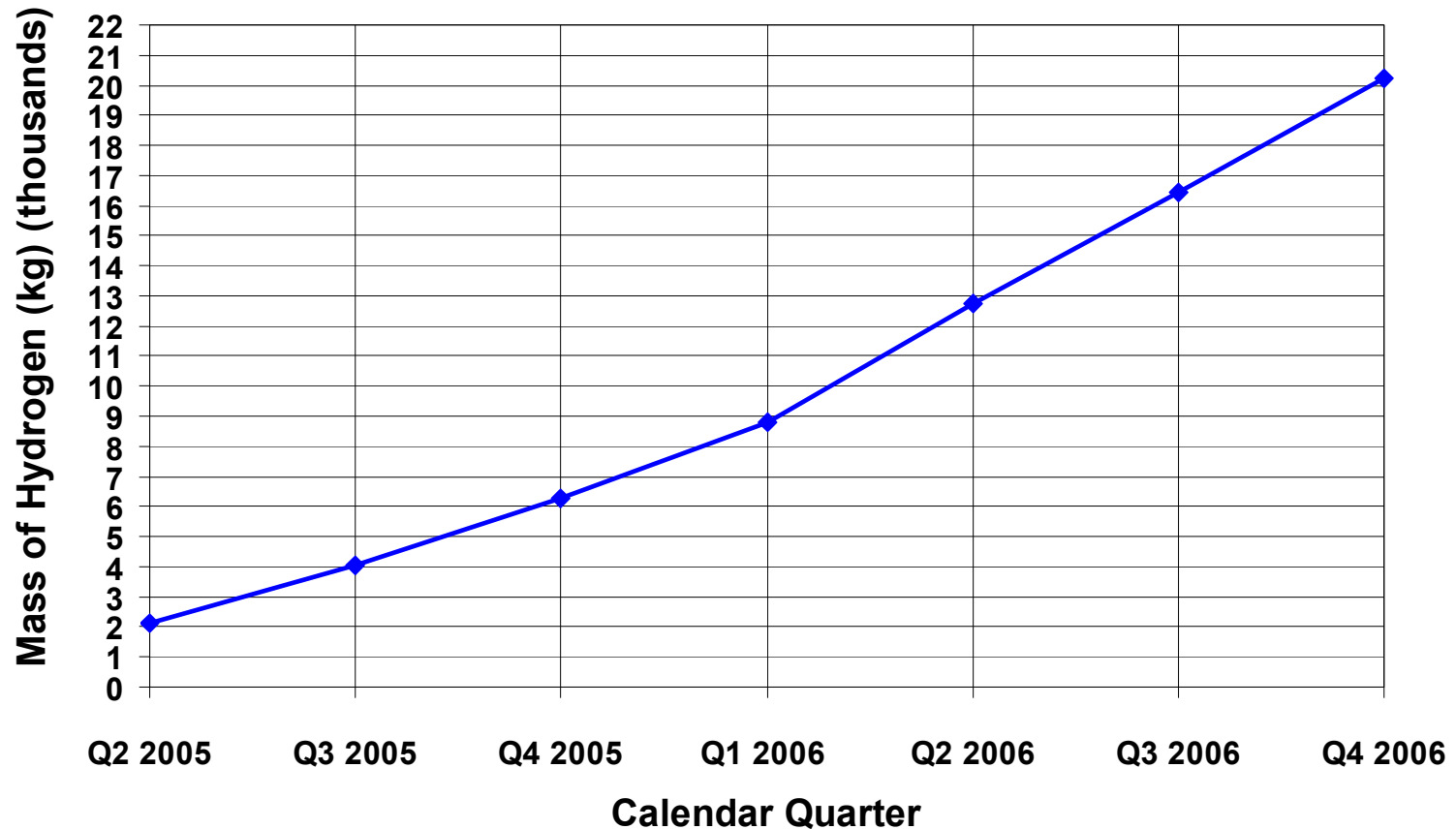
# CDP#25: Vehicle H2 Storage Technologies



Created Feb-28-2007

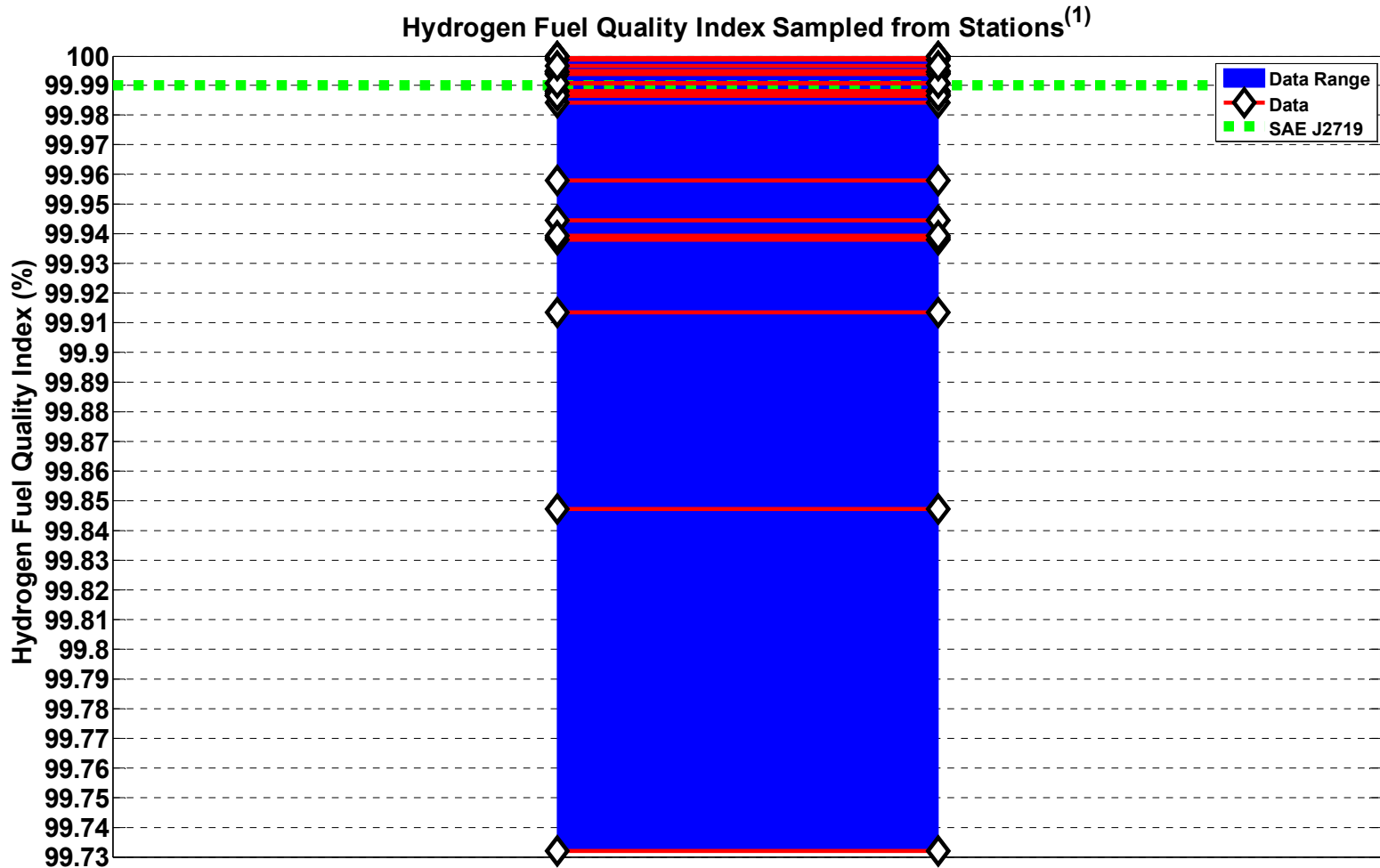
# CDP#26: Cumulative H2 Produced or Dispensed

## Cumulative Hydrogen Produced or Dispensed



Created 20-Feb-2007

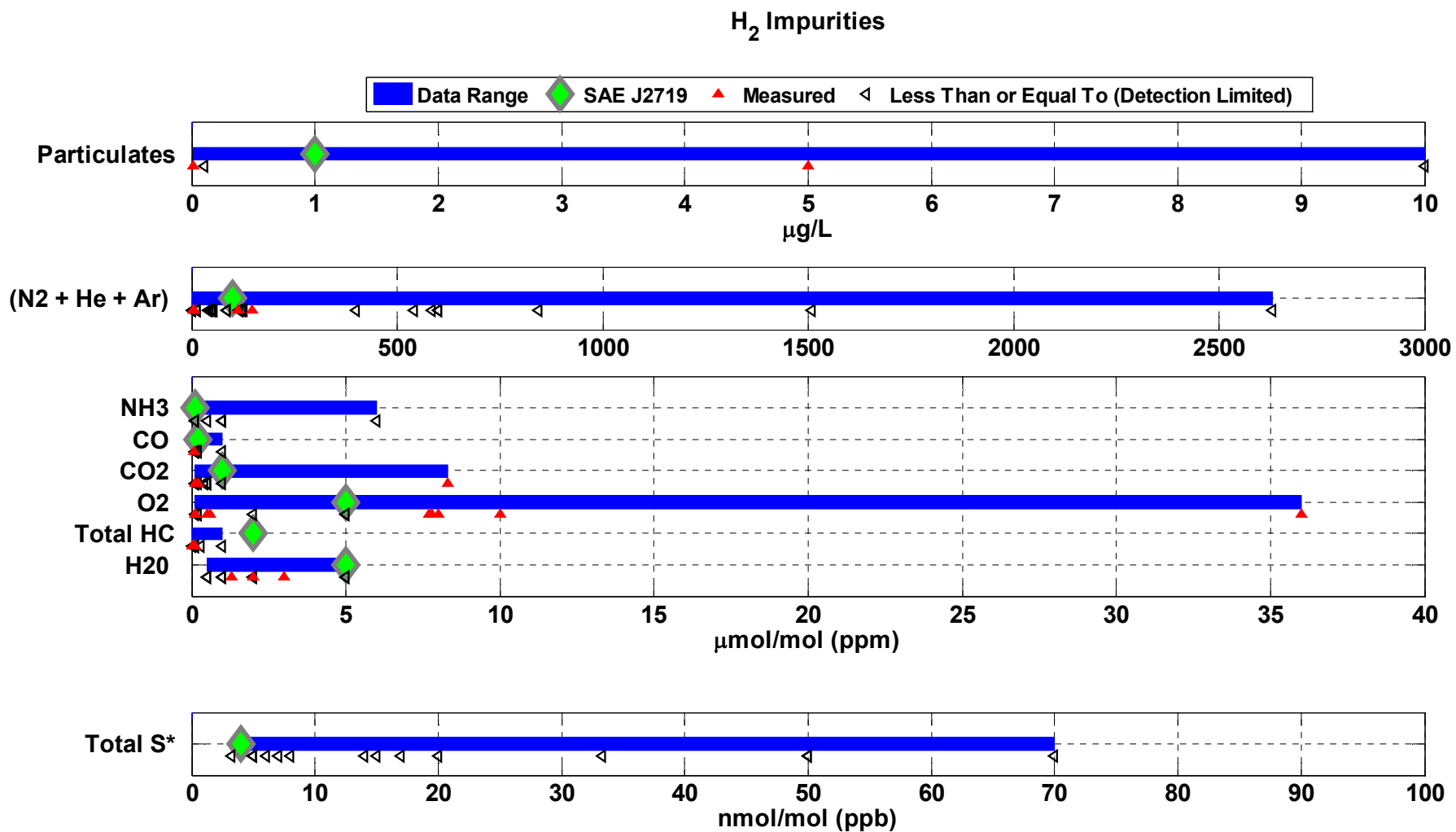
# CDP#27: Hydrogen Purity Scatter Plot



(1) Includes sampling from both electrolysis and reforming

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# CDP #28: Hydrogen Impurities Scatter Plot

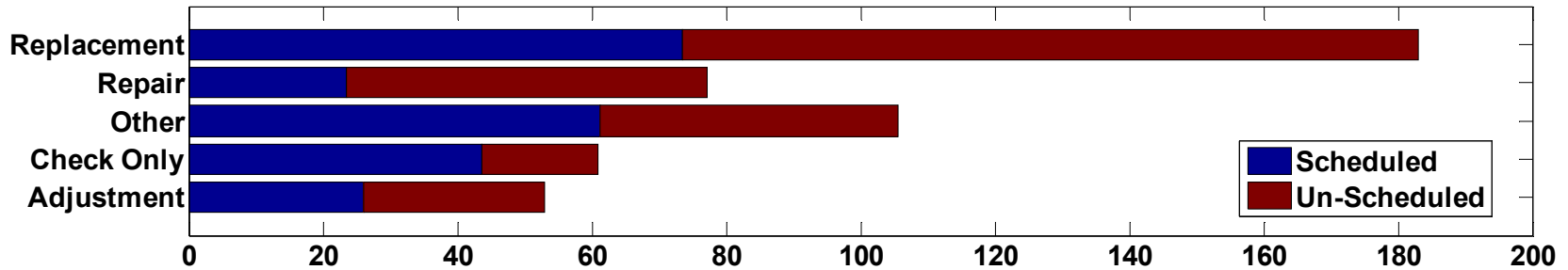


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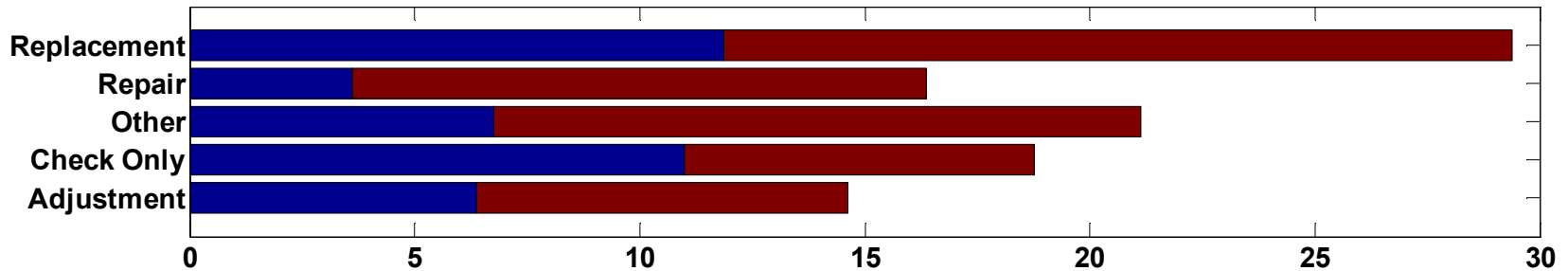
\*Calculated from SO<sub>2</sub>, COS, H<sub>2</sub>S, CS<sub>2</sub>, and Methyl Mercaptan (CH<sub>3</sub>SH).

# CDP#30: Infrastructure Maintenance

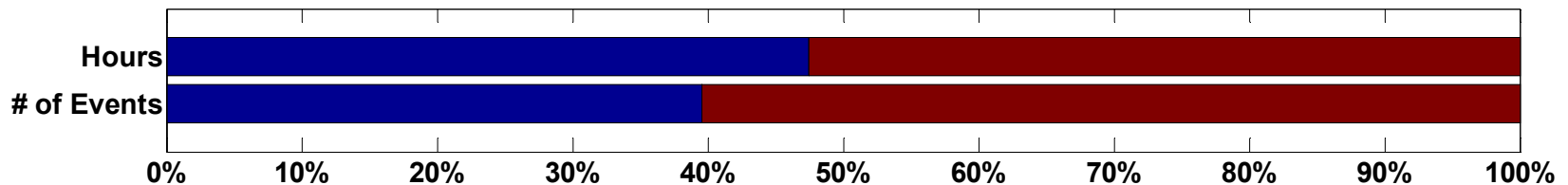
Maintenance: Average Labor Hours Per Station Since Inception



Maintenance: Average Number of Events Per Station Since Inception



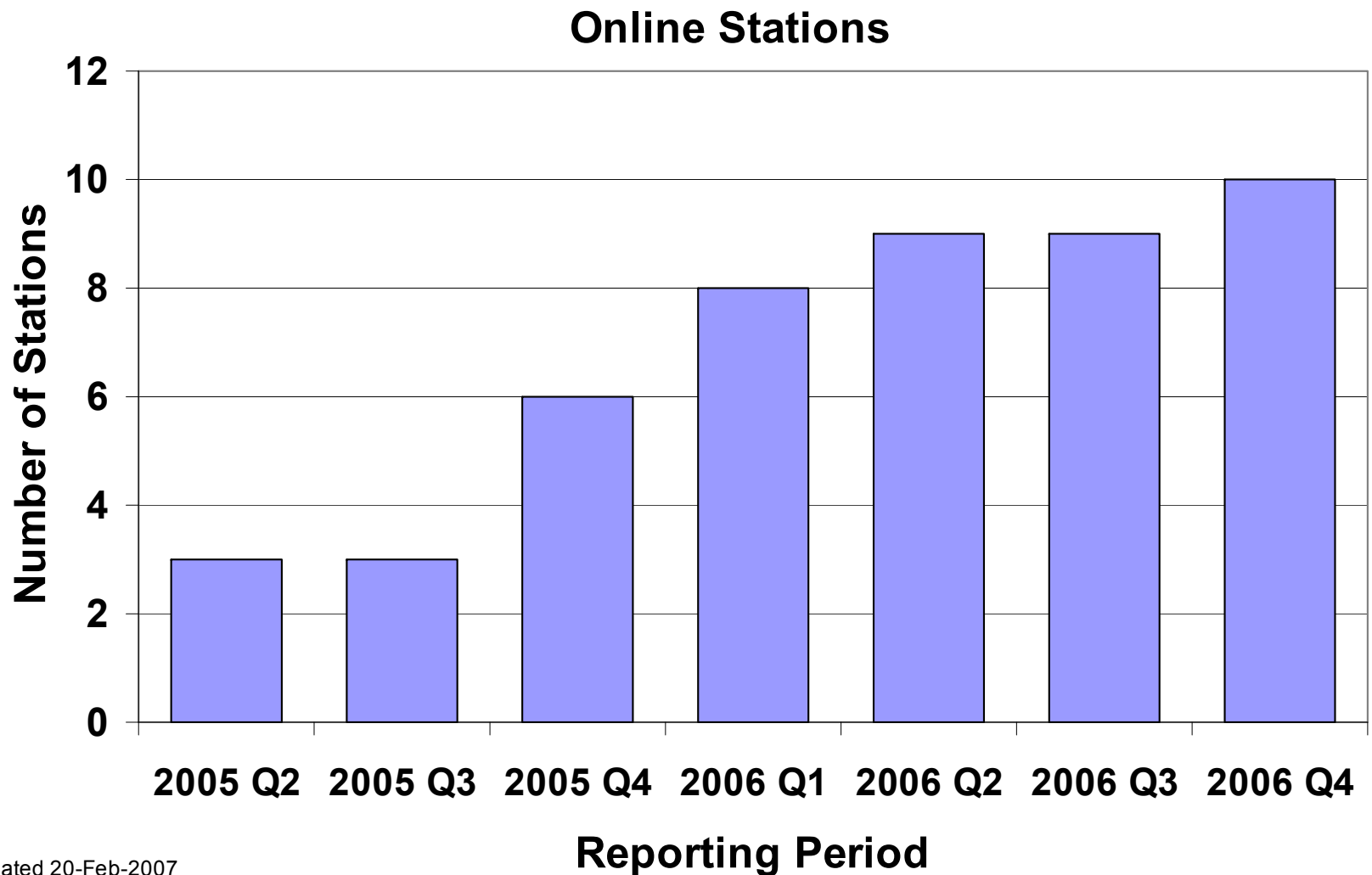
Comparison of Scheduled/Un-Scheduled Maintenance



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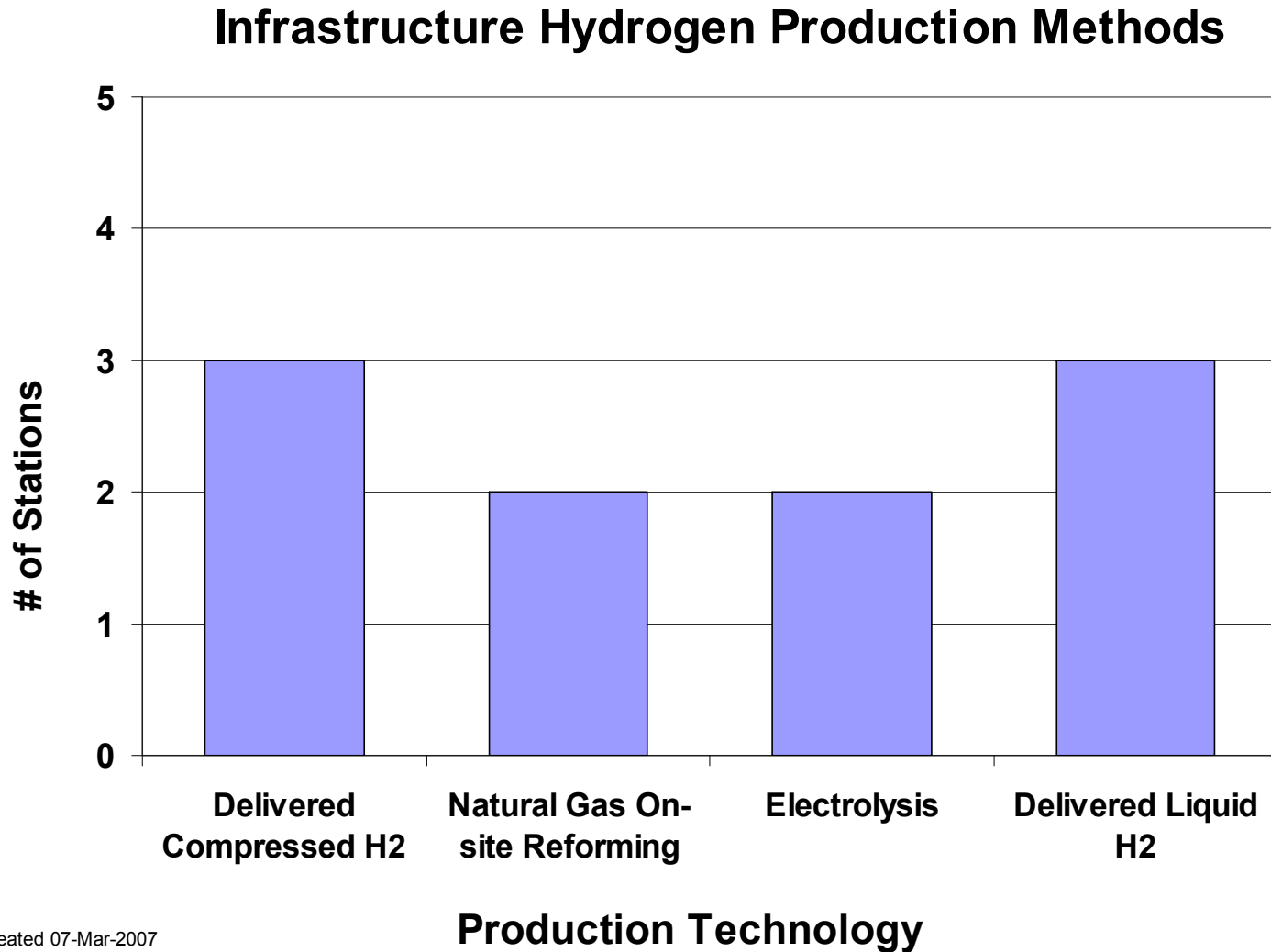


# CDP#31: Number of Reporting Stations



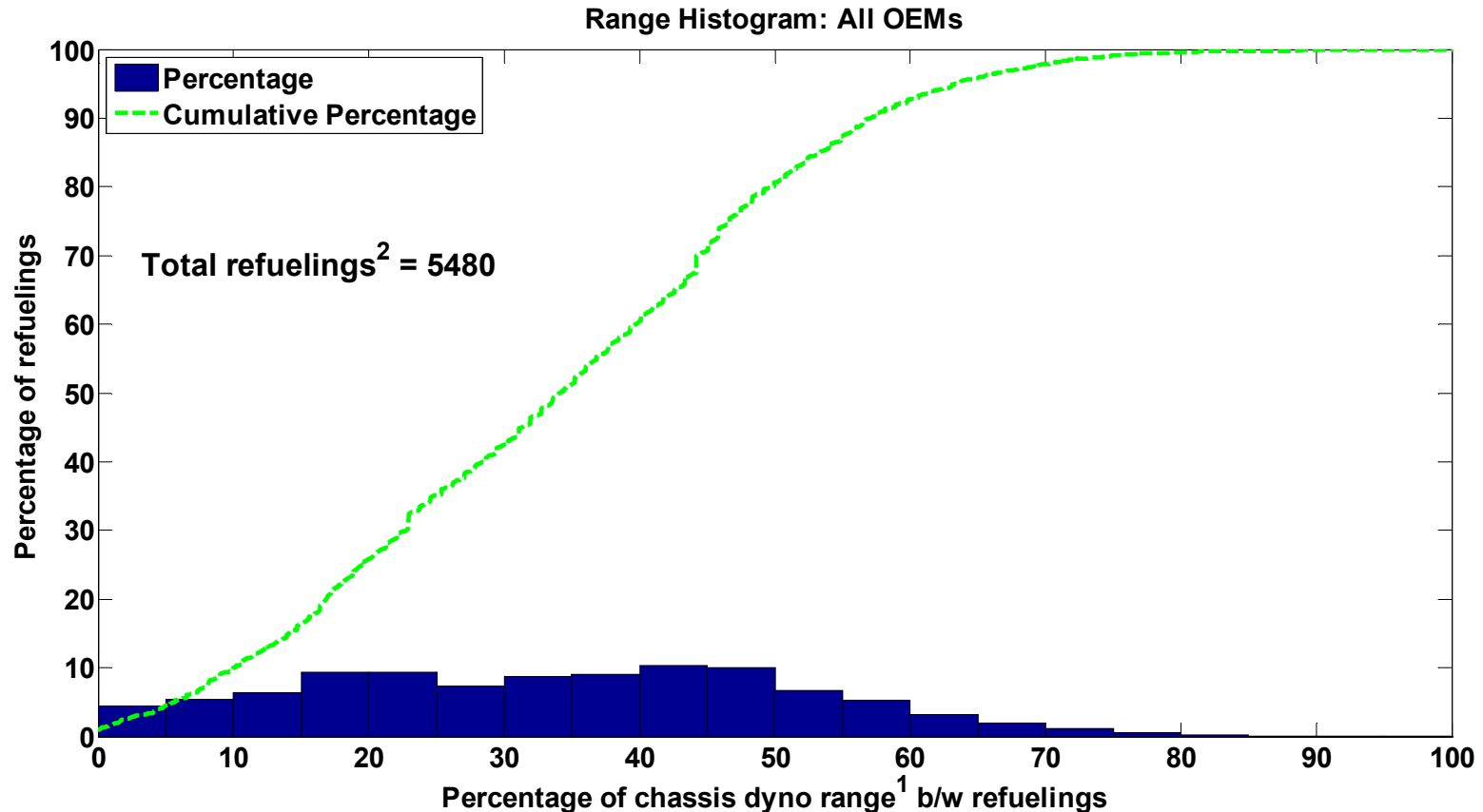
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# CDP#32: Infrastructure Hydrogen Production Methods



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

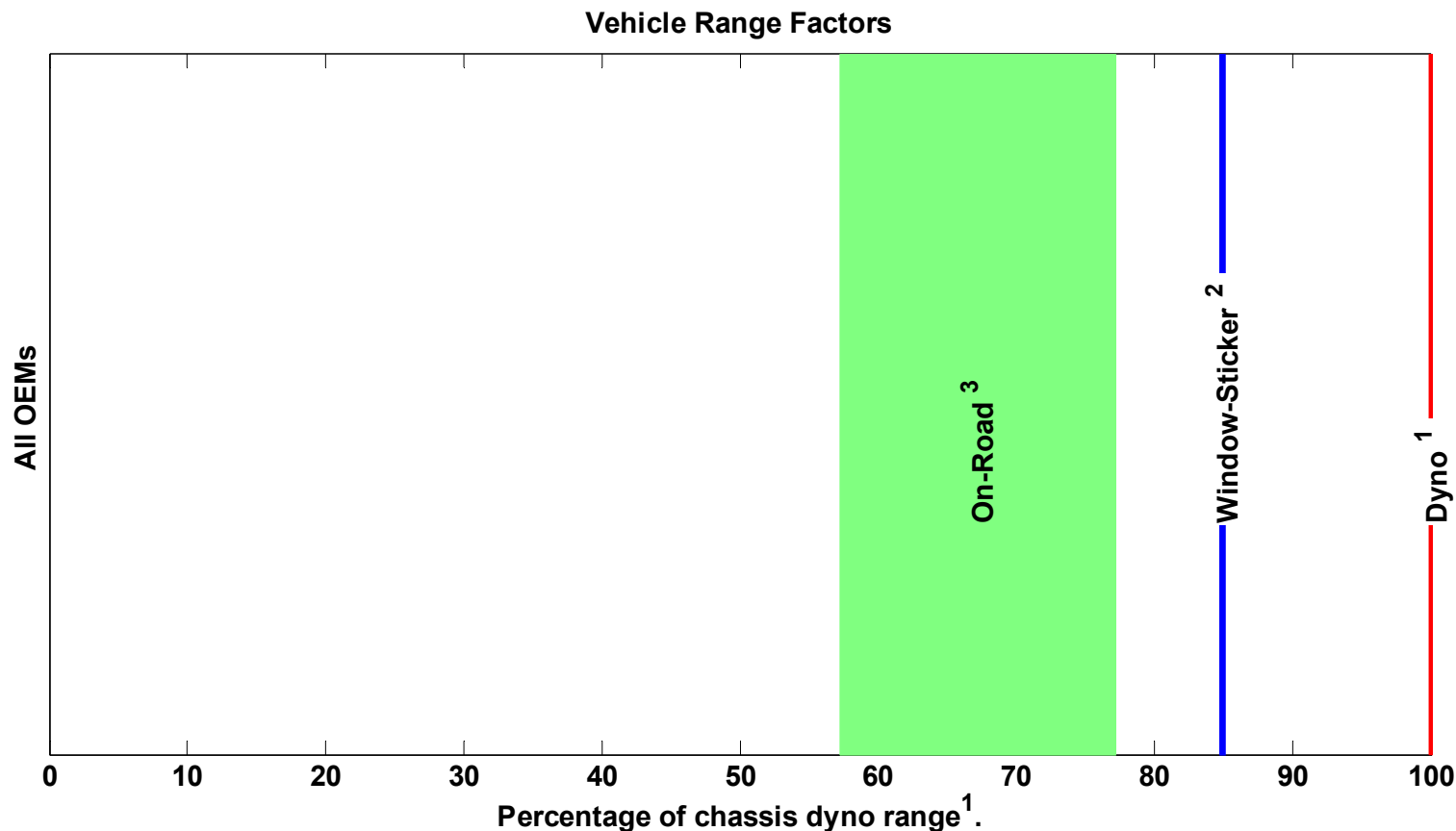


1. Range calculated using the combined City/Hwy fuel economy from dyno testing (not EPA adjusted) and usable fuel on board.

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

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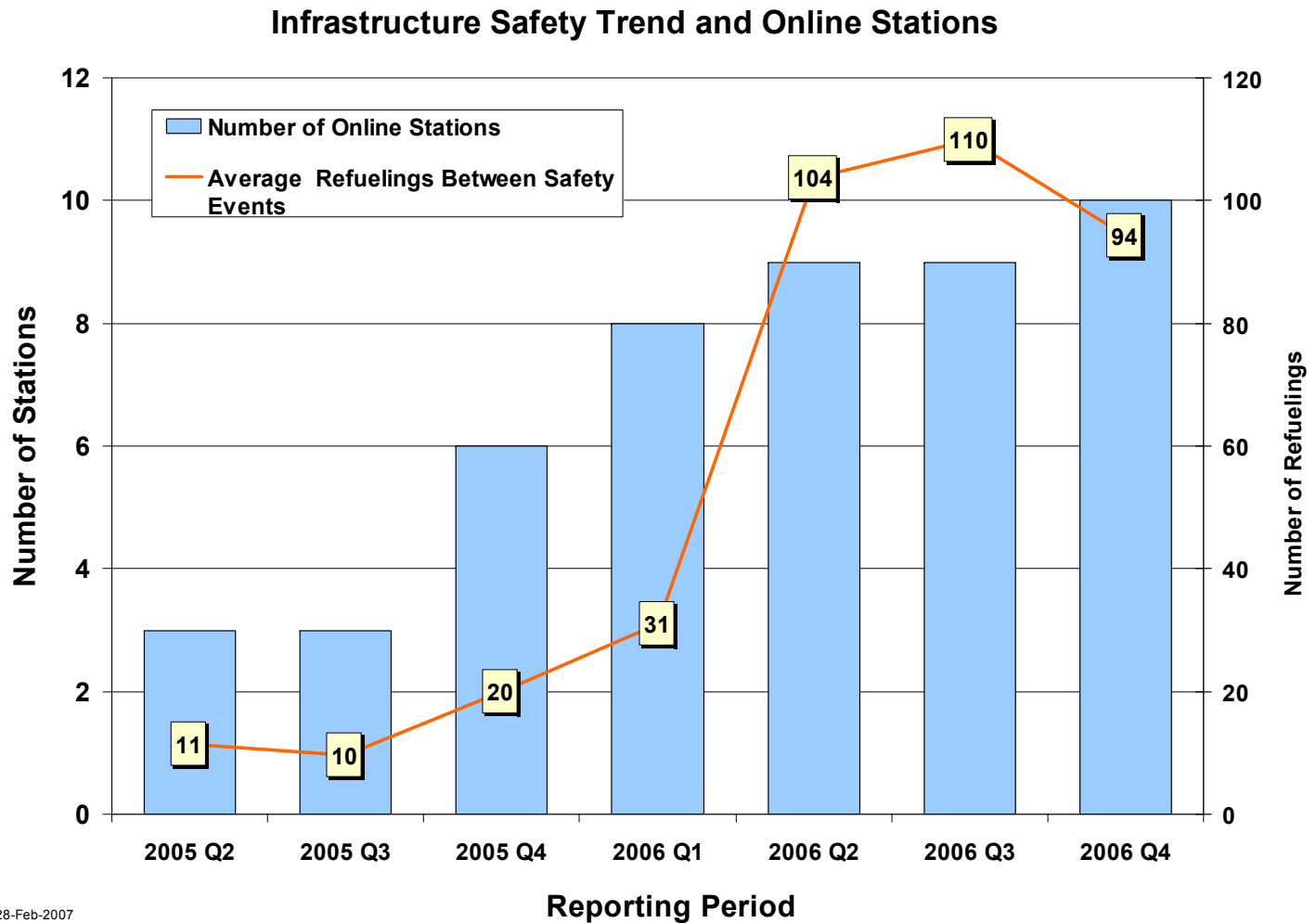
# CDP#34: Effective Vehicle Range



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:  $0.78 \times \text{Hwy}$  and  $0.9 \times \text{City}$ .
3. Using fuel economy from on-road data (excluding trips > 1 mile, consistent with other data products).

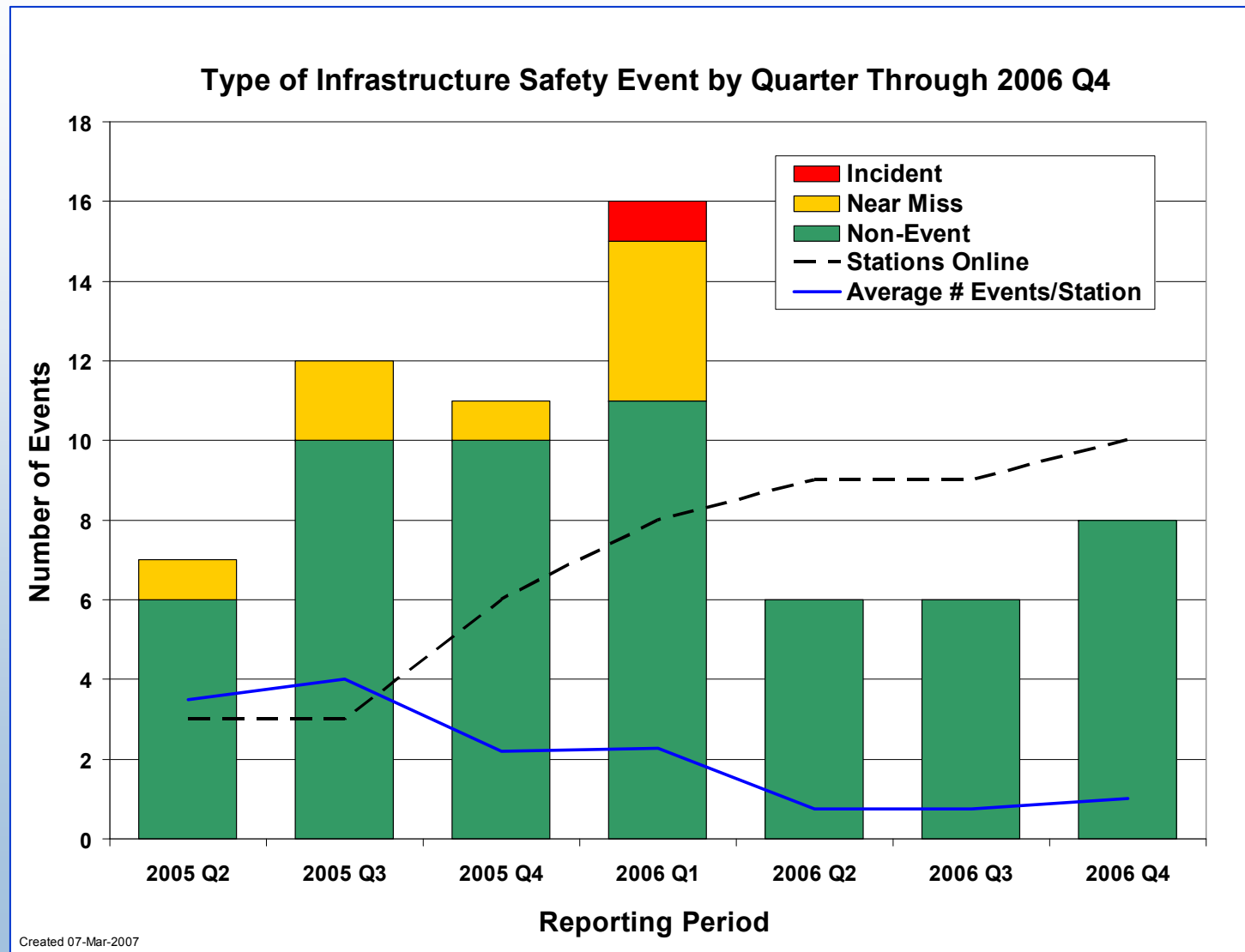
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# CDP#35: Average Refuelings Between Infrastructure Safety Events



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

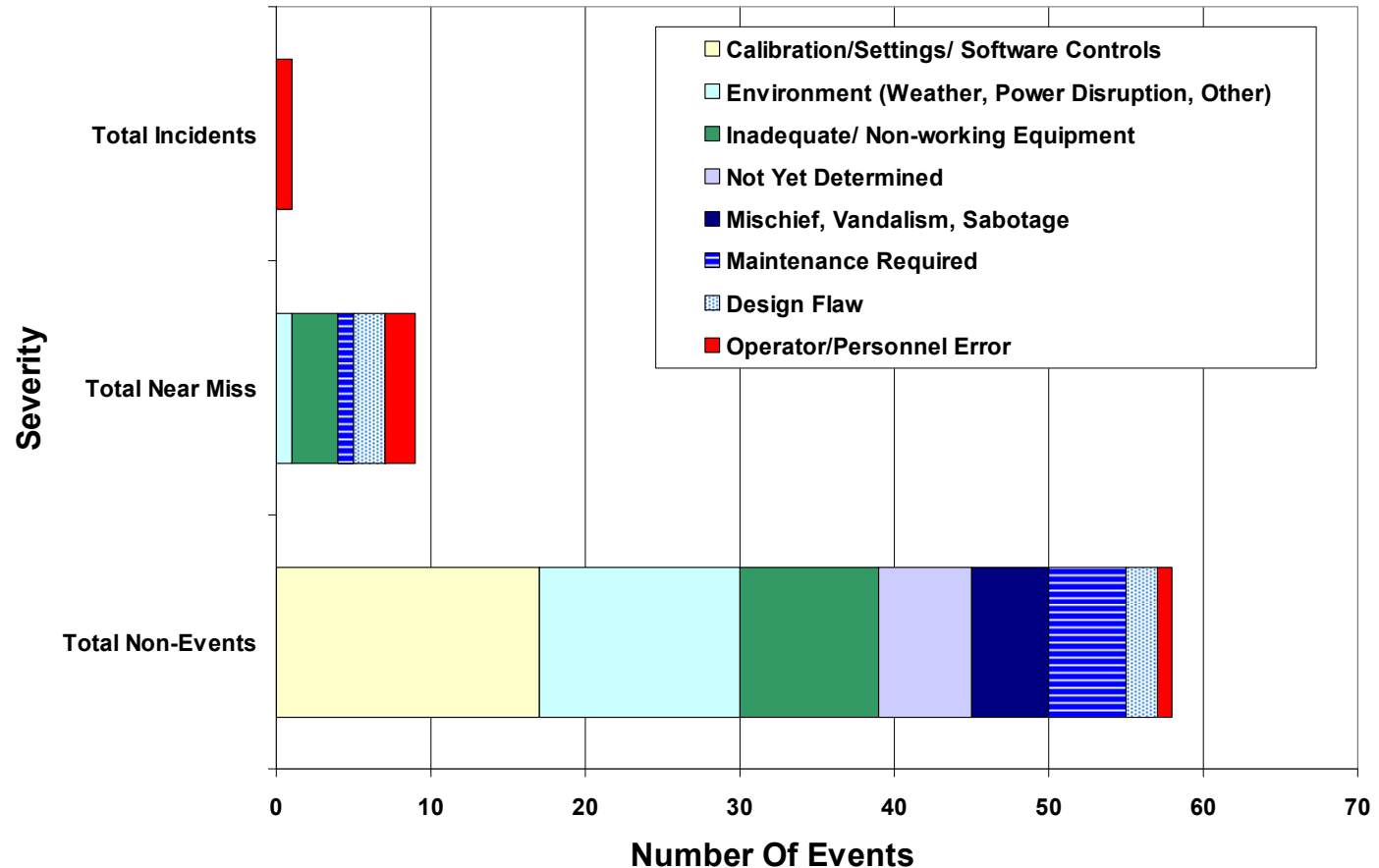


Created 07-Mar-2007

# CDP#37: Primary Factors of Infrastructure Safety Events

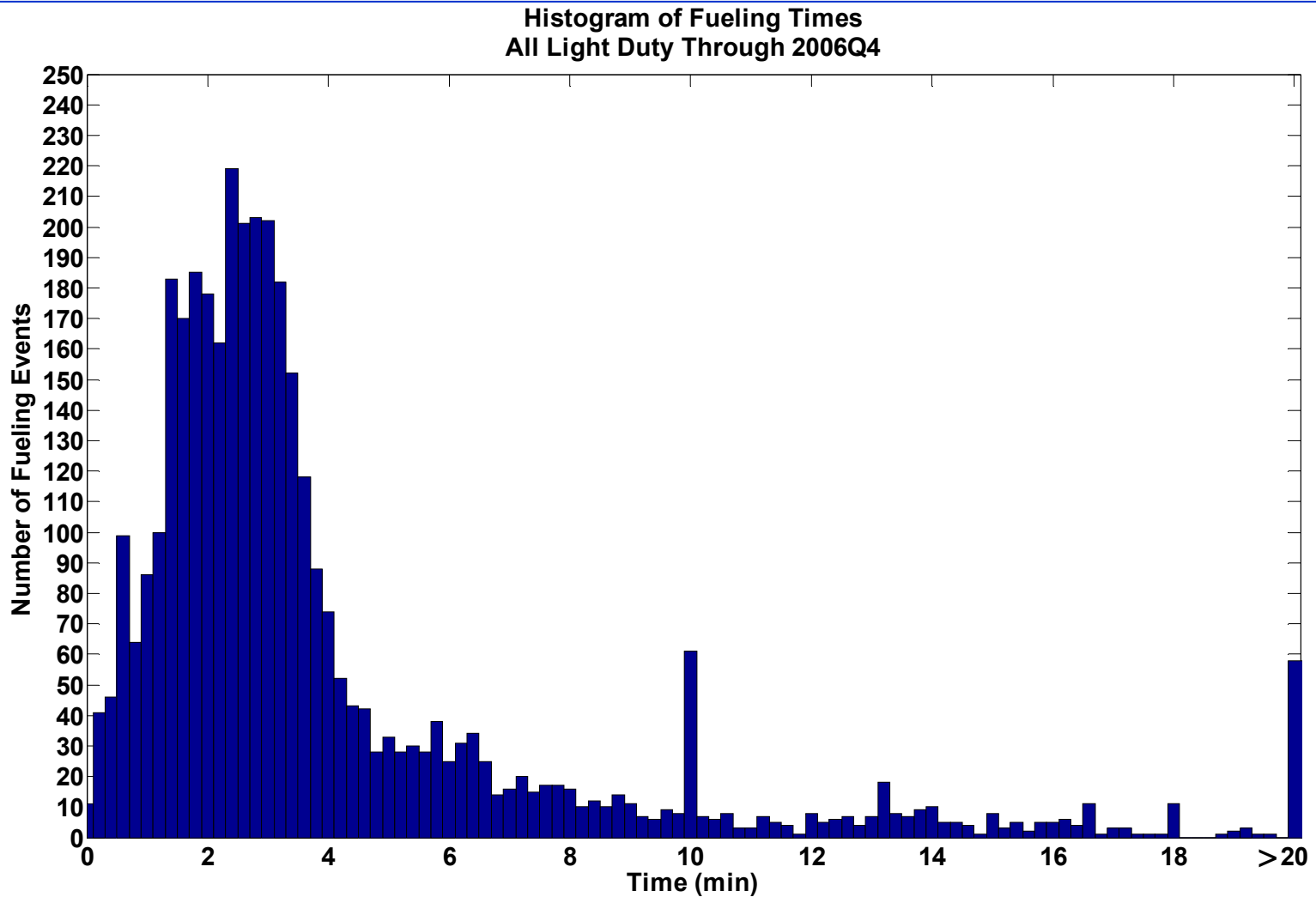
## Safety Events

### Primary Factors of Infrastructure Safety Events Through 2006 Q4



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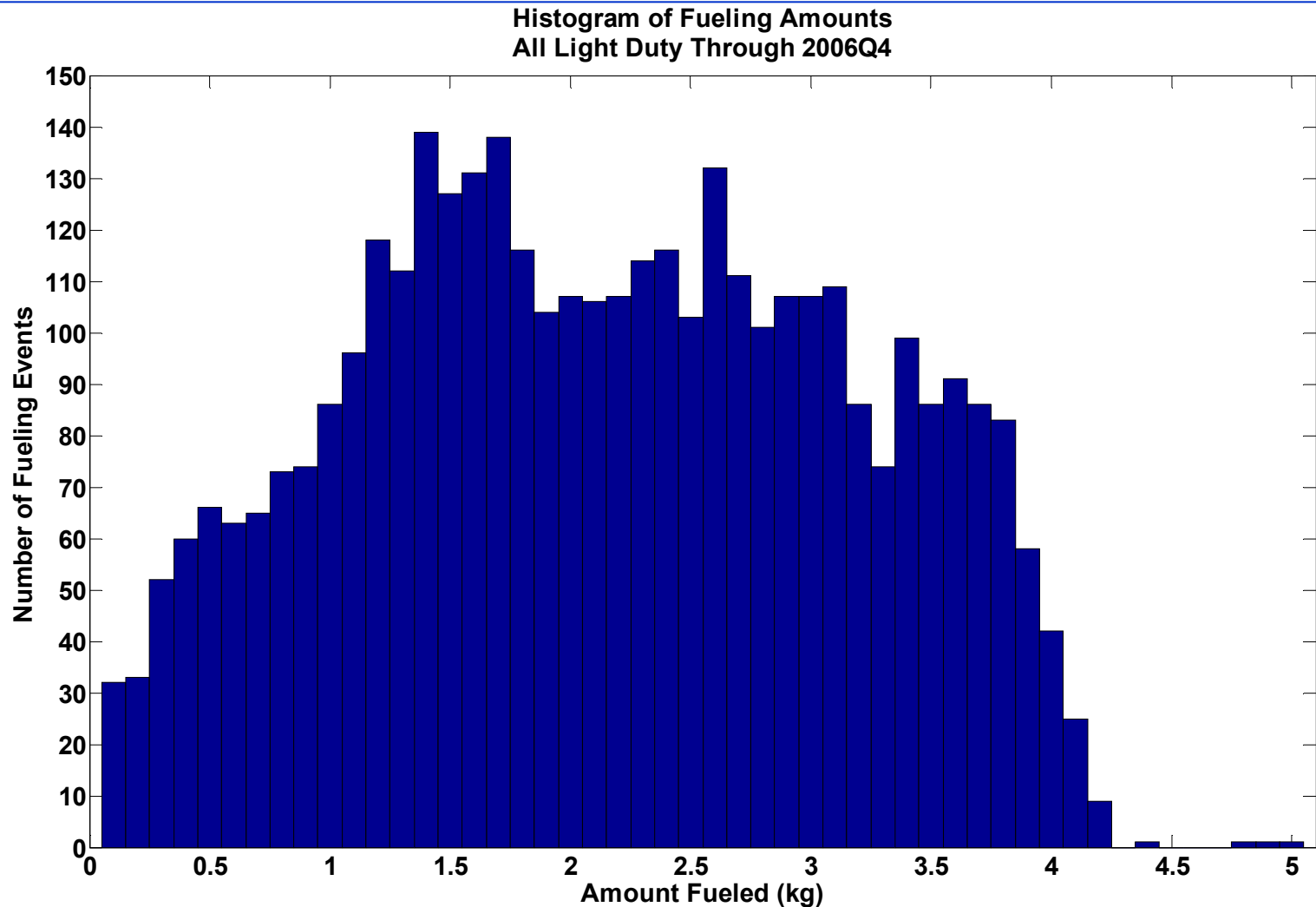
# CDP#38: Refueling Times



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# CDP#39: Refueling Amounts



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# REPORT DOCUMENTATION PAGE

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| <b>14. ABSTRACT (Maximum 200 Words)</b><br>This presentation provides the composite data products as of Spring 2007 from NREL's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project. |                                    |   |   |  |  |  |
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