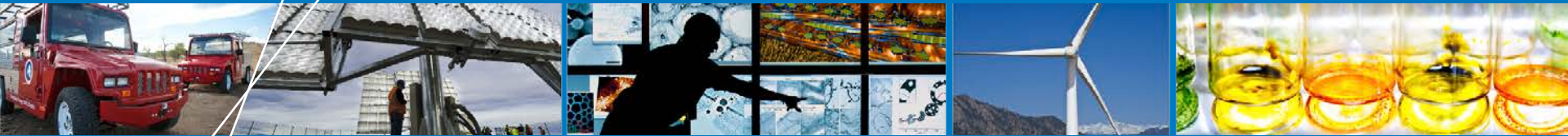


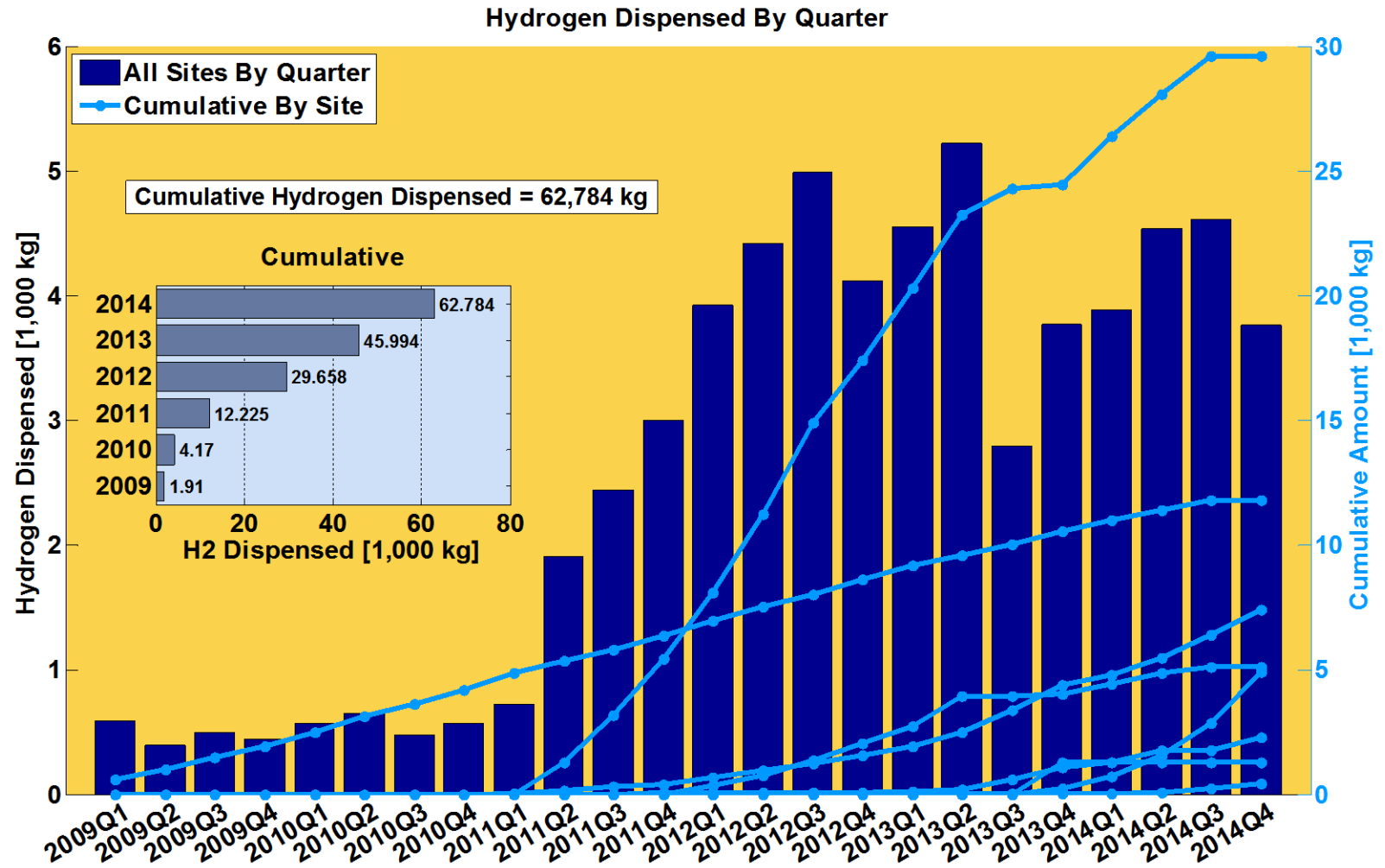
Next Generation Hydrogen Station Composite Data Products Data through Quarter 4 of 2014



**Sam Sprik, Jennifer Kurtz,
Chris Ainscough, Mike Peters**

May 2015

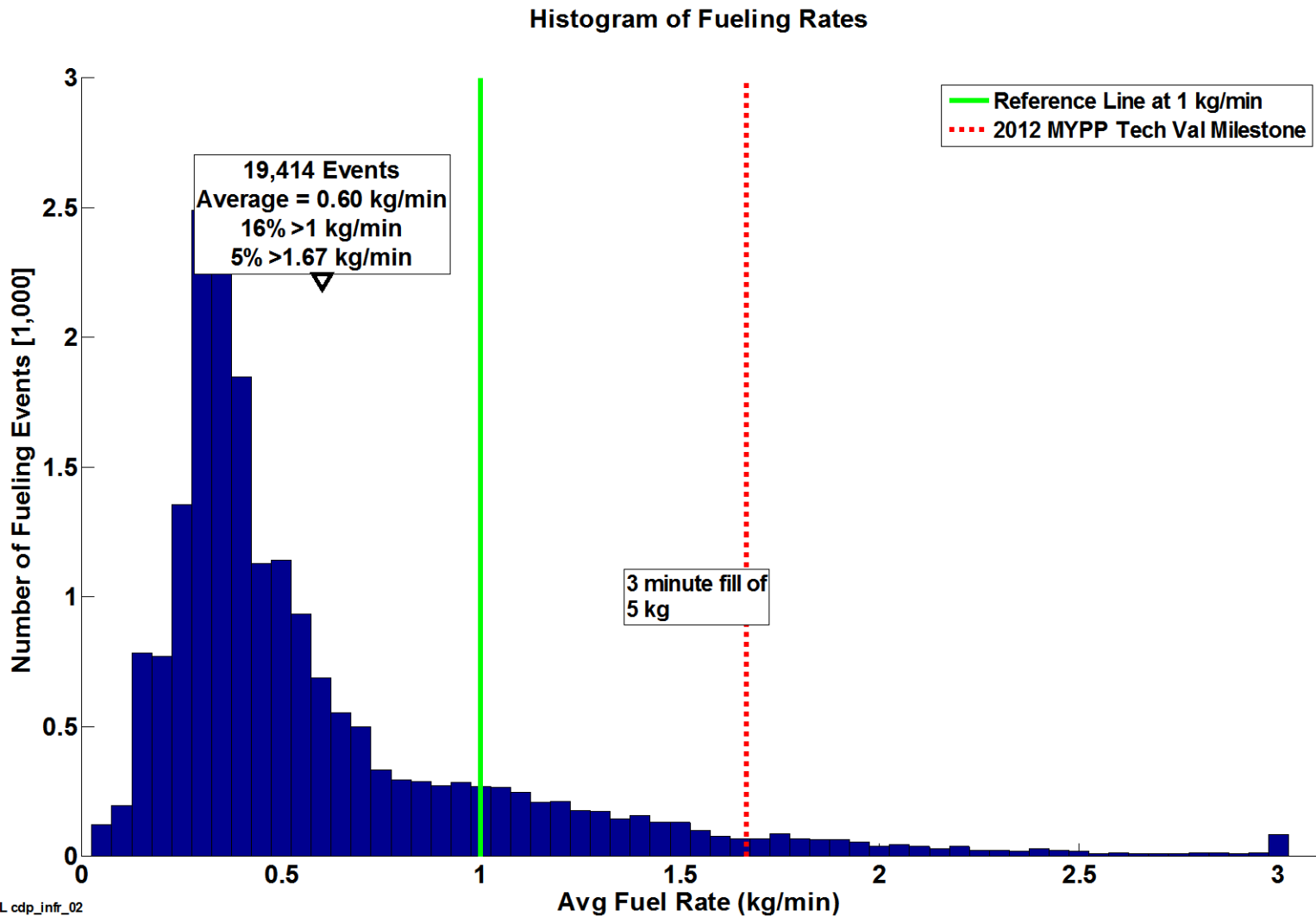
Hydrogen Dispensed by Quarter



NREL cdp_infr_01

Created: Apr-29-15 8:53 AM | Data Range: 2008Q3-2014Q4

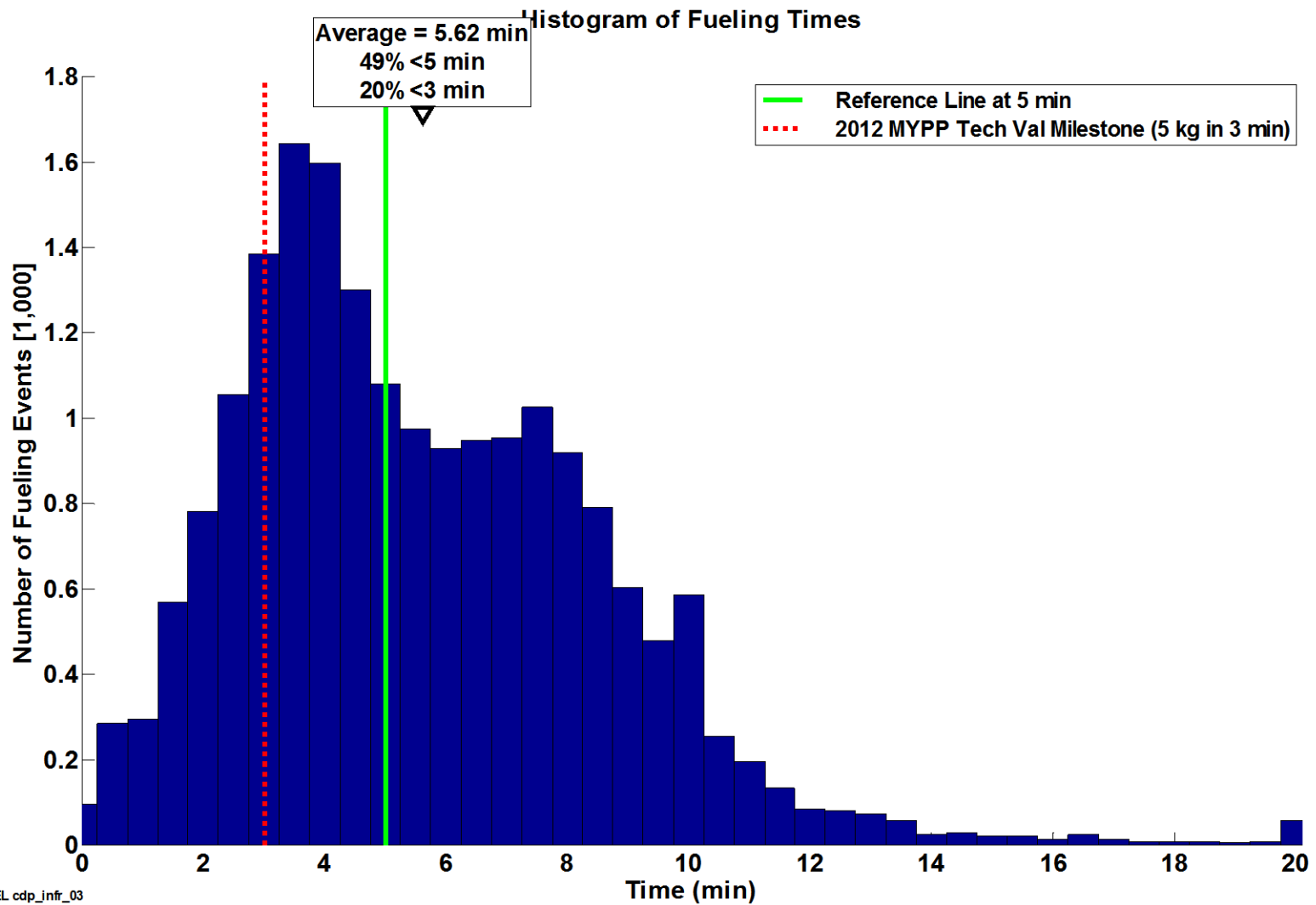
Histogram of Fueling Rates



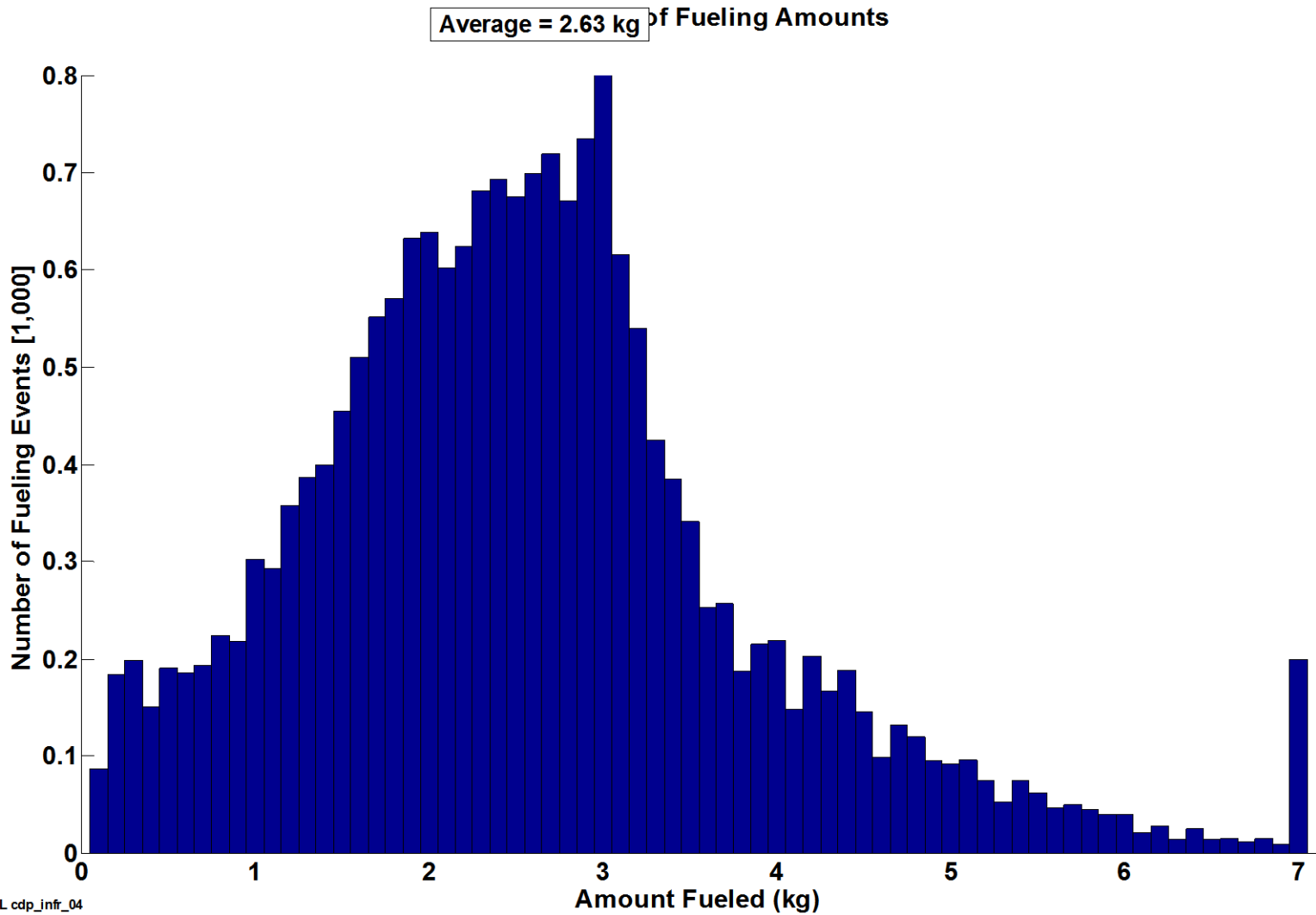
NREL cdp_infr_02

Created: Apr-09-15 3:49 PM | Data Range: 2008Q3-2014Q4

Histogram of Fueling Times



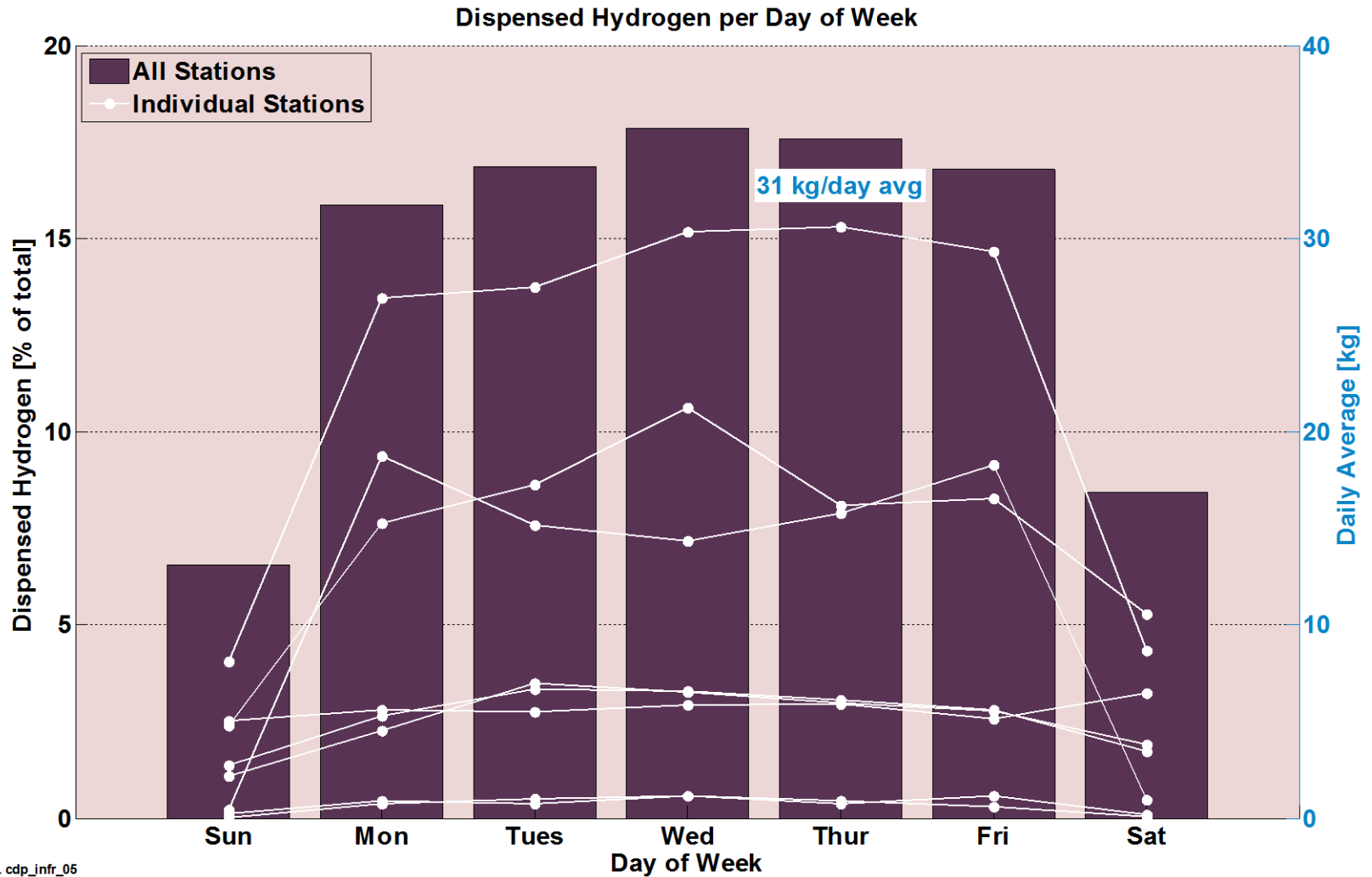
Histogram of Fueling Amounts



NREL cdp_infr_04

Created: Apr-09-15 3:52 PM | Data Range: 2008Q3-2014Q4

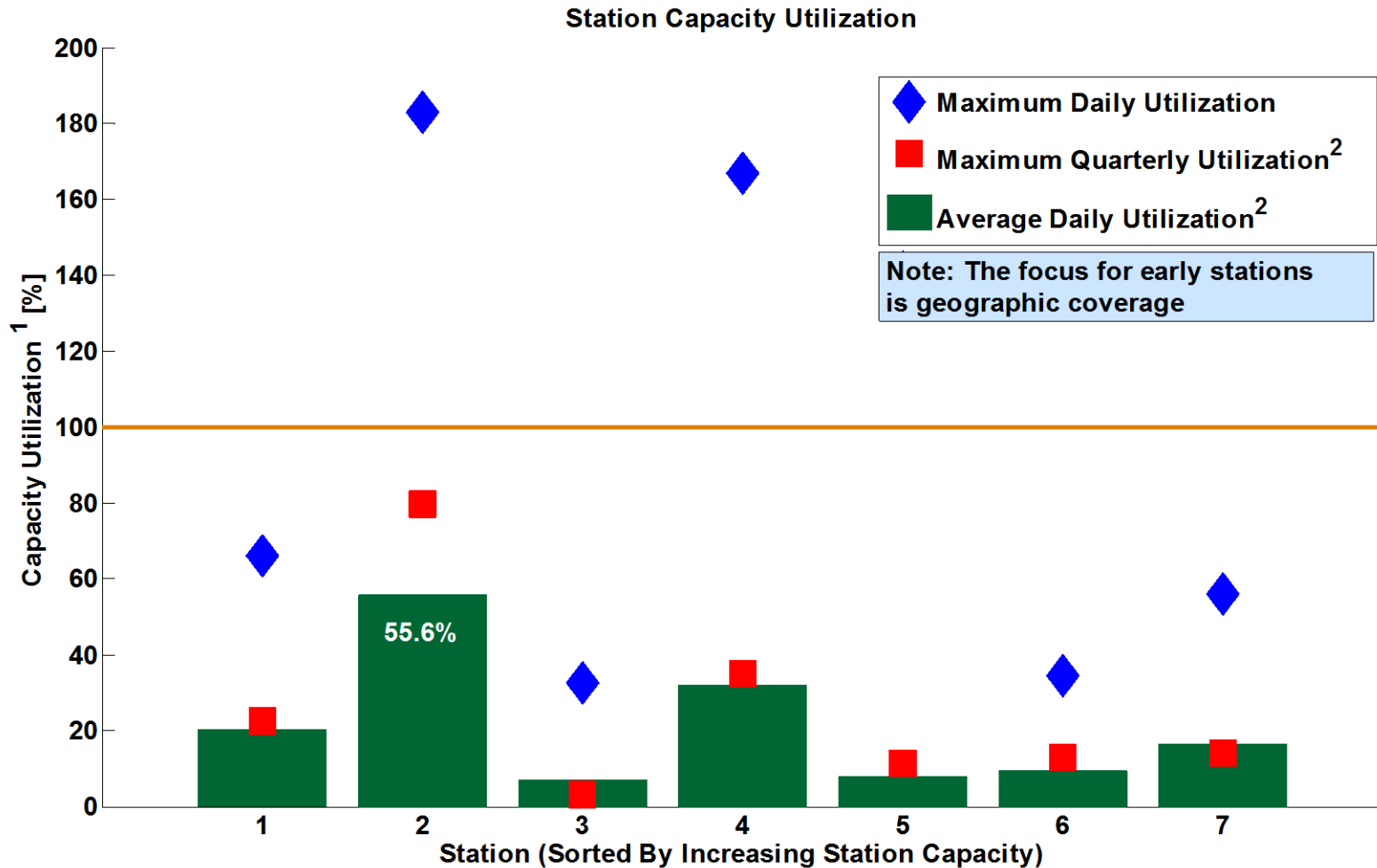
Dispensed Hydrogen per Day of Week



NREL_cdp_infr_05

Created: Apr-09-15 3:54 PM | Data Range: 2008Q3-2014Q4

Station Capacity Utilization

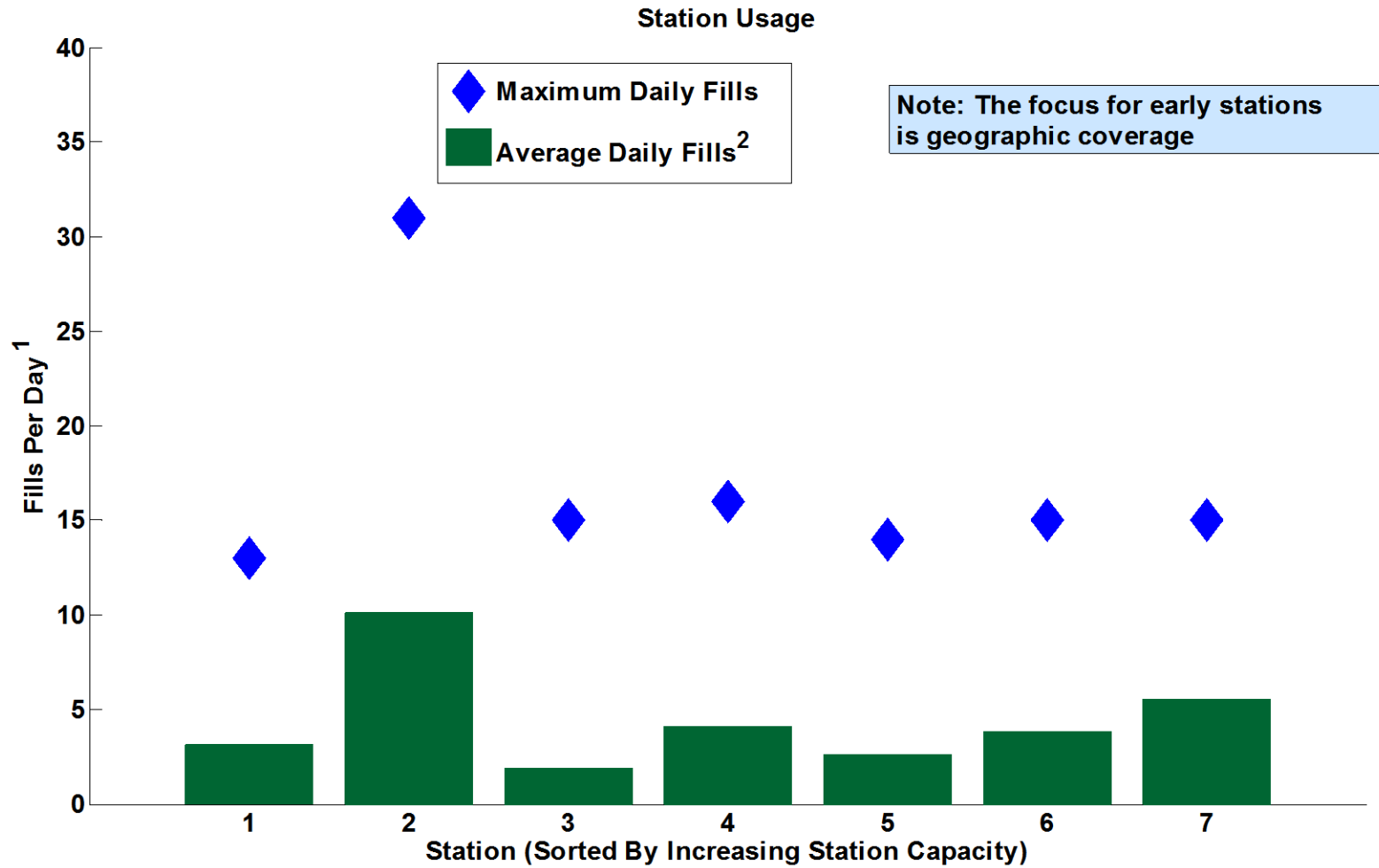


¹ Station nameplate capacity reflects a variety of system design considerations including system capacity, throughput, system reliability and durability, and maintenance. Actual daily usage may exceed nameplate capacity.

² Maximum quarterly utilization considers all days; average daily utilization considers only days when at least one filling occurred

CDP-INFR-07

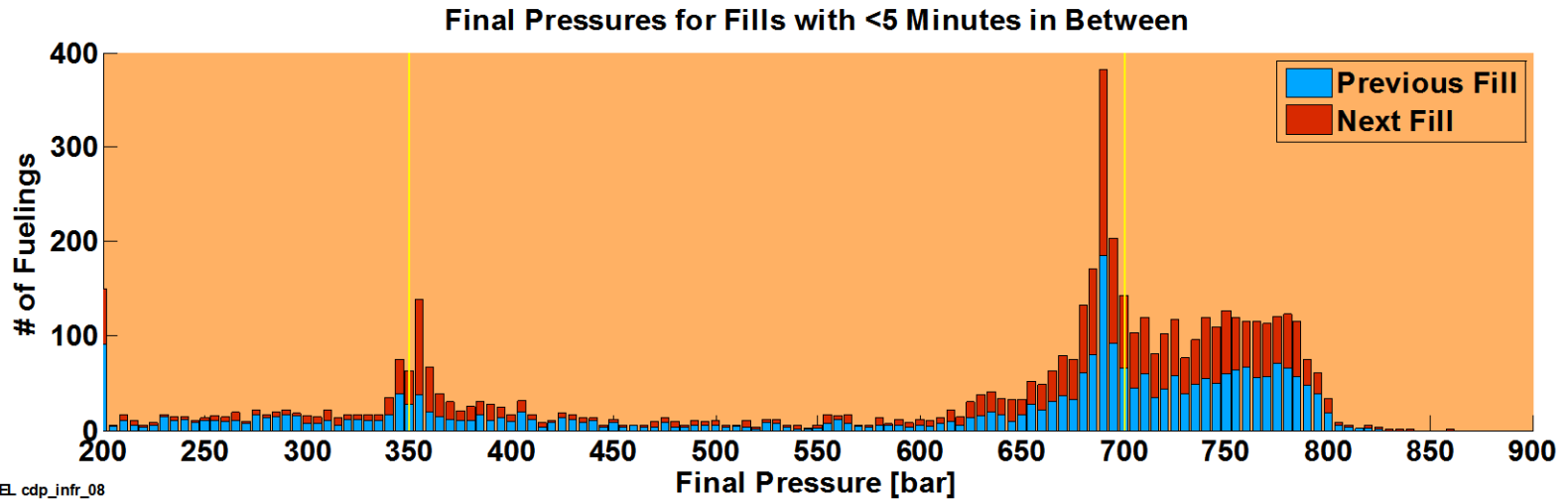
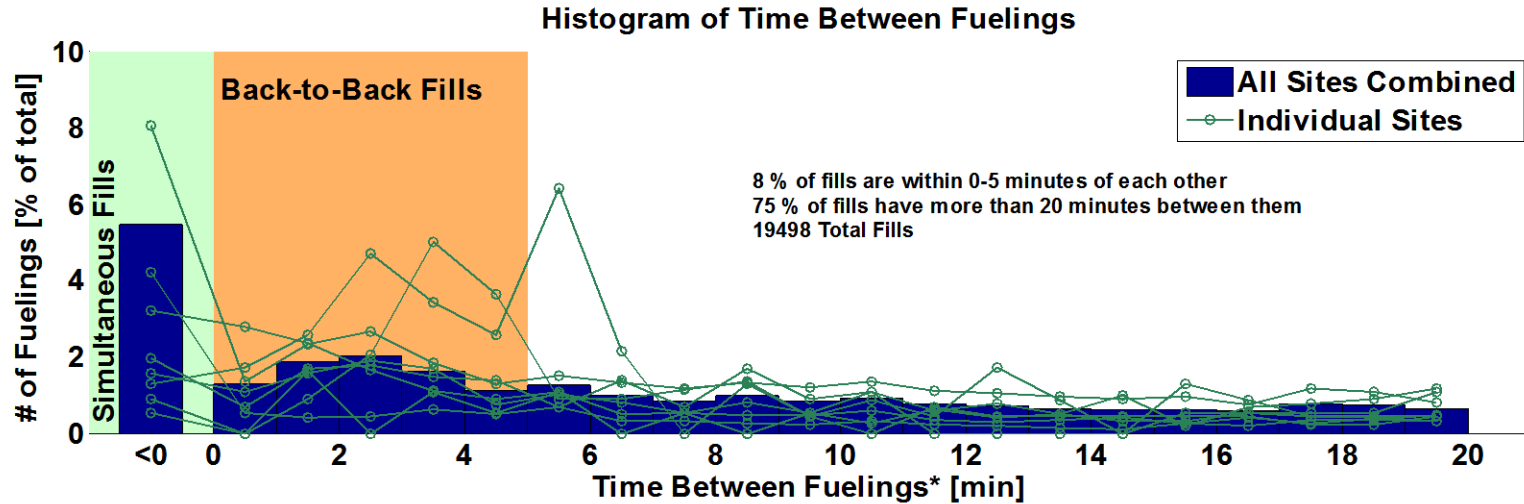
Station Usage



 NREL cdp_infr_07
Created: Apr-09-15 3:56 PM | Data Range: 2008Q3-2014Q4

¹Excludes hydrogen fills of < 0.5 kg
²Average daily fills considers only days when at least one fill occurred

Time Between Fueling

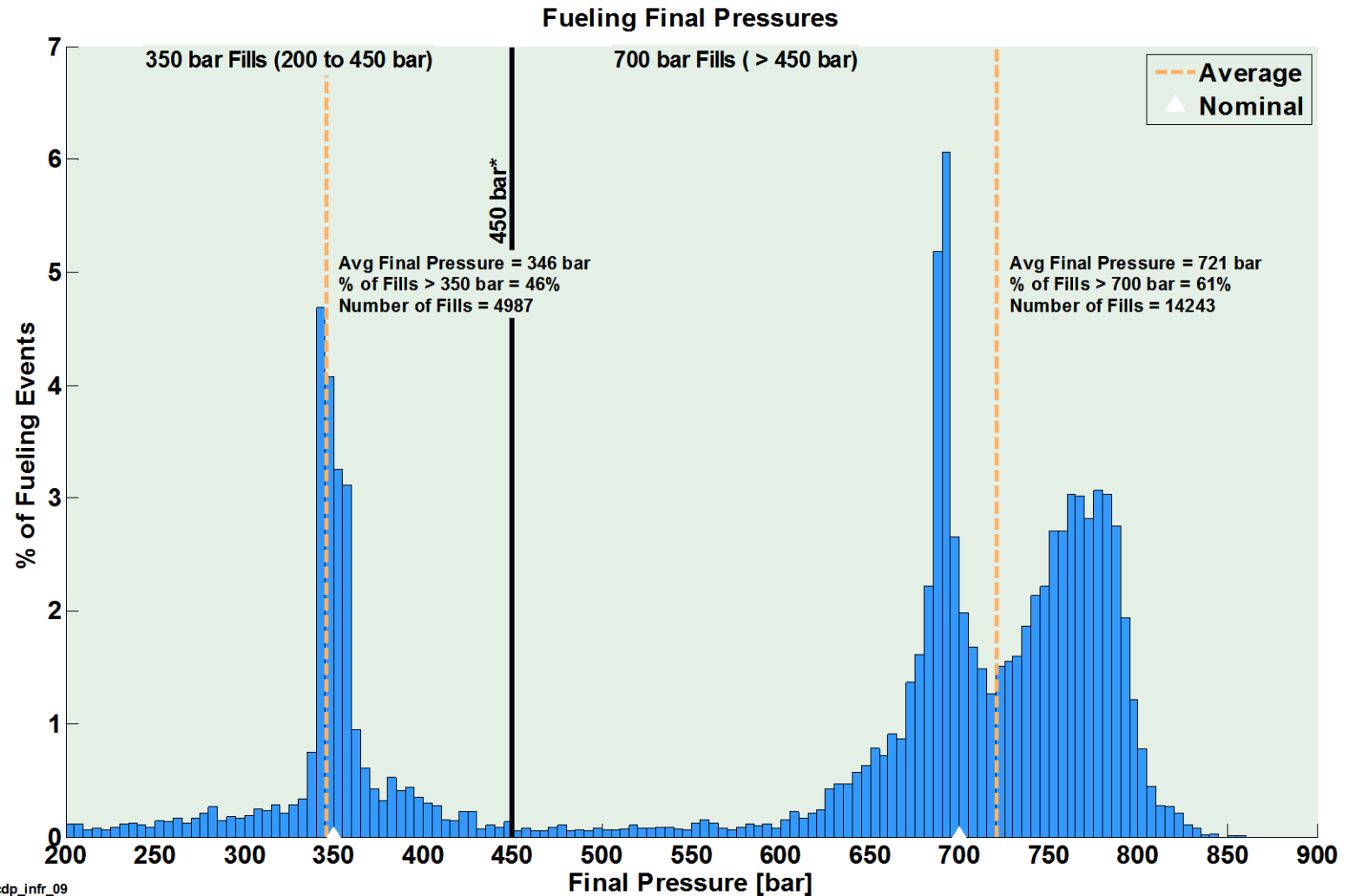


NREL_cdp_infr_08

Created: Apr-09-15 3:57 PM | Data Range: 2008Q3-2014Q4

*Time is from end of fill to start of next fill.

Fueling Final Pressures



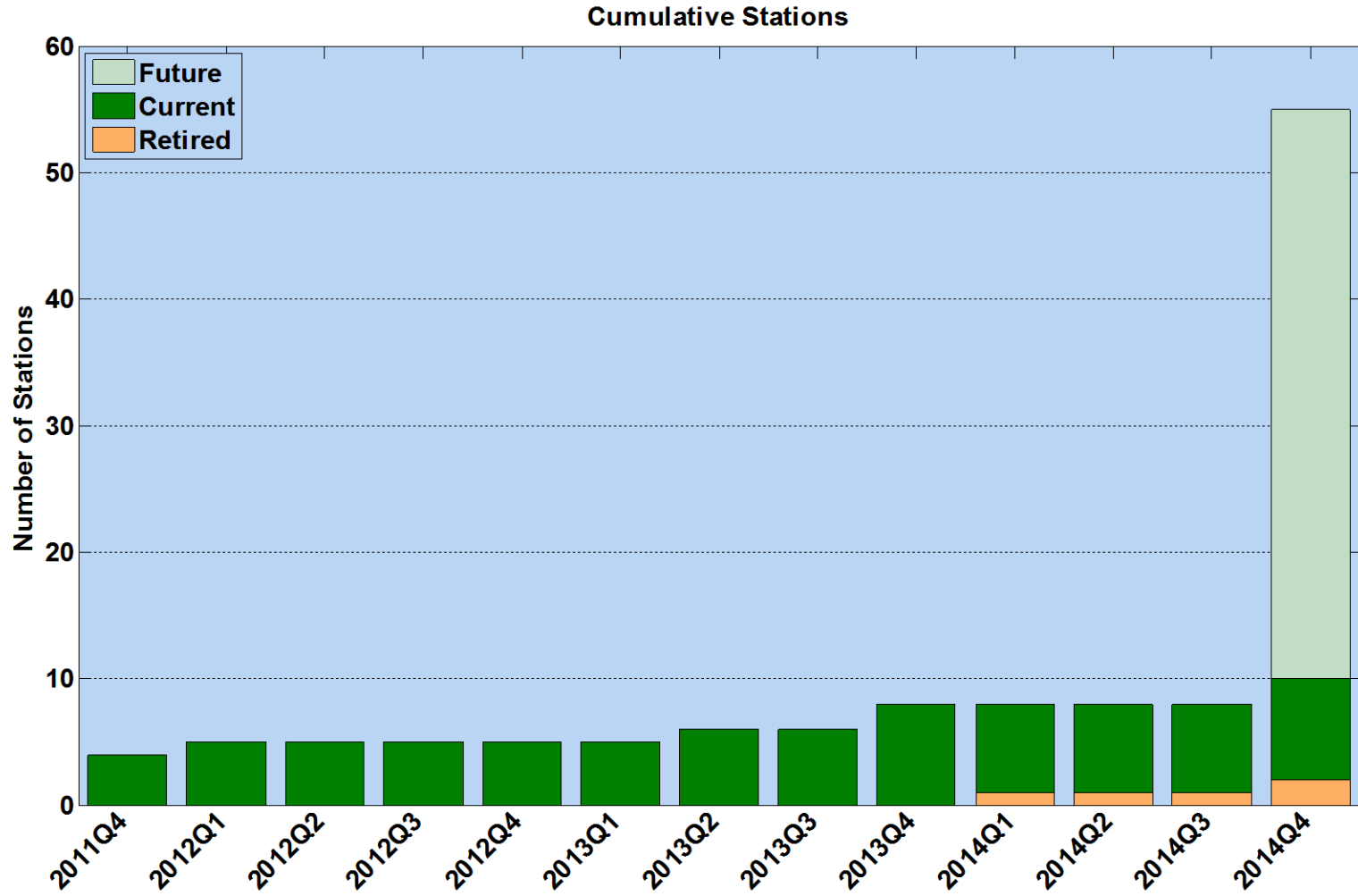
NREL_cdp_infr_09

Created: Apr-09-15 3:58 PM | Data Range: 2008Q3-2014Q4

*The line at 450 bar separates 350 bar fills from 700 bar fills. It is slightly over the allowable 125% of nominal pressure (437.5 bar) from SAE J2601.

CDP-INFR-10

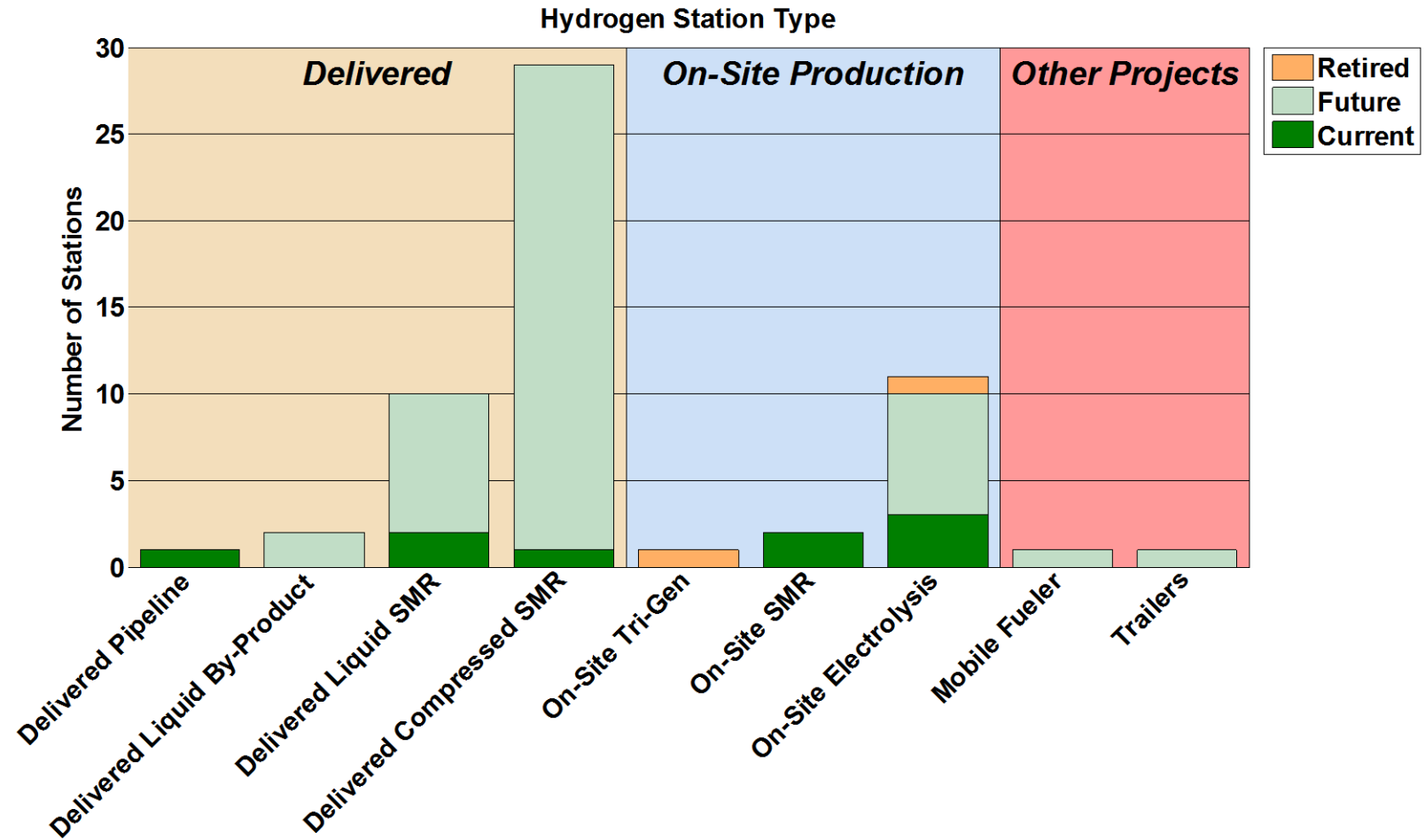
Cumulative Number of Stations



NREL cdp_infr_10

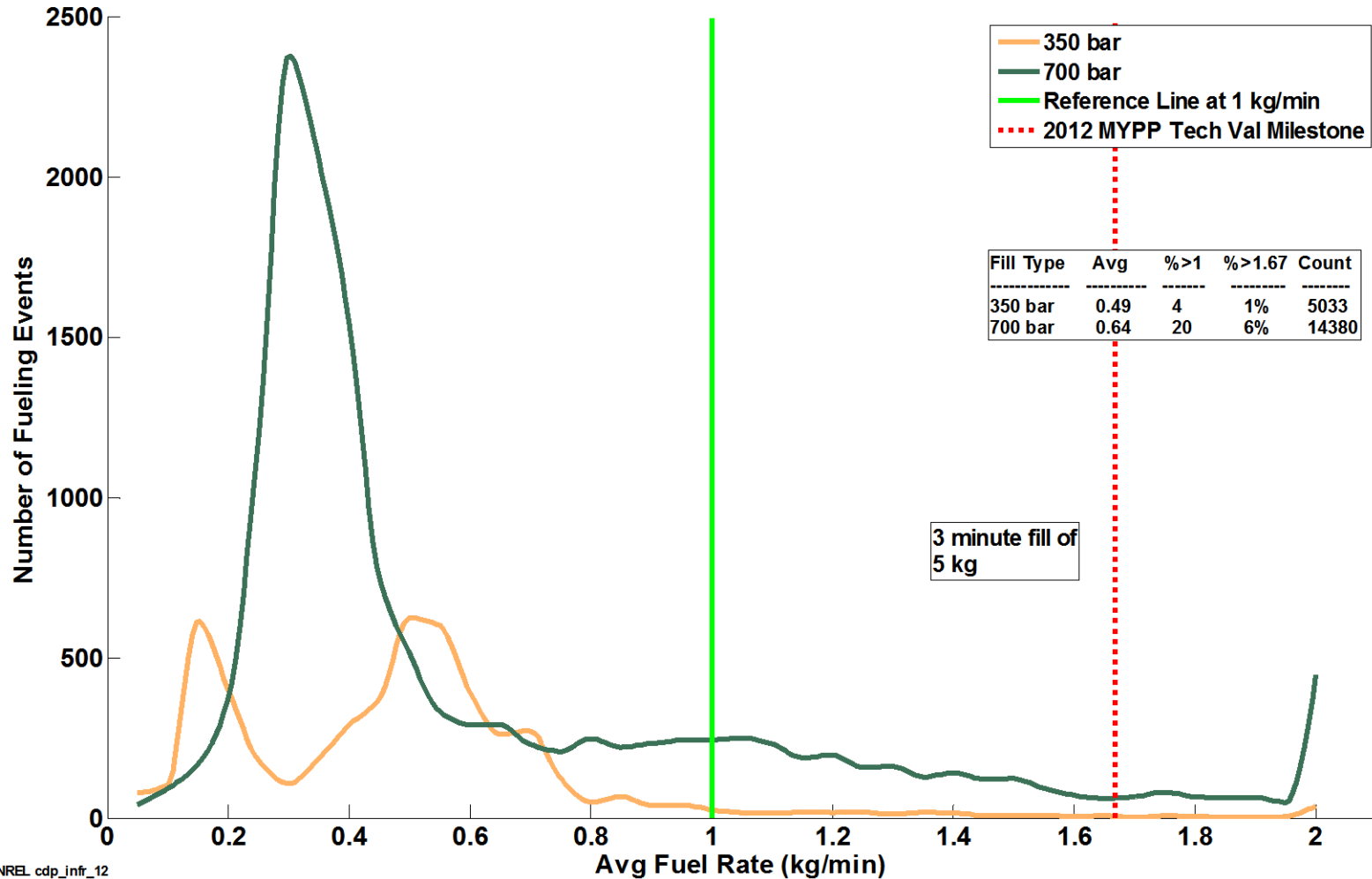
Created: Apr-29-15 11:39 AM | Data Range: 2009Q1-2014Q4

Hydrogen Stations by Type



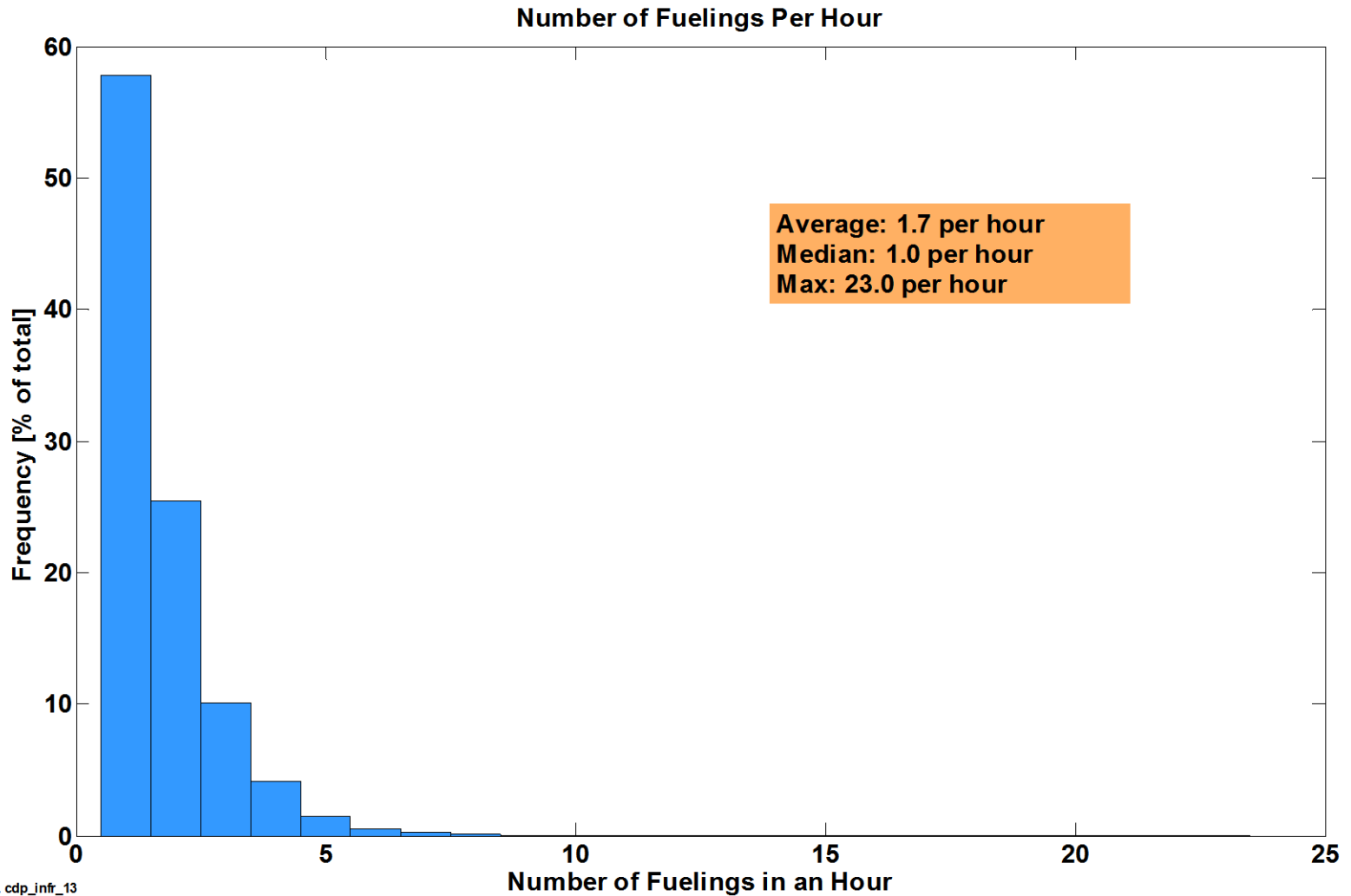
Fueling Rates 350 vs. 700 bar

Histogram of Fueling Rates
350 vs 700 bar Fills



CDP-INFR-13

Number of Fueling Events per Hour

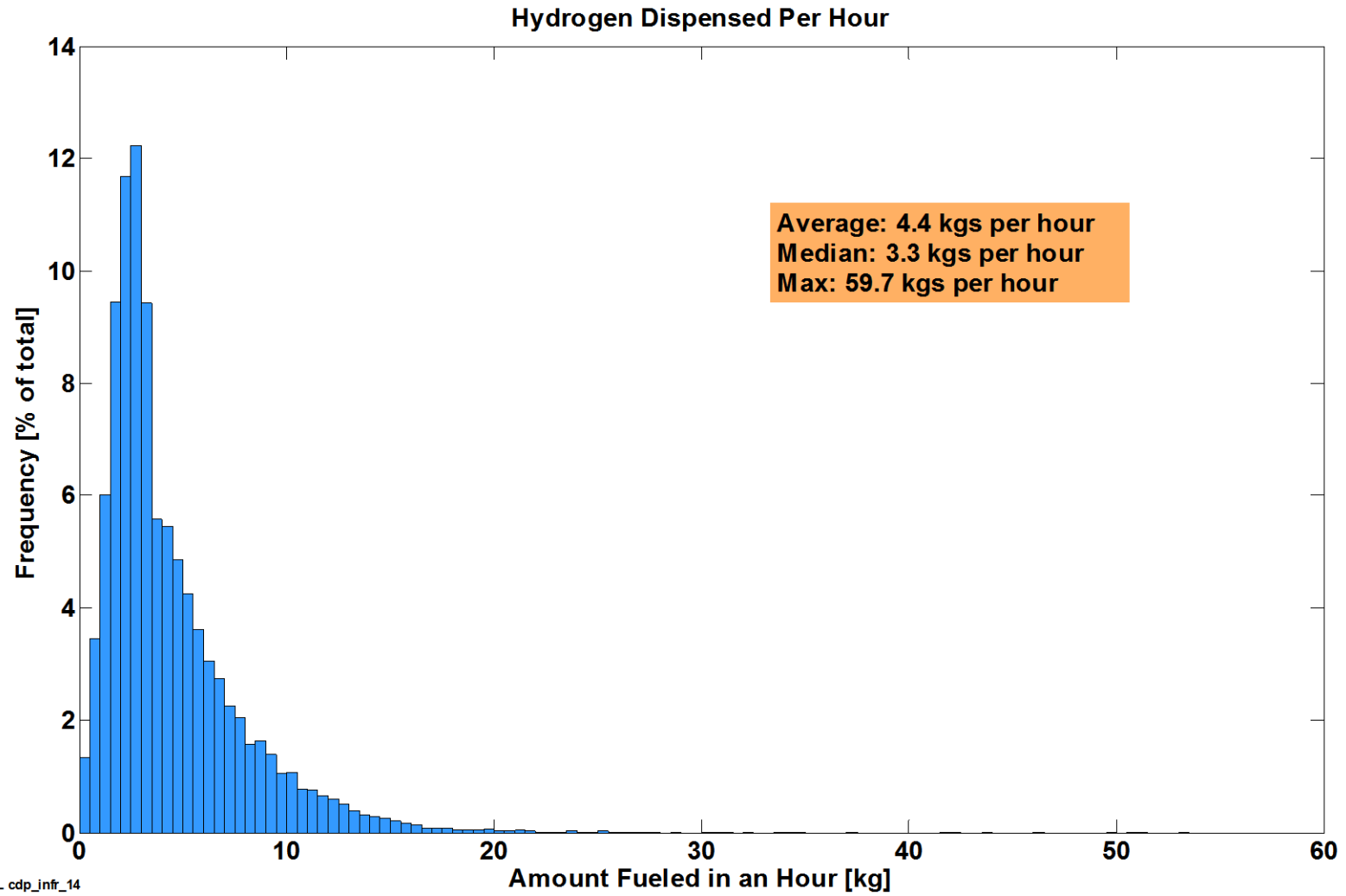



NREL cdp_infr_13

Created: Apr-09-15 4:02 PM | Data Range: 2008Q3-2014Q4

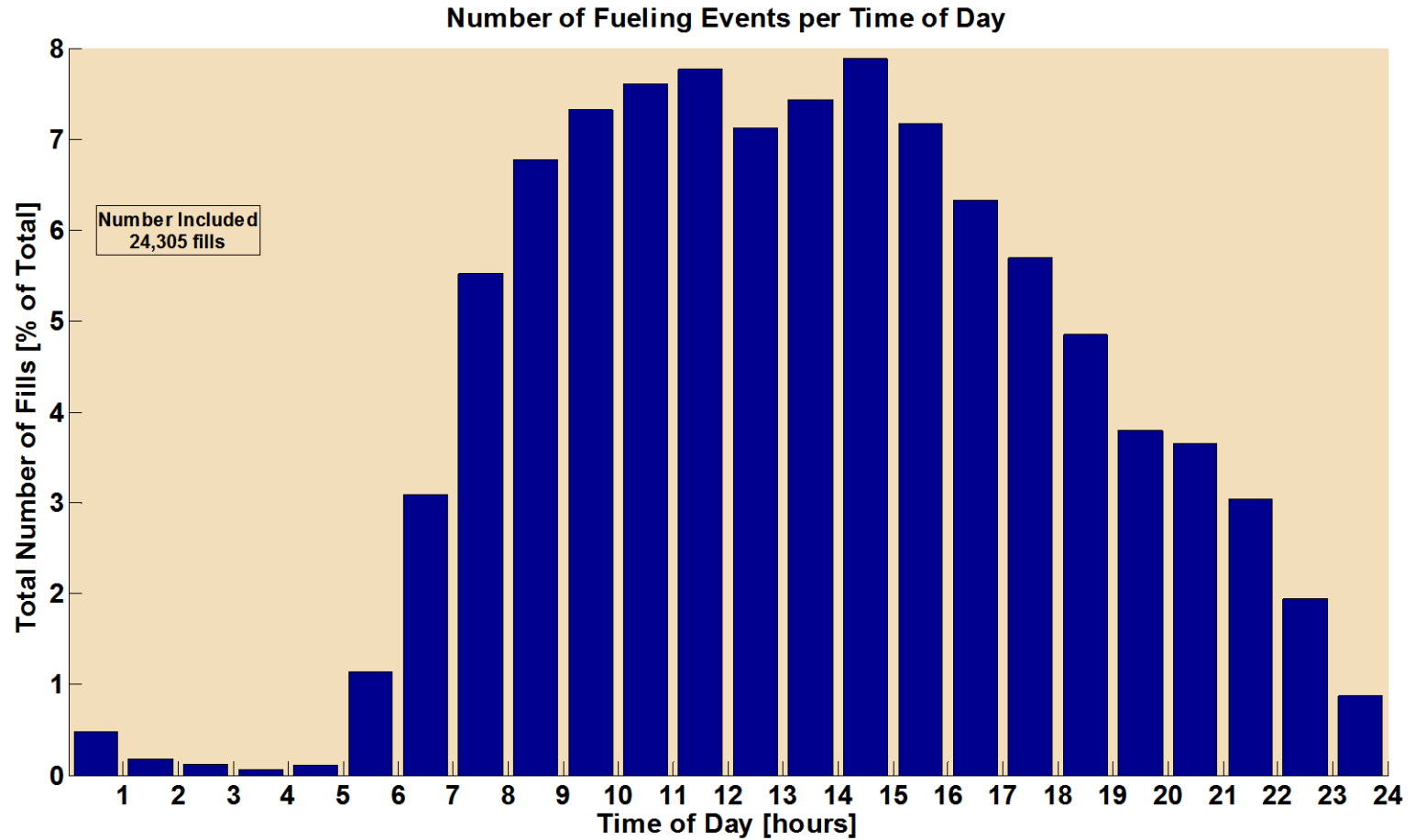
CDP-INFR-14

Hydrogen Dispensed per Hour



 NREL cdp_infr_14
Created: Apr-09-15 4:04 PM | Data Range: 2008Q3-2014Q4

Number of Fills by Time of Day

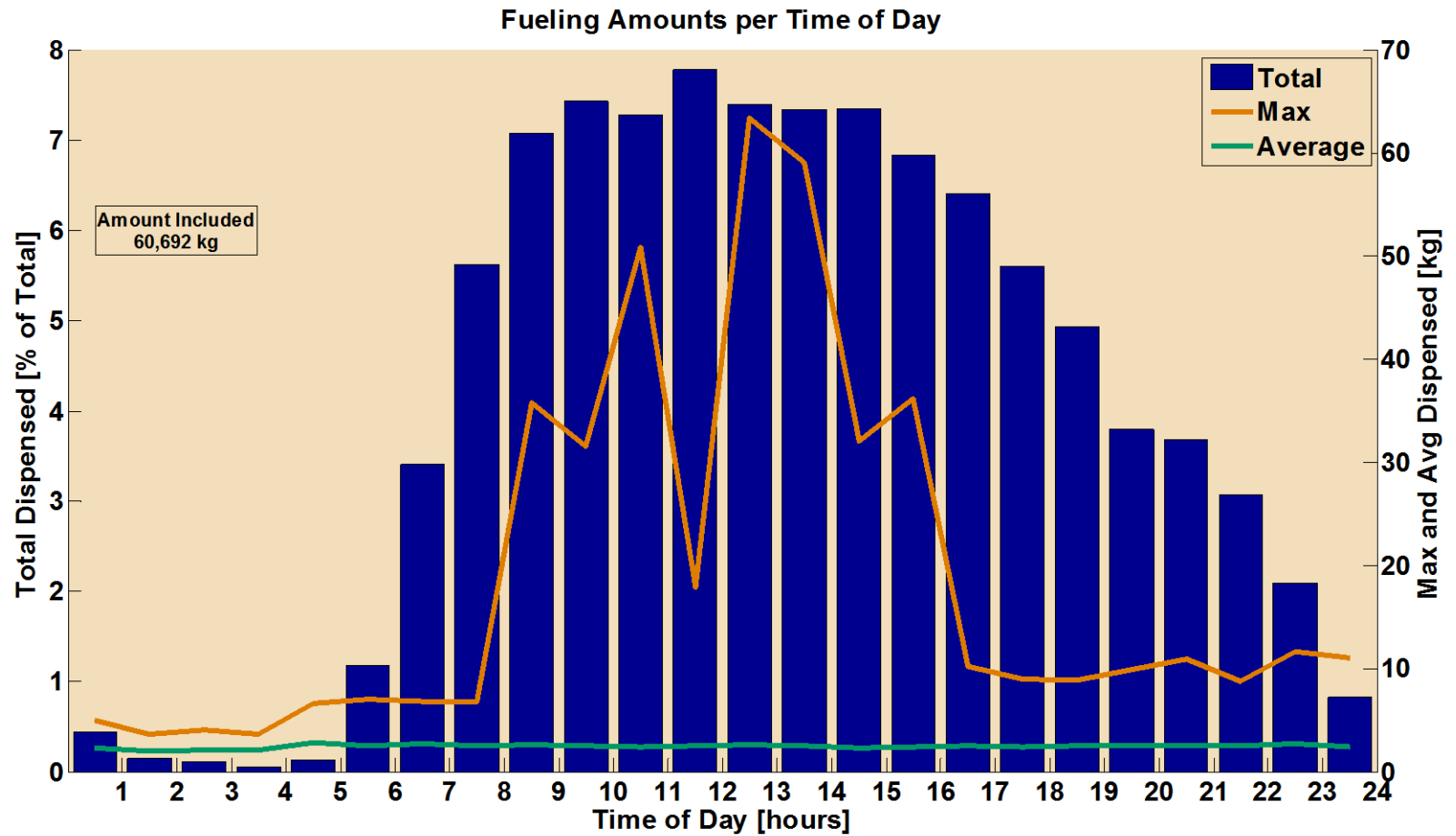


NREL cdp_infr_15

Created: Apr-09-15 4:05 PM | Data Range: 2008Q3-2014Q4

CDP-INFR-16

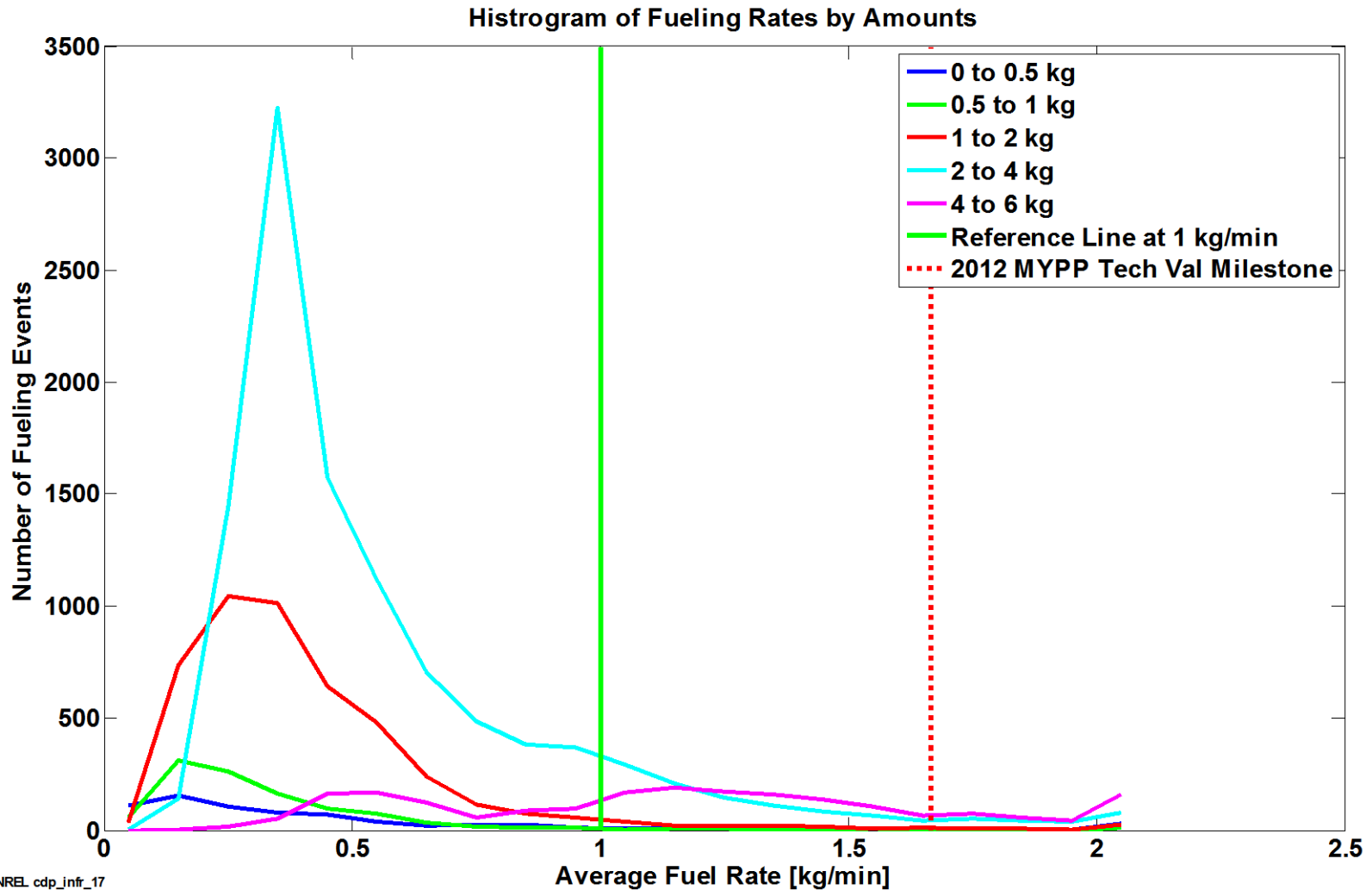
Fueling Amounts per Time of Day



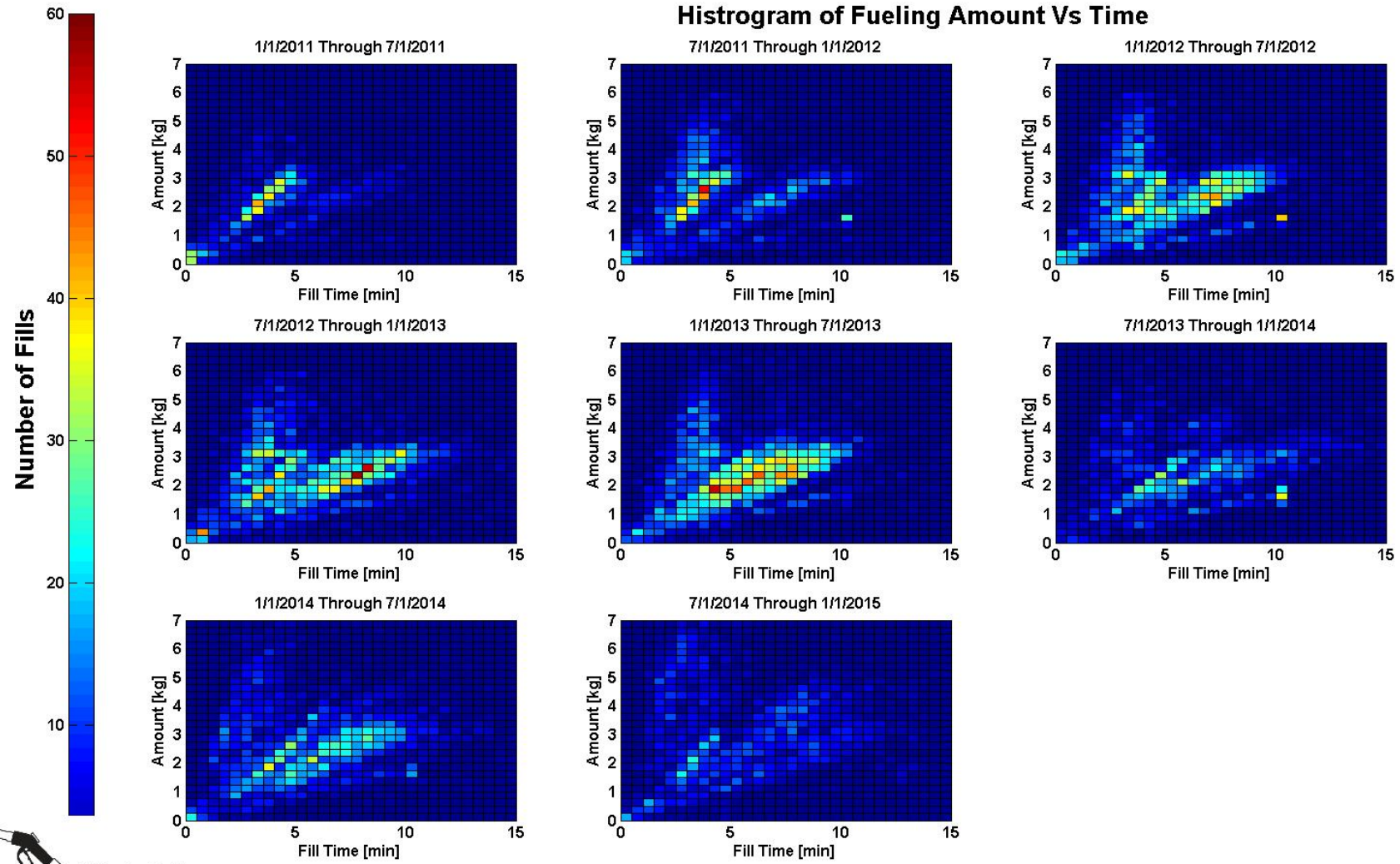
NREL cdp_infr_16

Created: Apr-09-15 4:06 PM | Data Range: 2008Q3-2014Q4

Fueling Rates by Amount Filled



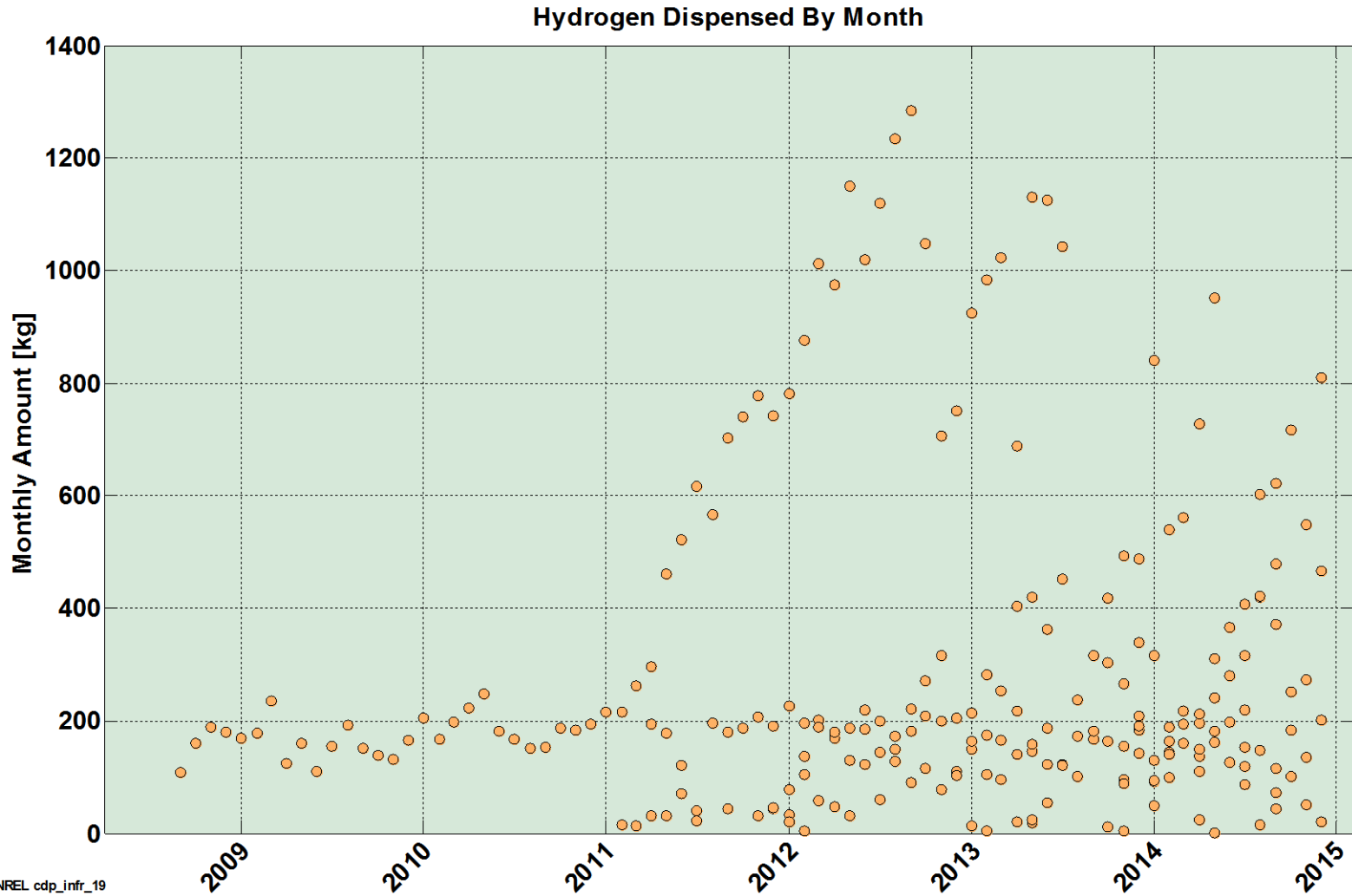
Fueling Amount vs. Time to Fill



NREL cdp_infr_18

Created: Apr-09-15 4:09 PM | Data Range: 2008Q3-2014Q4

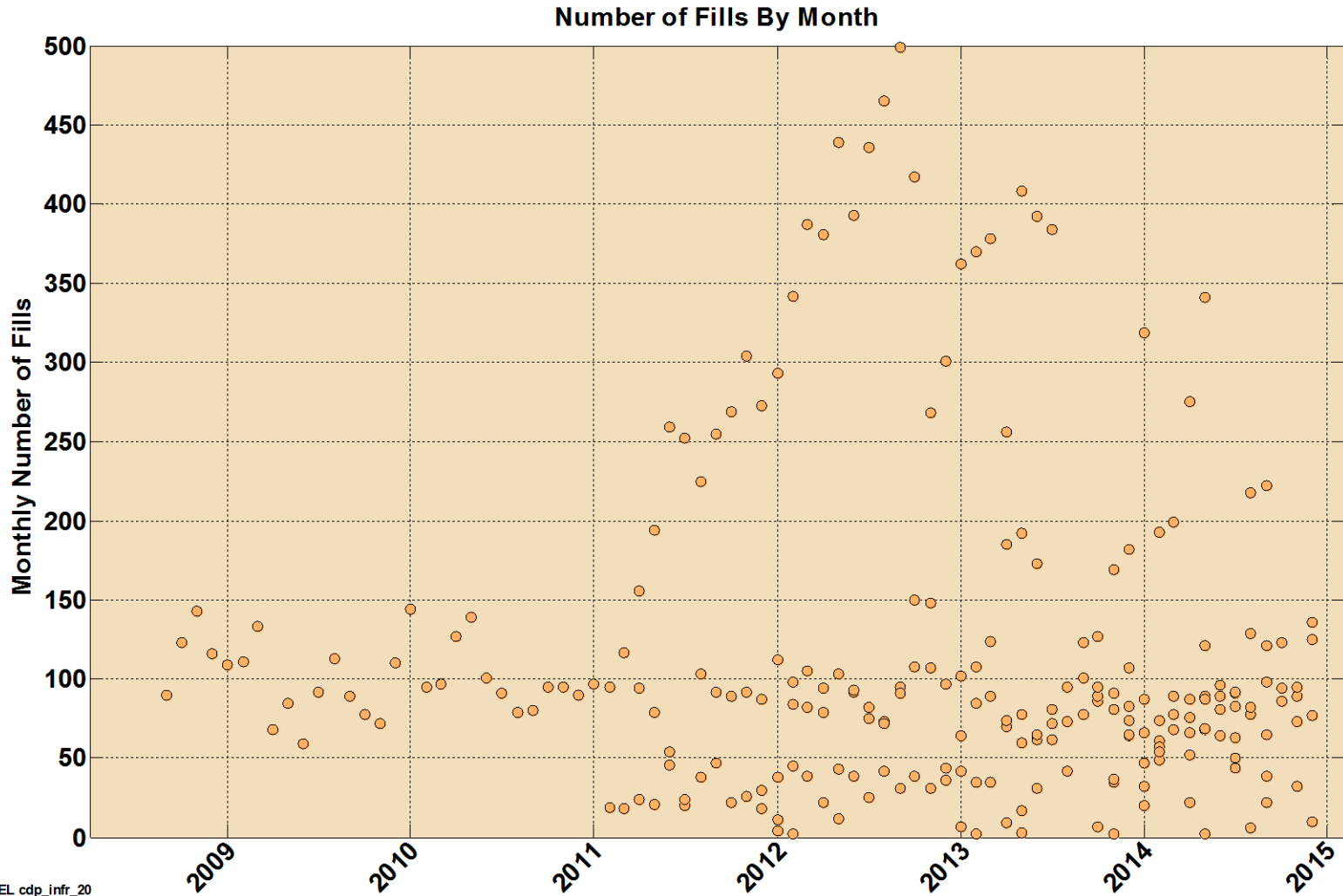
Hydrogen Dispensed by Month




NREL cdp_infr_19

Created: Apr-09-15 4:10 PM | Data Range: 2008Q3-2014Q4

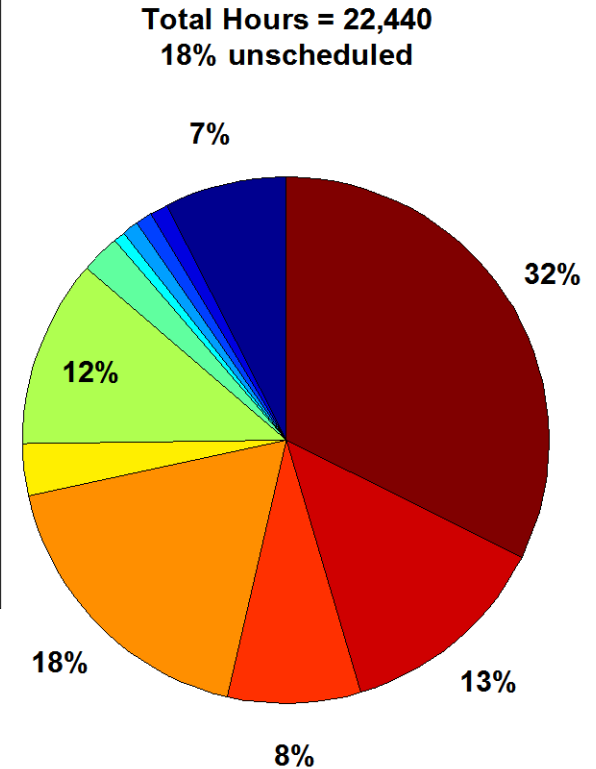
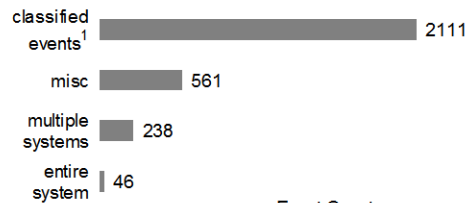
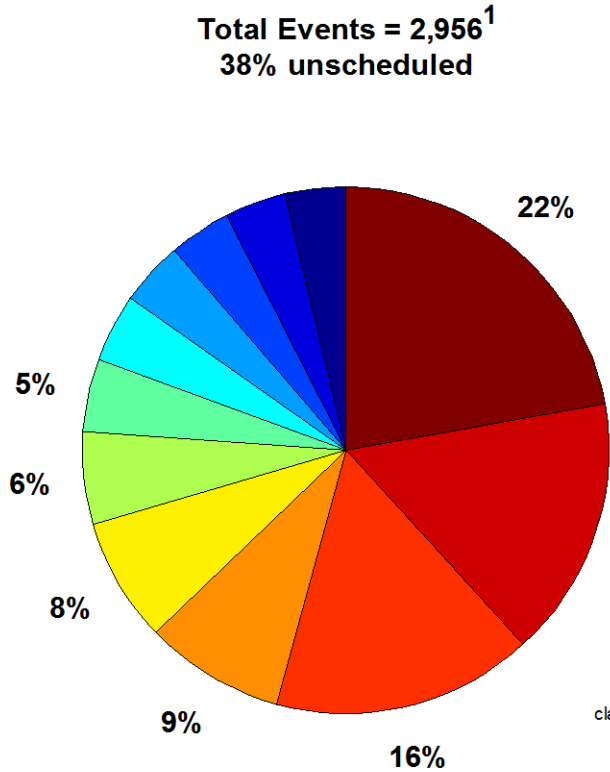
Number of Fills by Month



 NREL cdp_infr_20
Created: Apr-09-15 4:10 PM | Data Range: 2008Q3-2014Q4

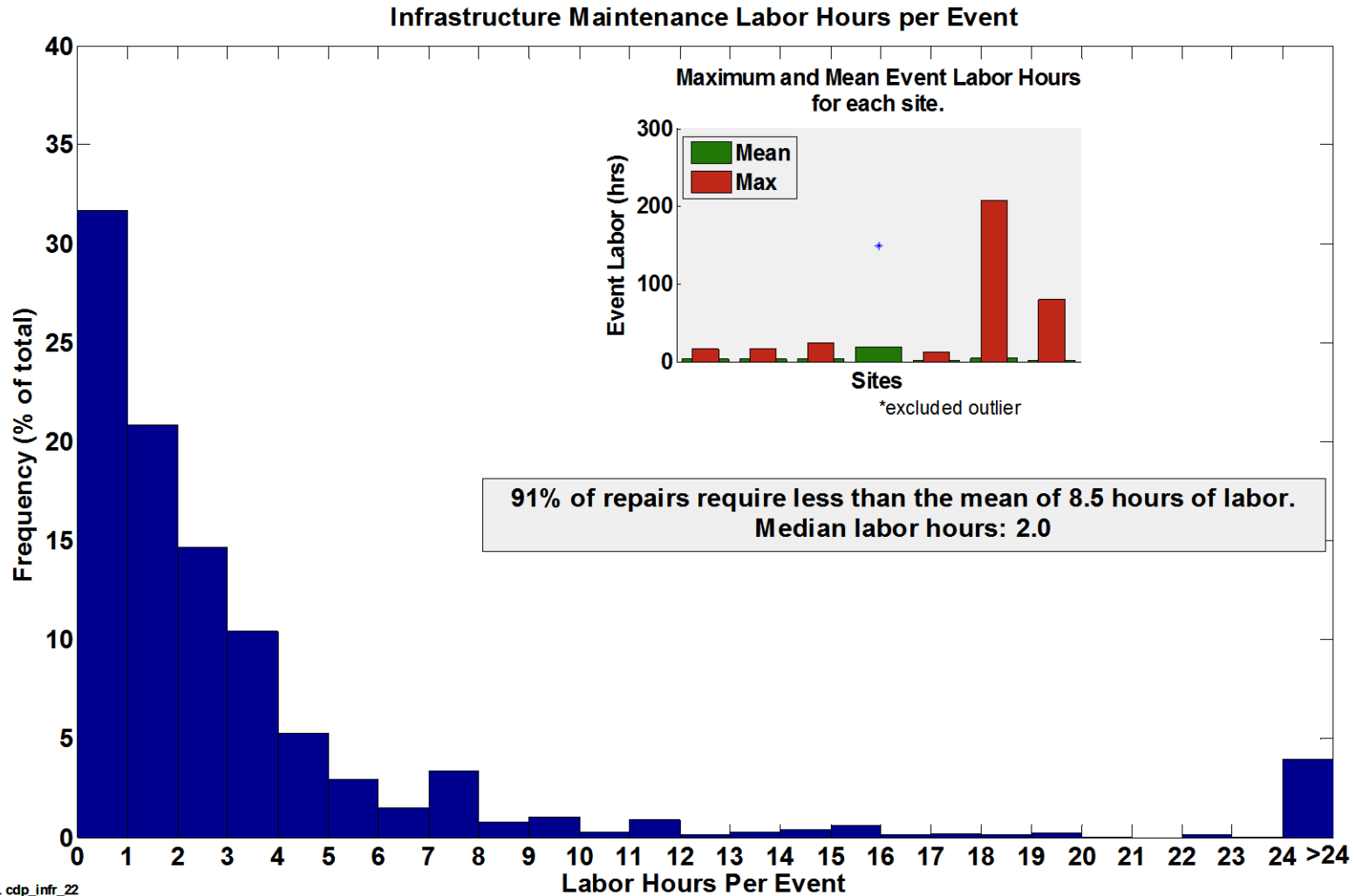
Maintenance by Equipment Type

Maintenance by Equipment Type



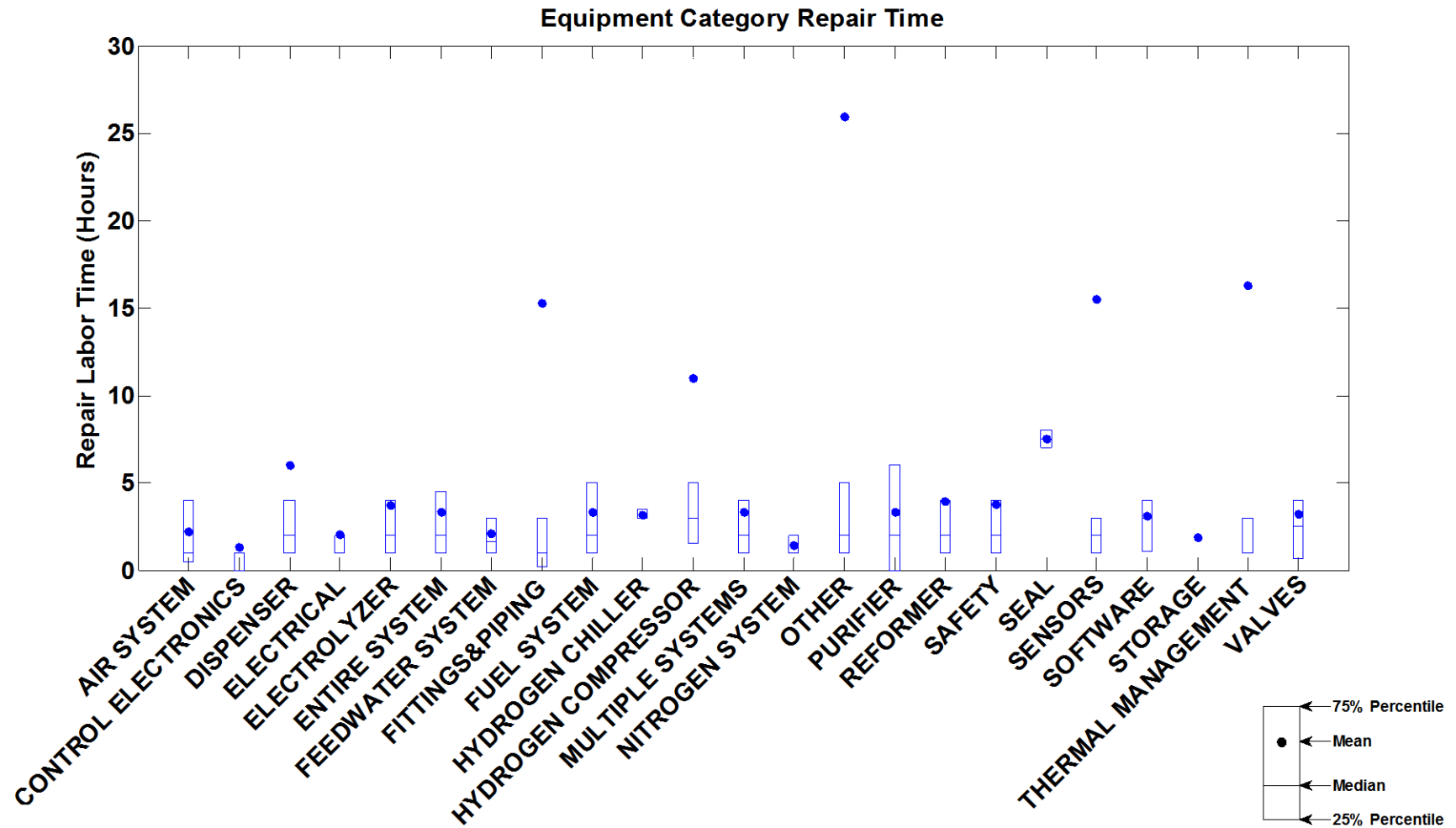
MISC includes the following failure modes: seal, nitrogen system, hydrogen chiller, fuel system, software, air system, purifier, valves, other

Maintenance Labor Hours per Event



CDP-INFR-23

Equipment Category Repair Time

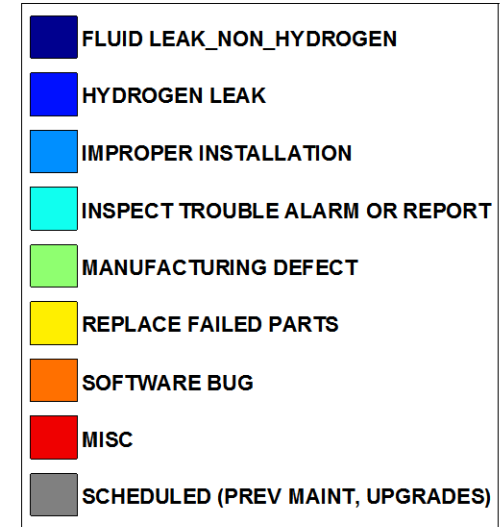
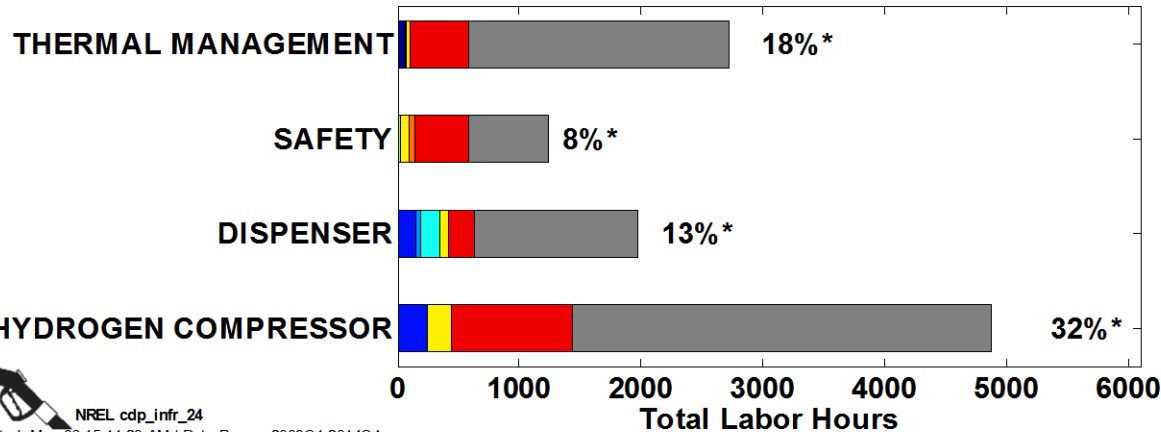
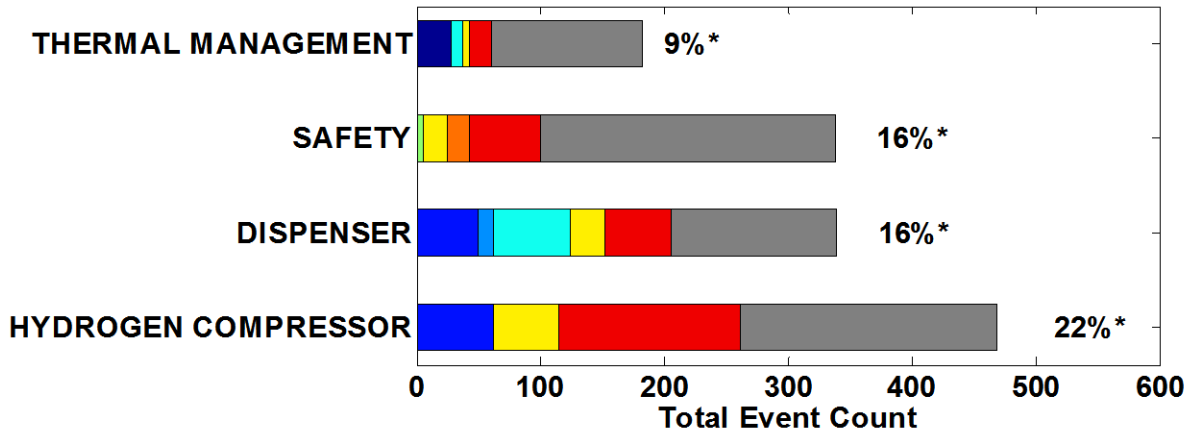


NREL cdp_infr_23

Created: Mar-17-15 3:20 PM | Data Range: 2008Q3-2014Q4

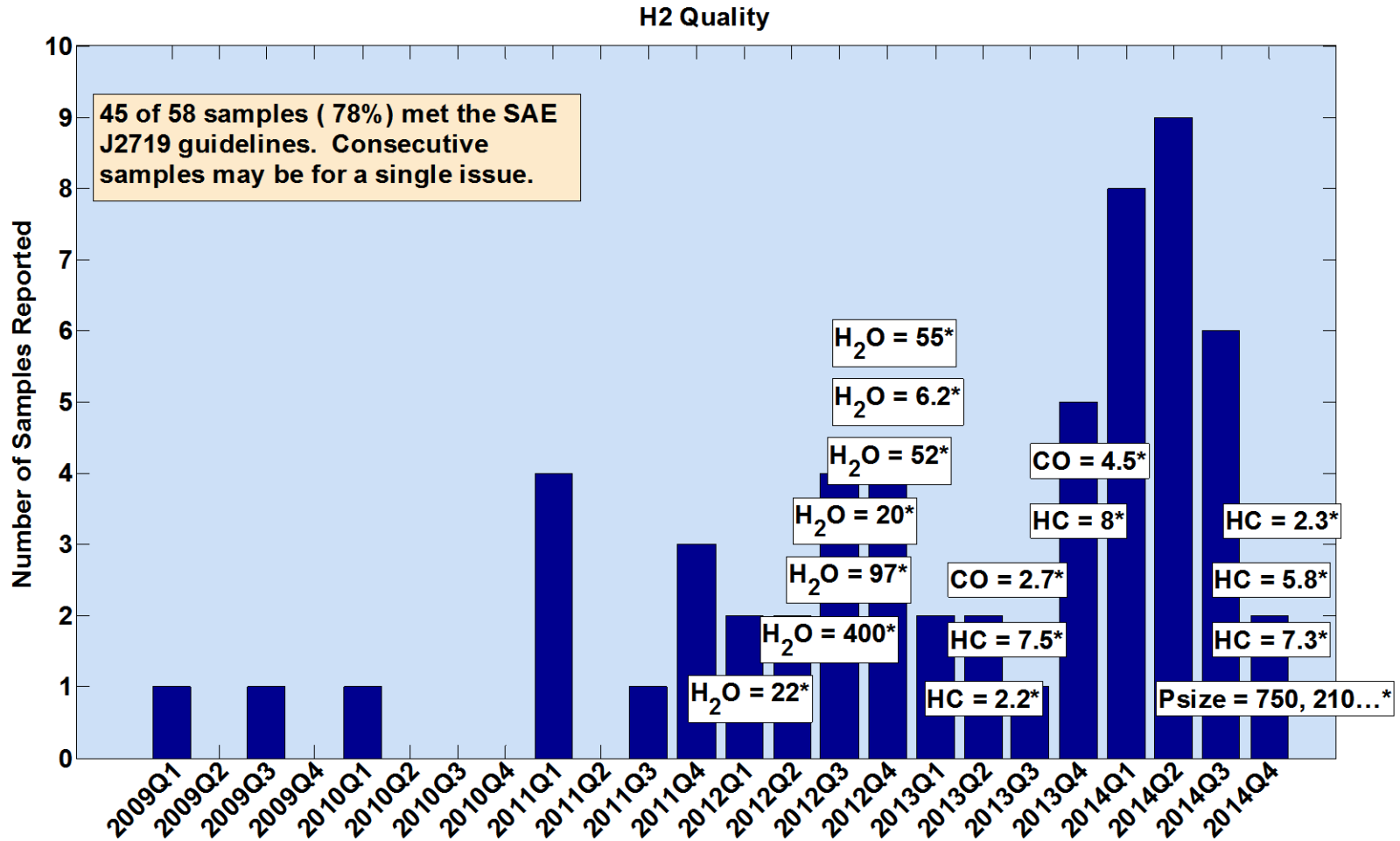
Failure Modes for Top Equipment Categories

Failure Modes for Top Equipment Categories



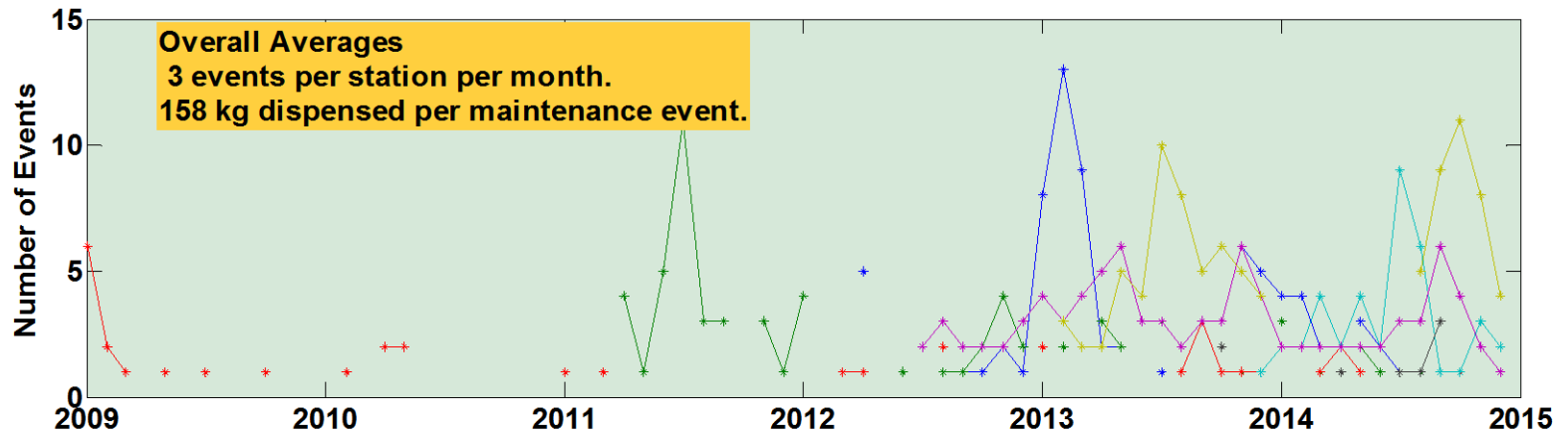
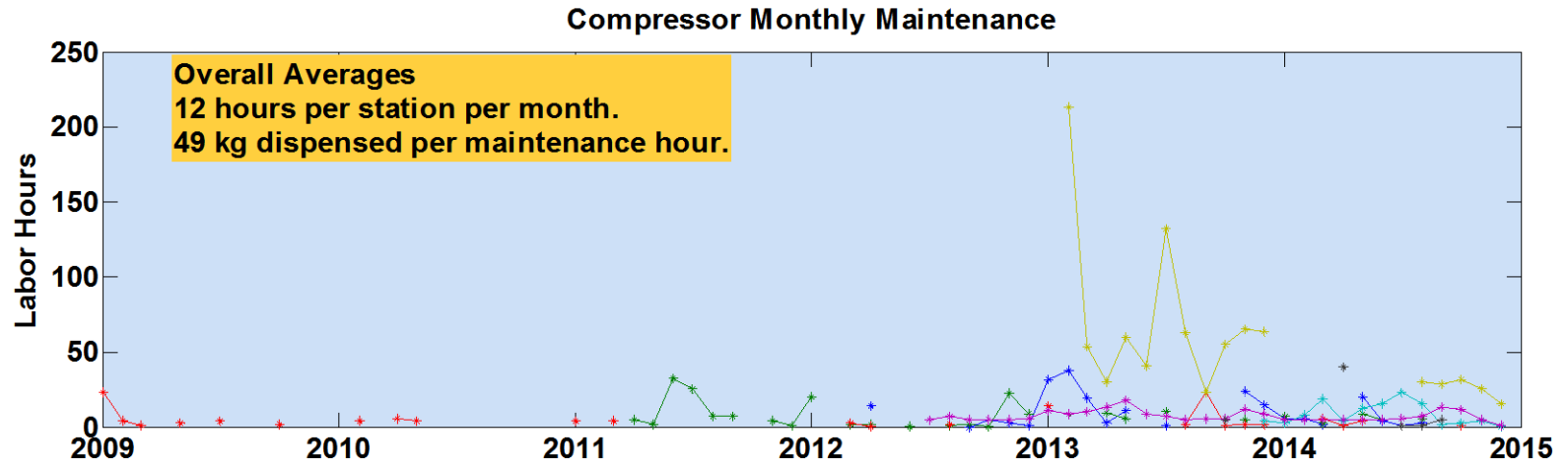
MISC includes the following failure modes: failed closed, flow low, inspect trouble alarm or report, manufacturing defect, operator protocol, other, out of calibration, pressure high, pressure low, software bug, unspecified electronics failure, other

* Percentage of total events or hours.



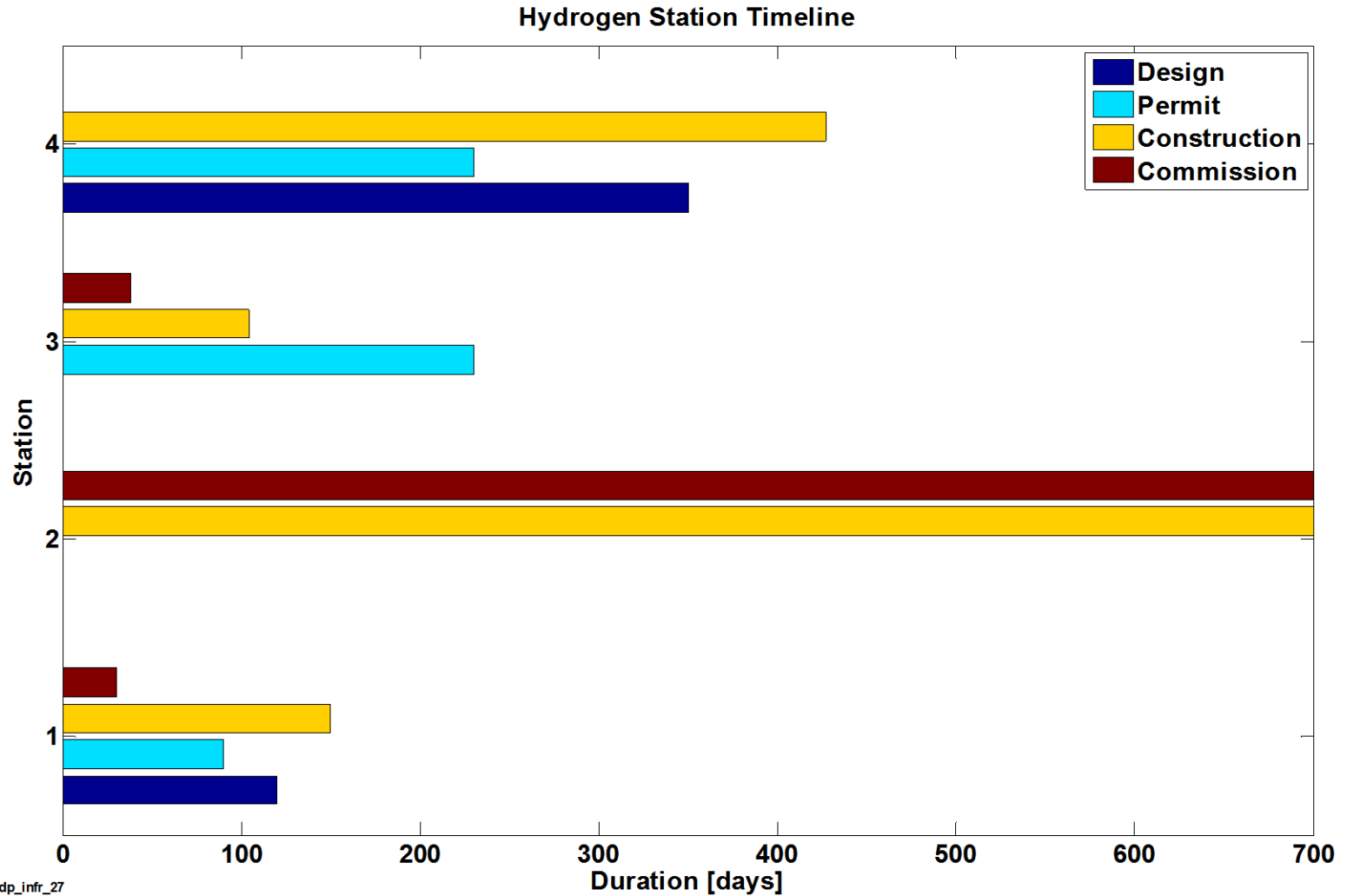
* Values are in micromole/mole, except for particulate size (Psize) in micrometer. Only values that exceed SAE J2719 guideline are shown in text. Left edge of text box aligns with date

Compressor Monthly Maintenance

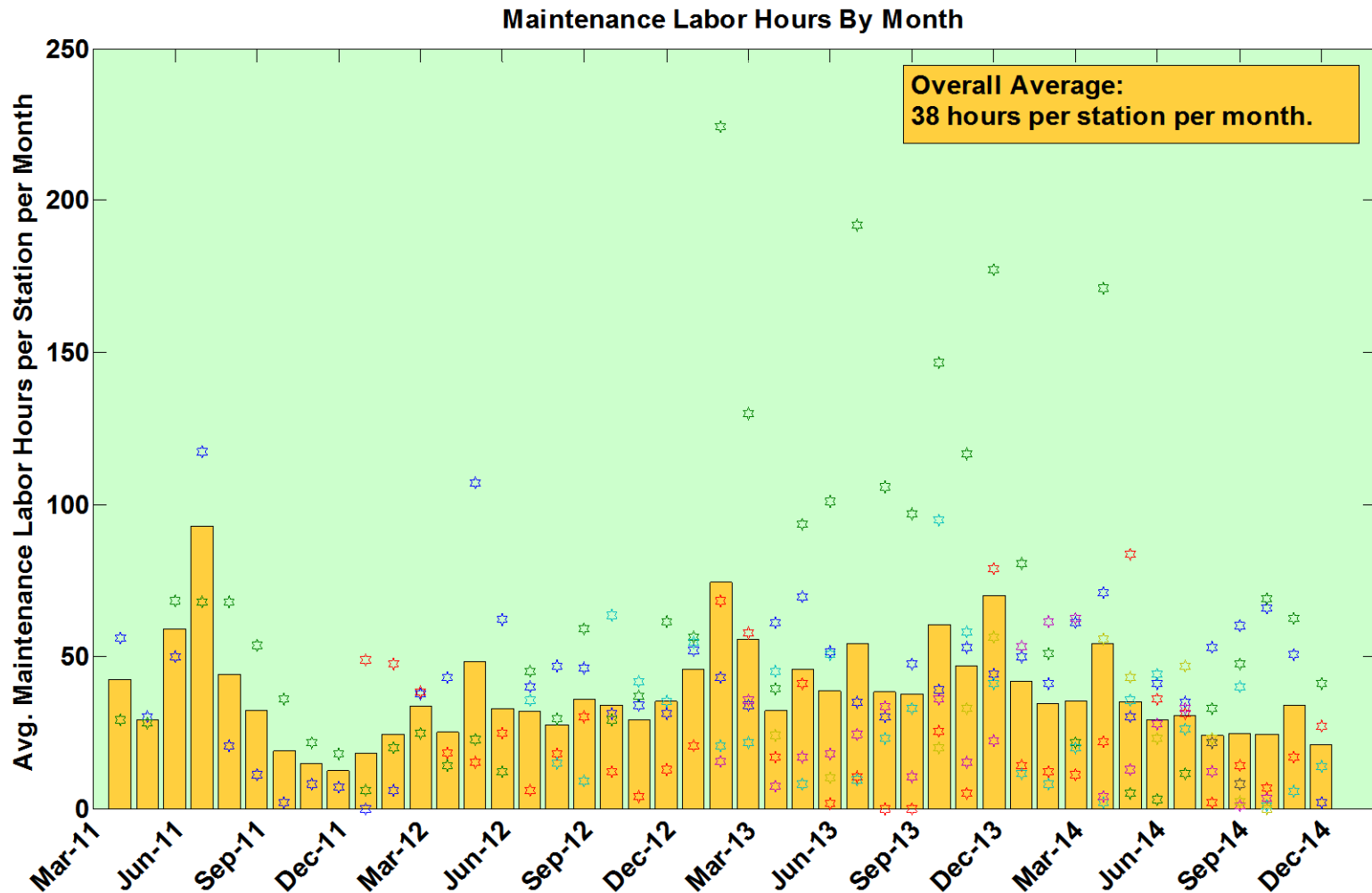


*Each color represents a unique station.

Hydrogen Station Timeline



Maintenance Labor Hours by Month



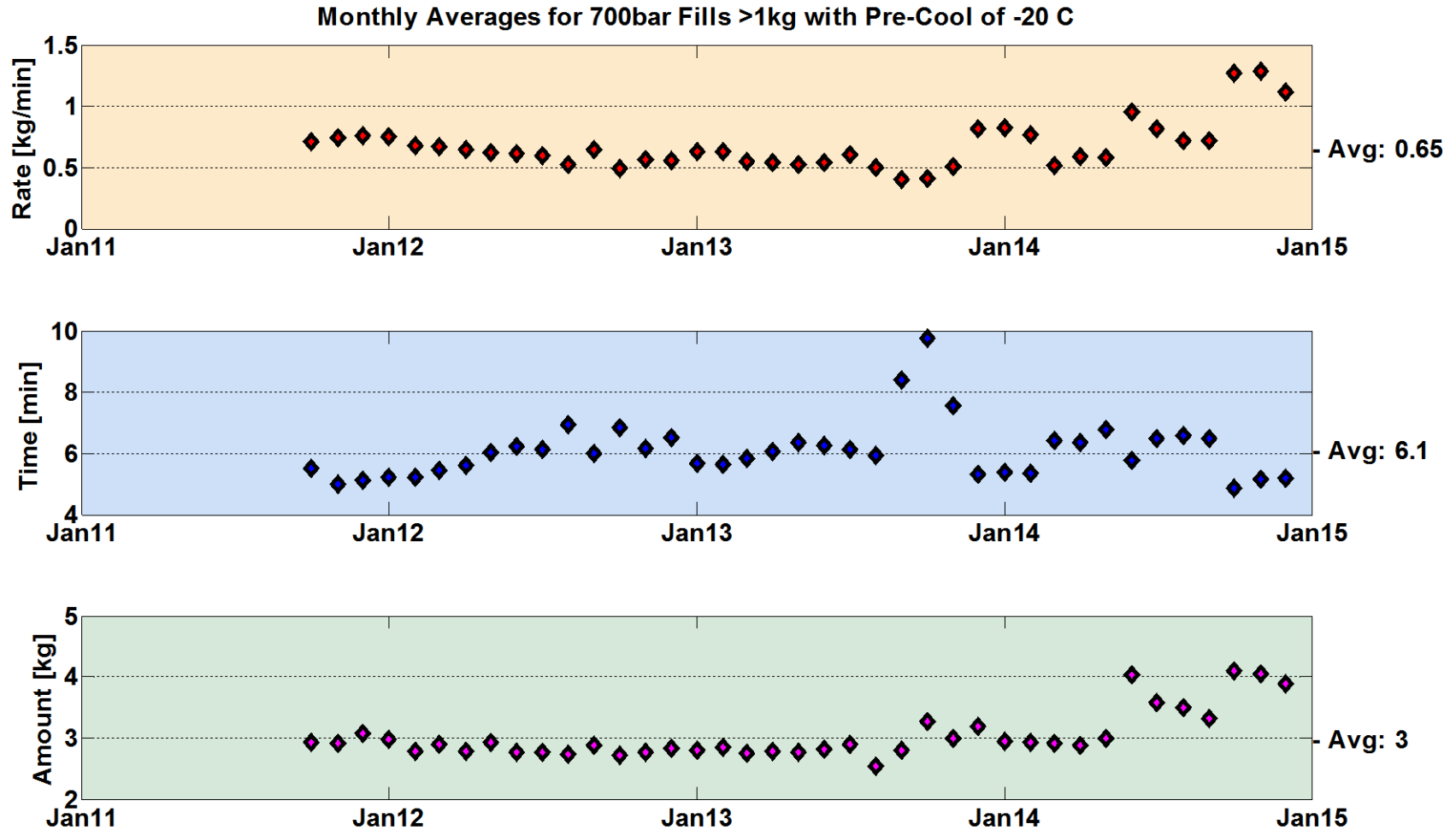
NREL cdp_infr_28

Created: May-06-15 11:34 AM | Data Range: 2009Q1-2014Q4

Stars represent individual station maintenance hours in a given month.

CDP-INFR-29

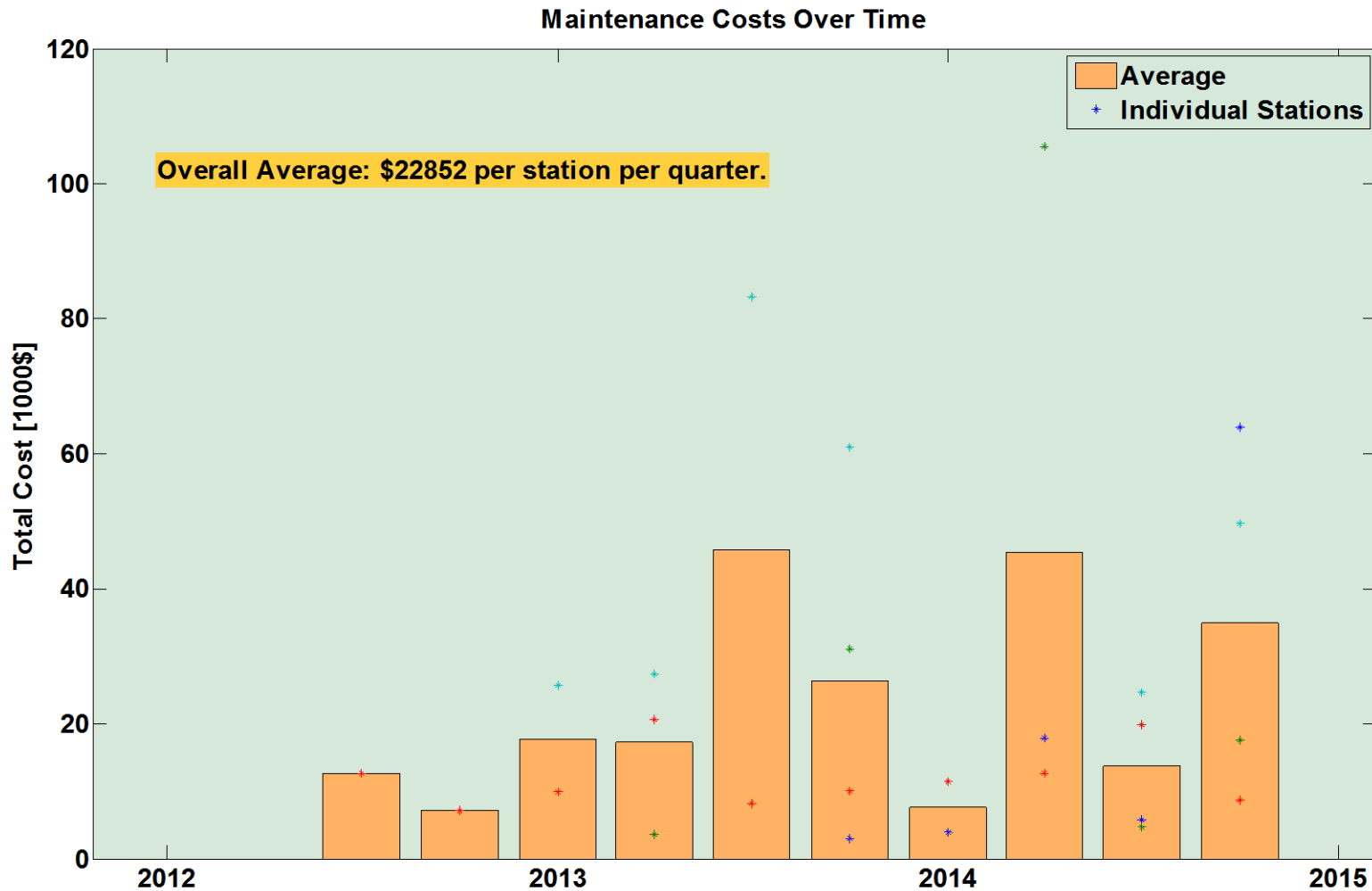
Monthly Averages for 700 bar Fills >1 kg with Pre-Cool of -20°C



NREL cdp_infr_29

Created: Apr-09-15 4:11 PM | Data Range: 2009Q1-2014Q4

Maintenance Costs over Time

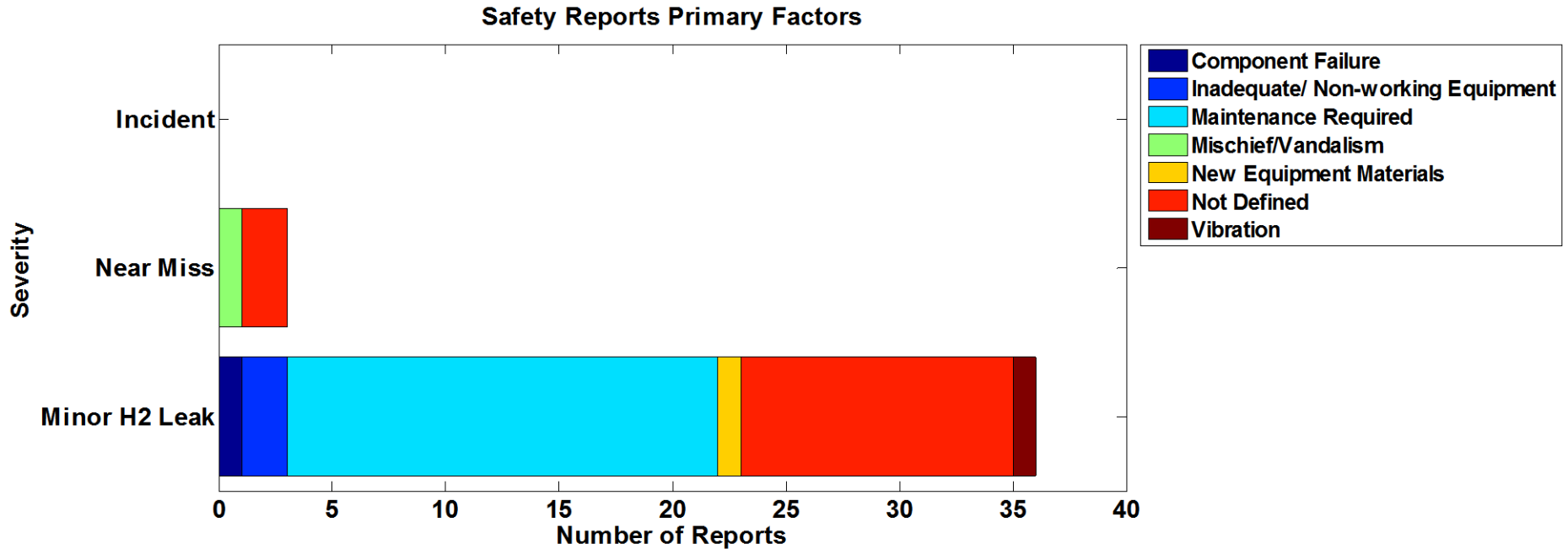


NREL cdp_infr_30

Created: May-06-15 8:31 AM | Data Range: 2009Q1-2014Q4

*Each color represents a unique station.

Safety Reports Primary Factors



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
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:

- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:

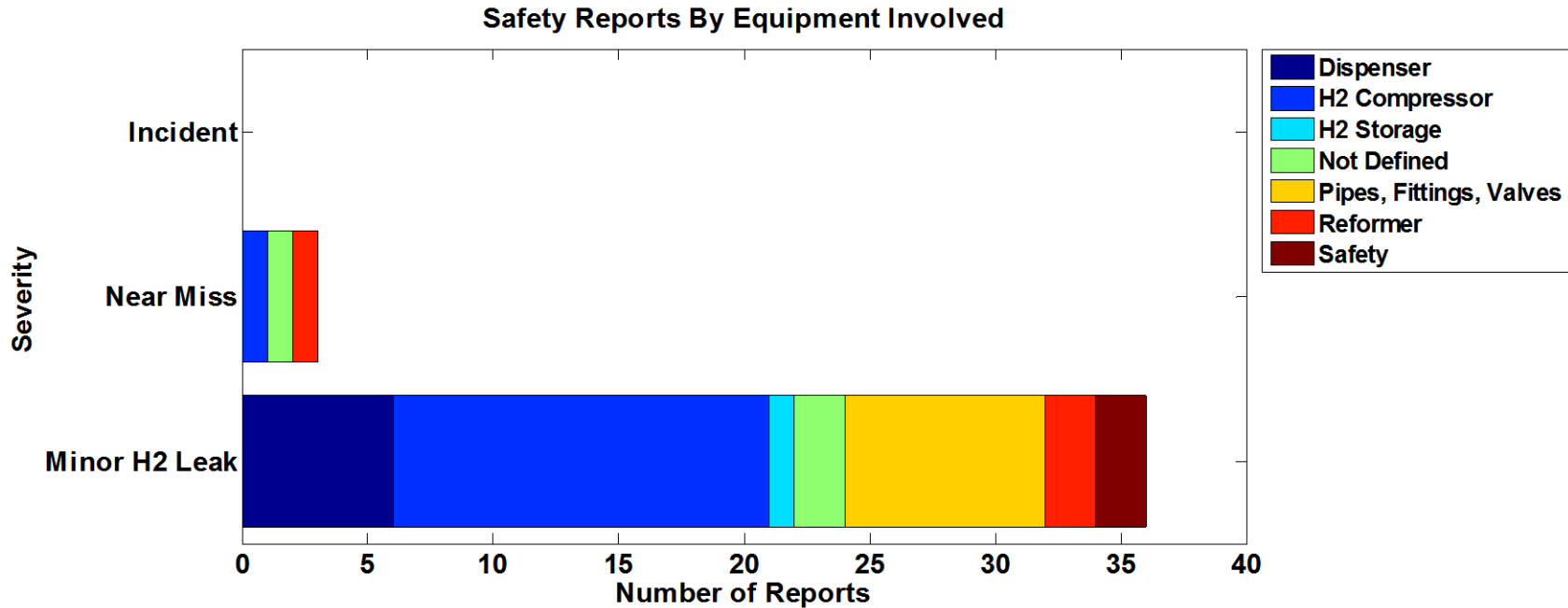
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite



NREL cdp_infr_31

Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

Safety Reports by Equipment Involved



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
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:

- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:

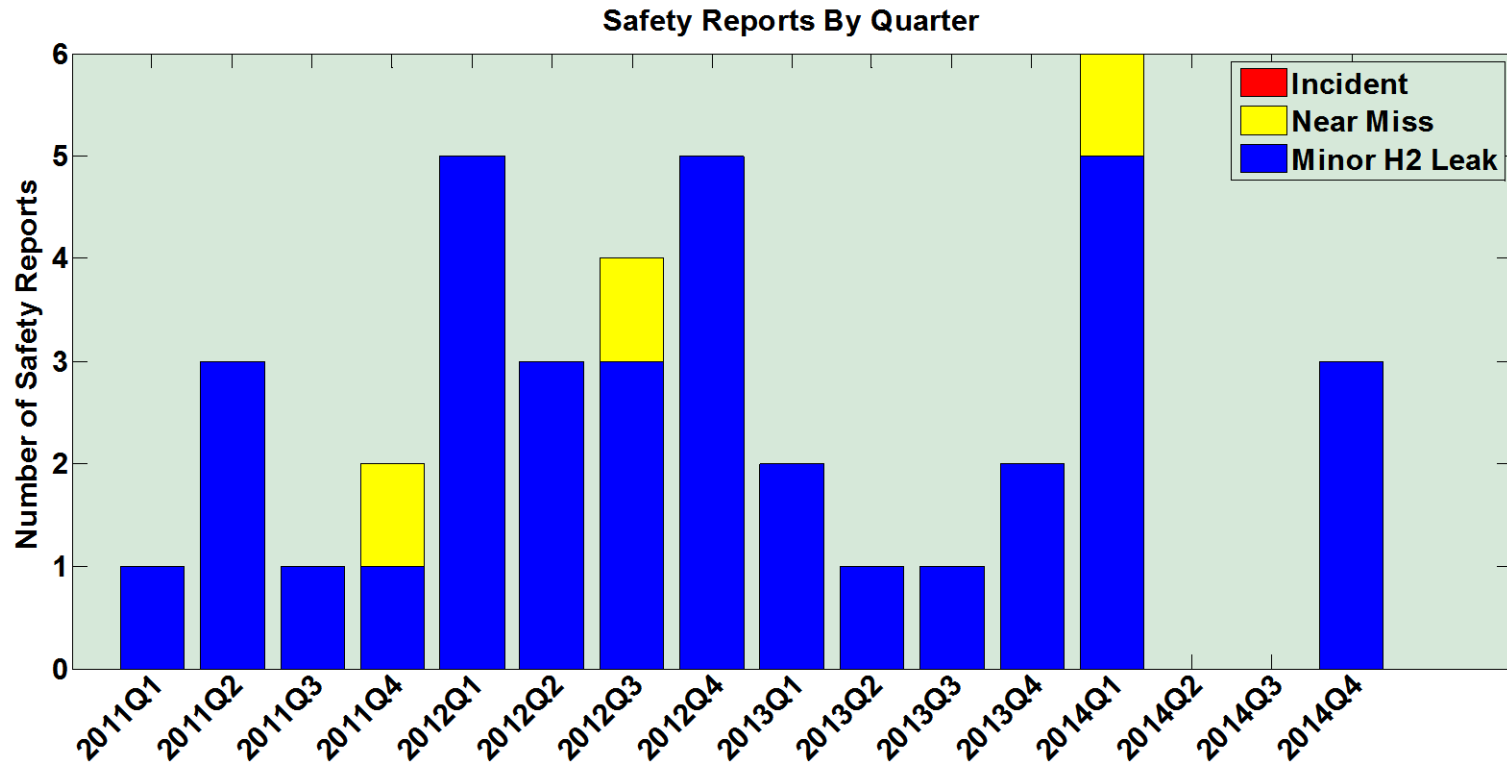
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite



NREL cdp_infr_32

Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

Safety Reports 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
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:

- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:

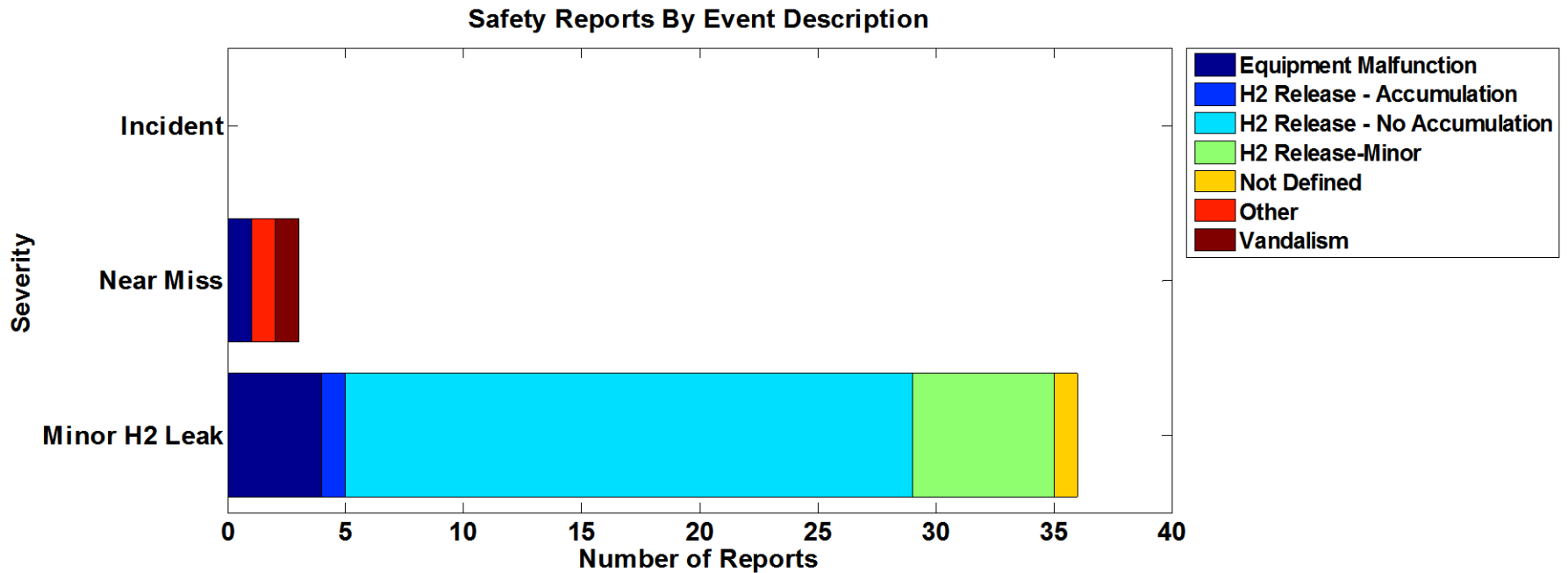
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite



NREL cdp_infr_33

Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

Safety Reports by Event Description



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
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:

- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:

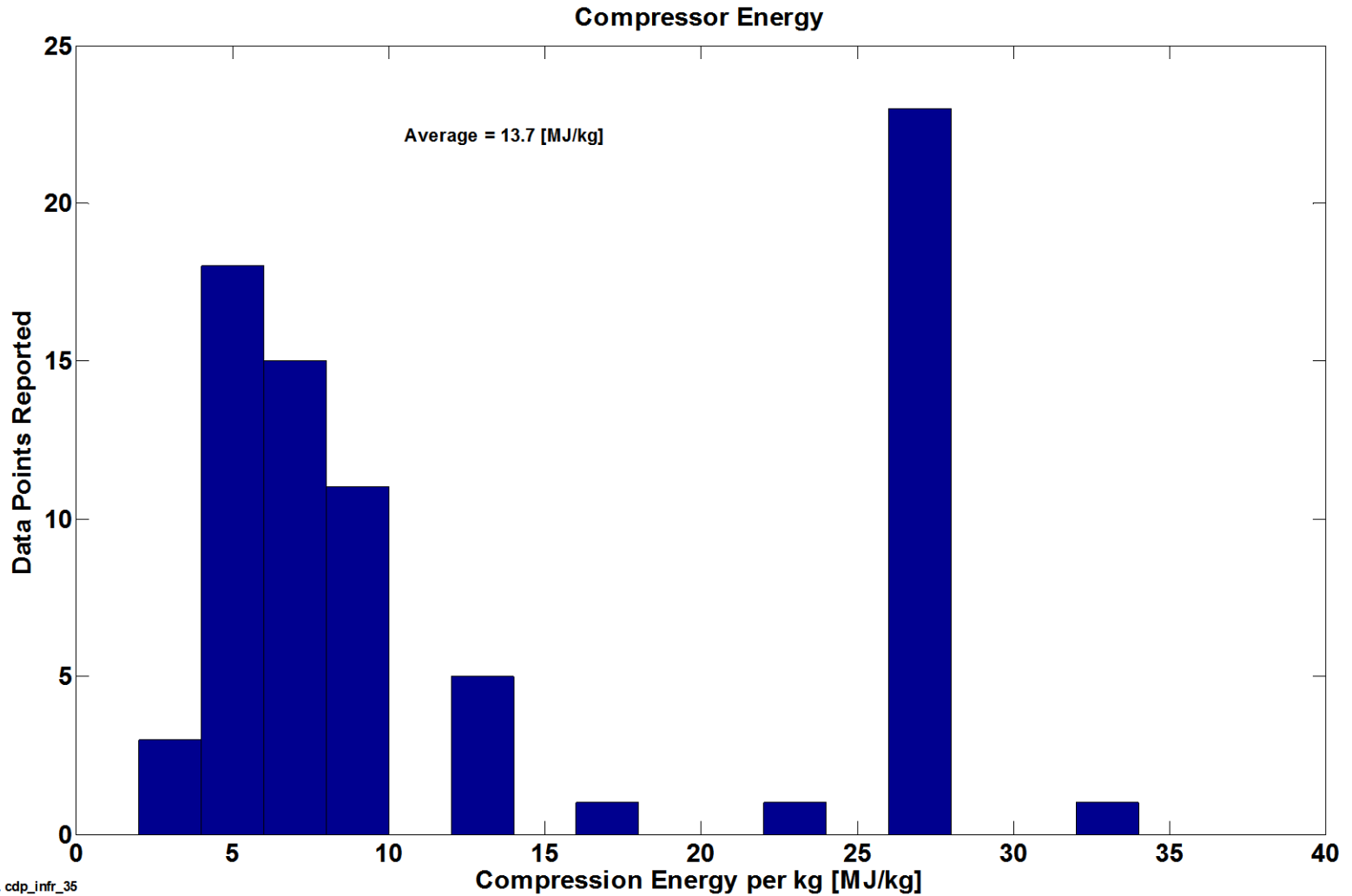
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite



NREL cdp_infr_34

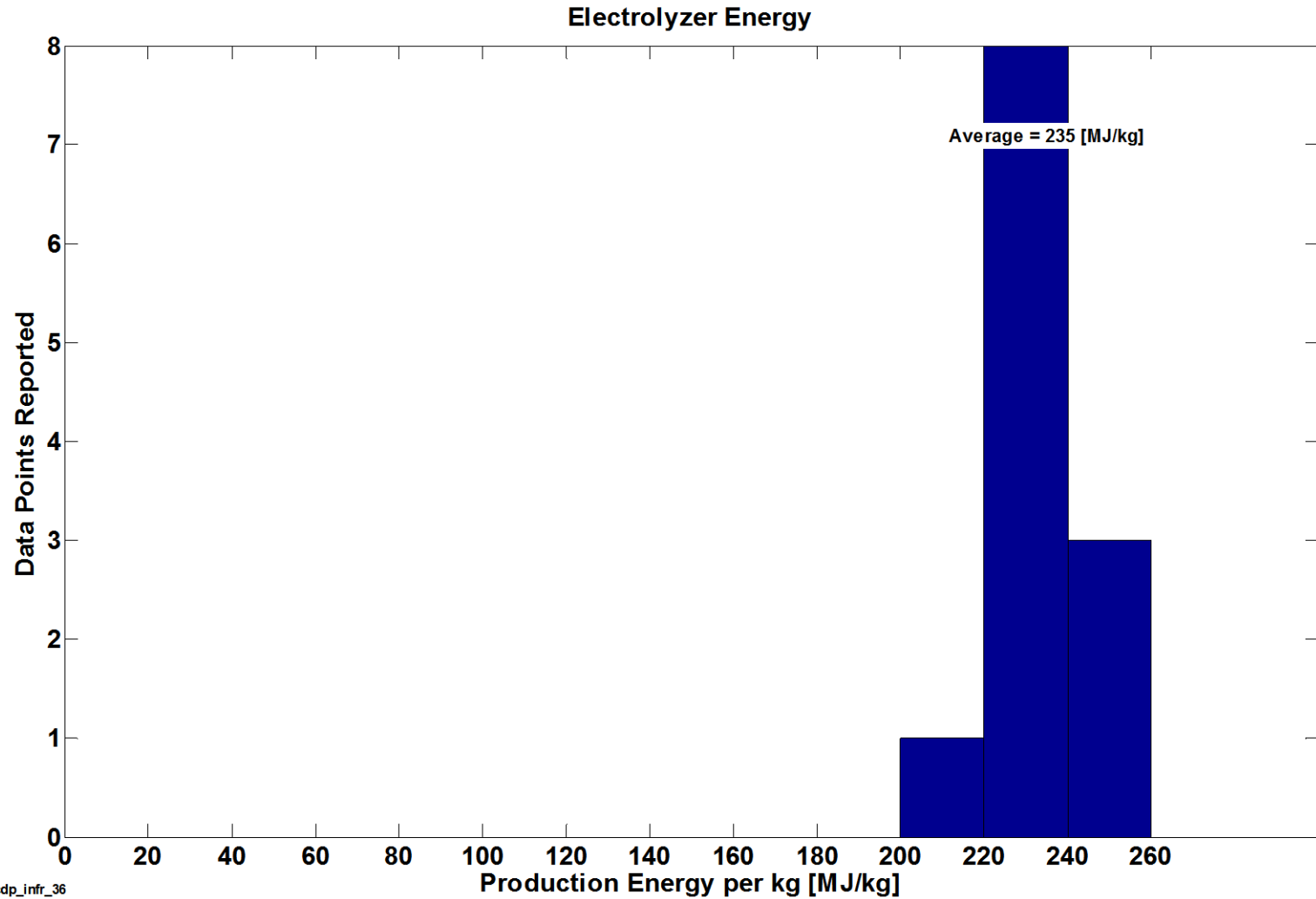
Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

Compressor Energy



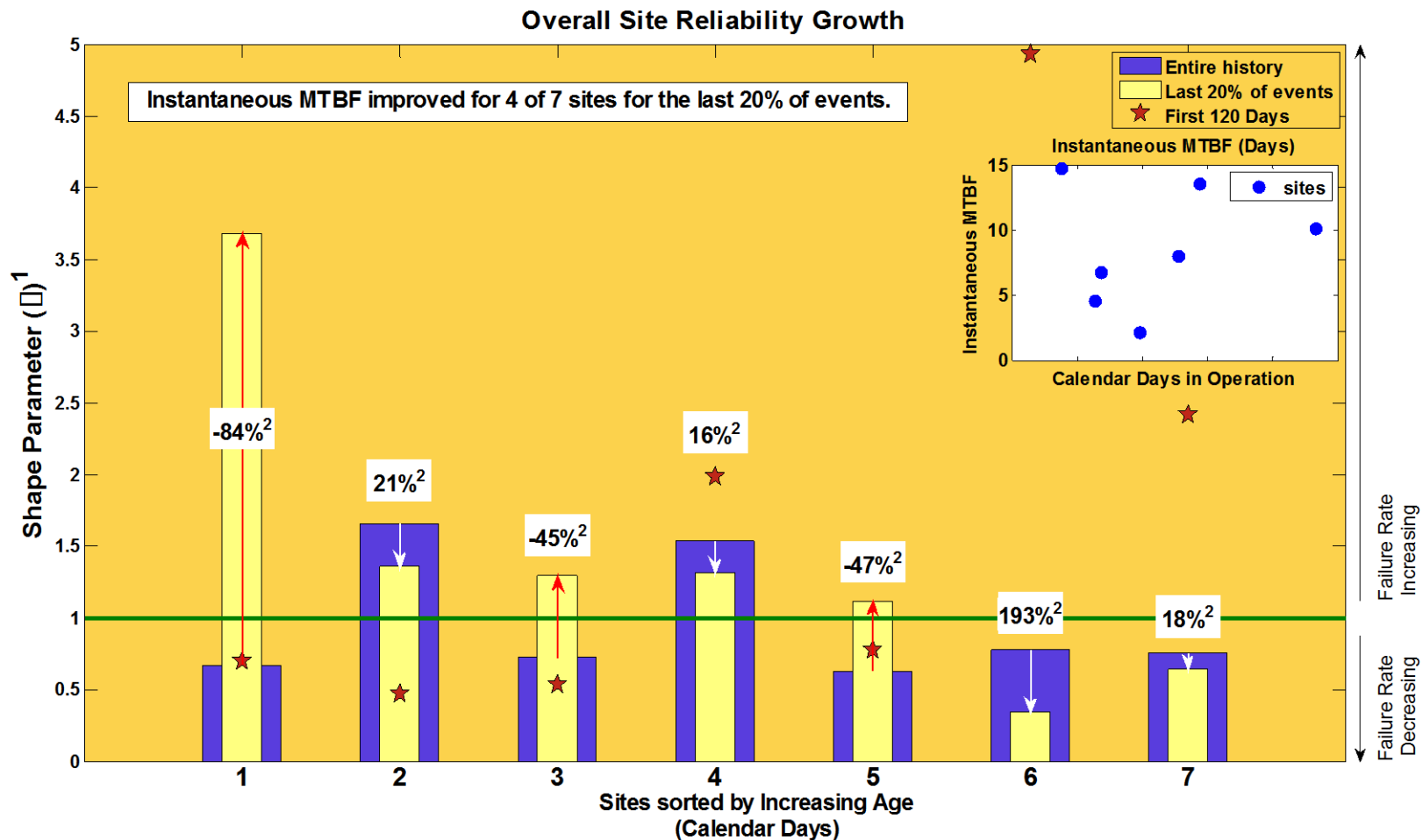
NREL cdp_infr_35

Created: Apr-29-15 4:00 PM | Data Range: 2009Q1-2014Q4



NREL cdp_infr_36

Created: Apr-29-15 3:56 PM | Data Range: 2009Q1-2014Q4



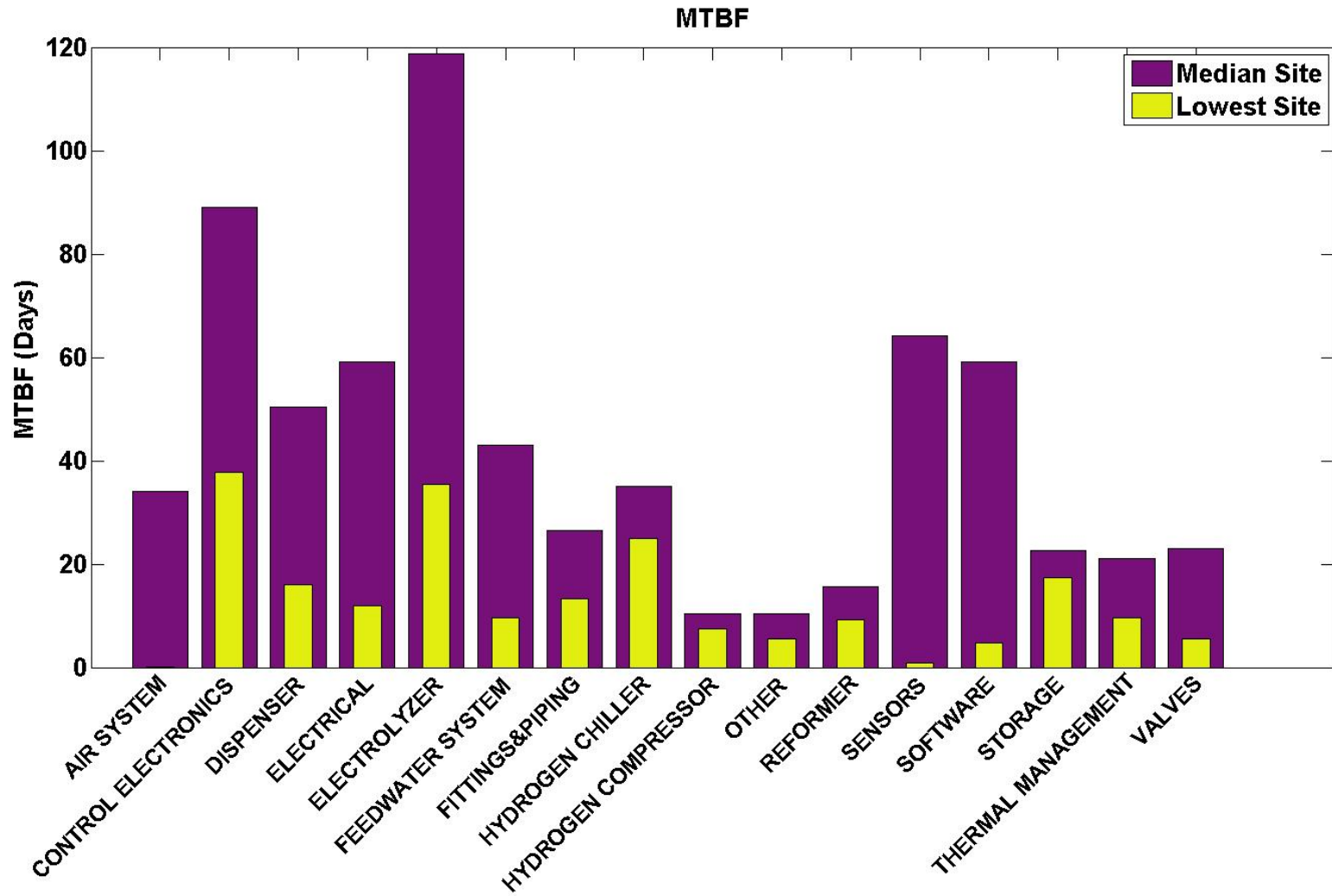
1. IEC 61164:2004(E), Reliability Growth - Statistical Test and Evaluation Methods, IEC. 2004.

2. % change in instantaneous MTBF

3. Some sites are no longer active. Final results are shown for those sites.

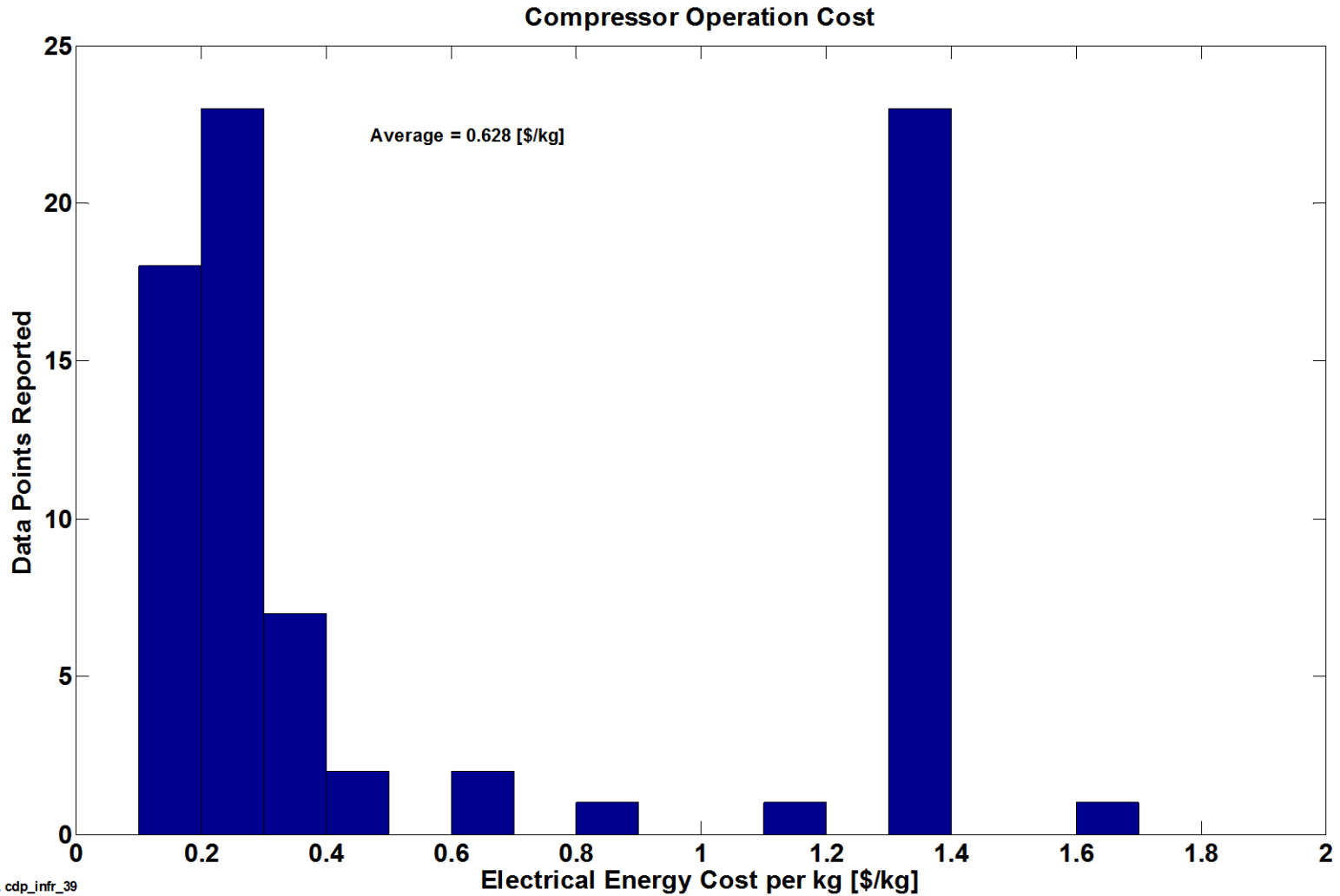


Maintenance Mean Time Between Failures (MTBF)



NREL cdp_infr_38
Created: Apr-14-15 9:32 AM | Data Range: 2008Q3-2014Q4

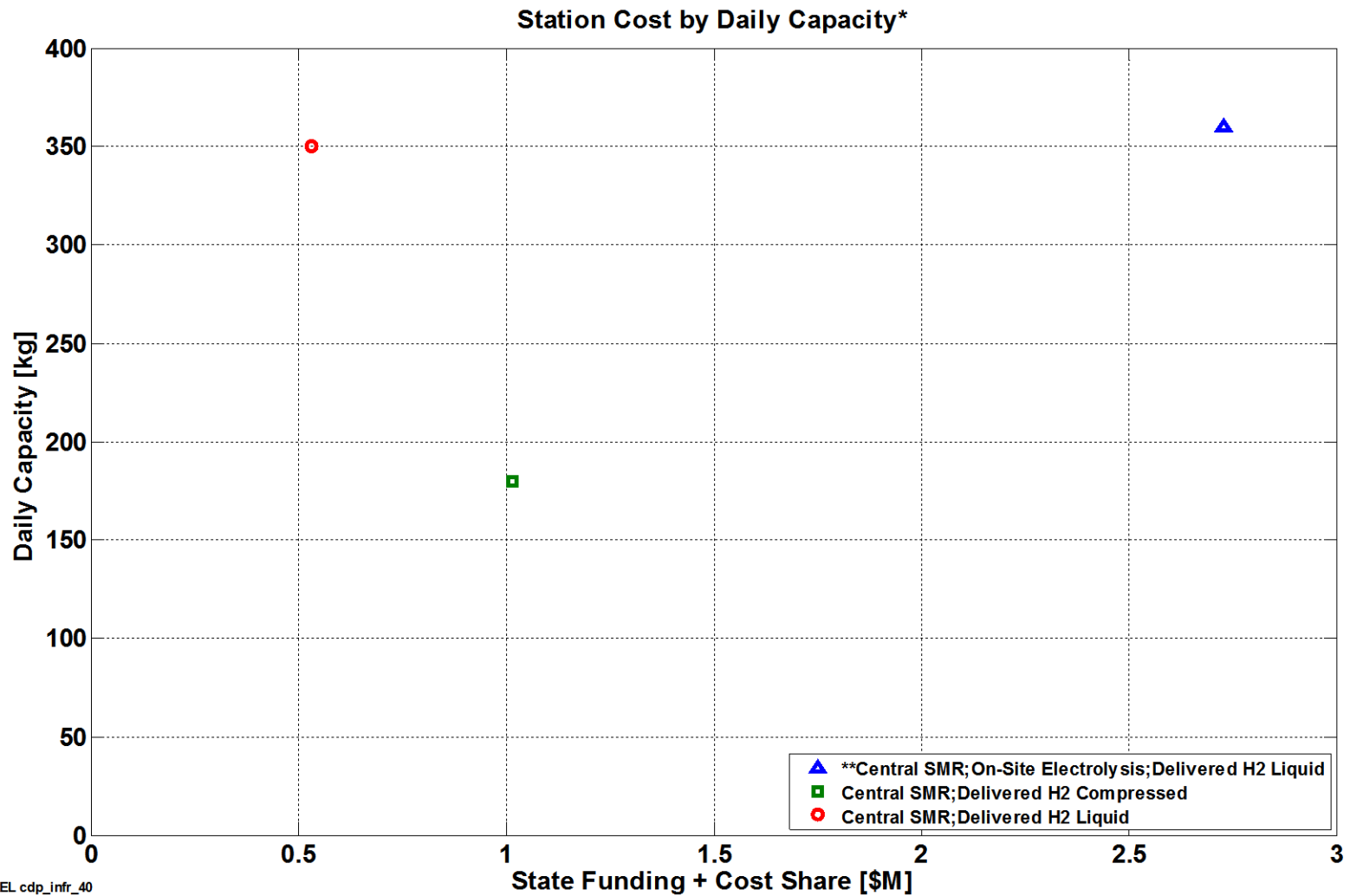
Compressor Operation Cost



NREL cdp_infr_39

Created: Apr-10-15 1:59 PM | Data Range: 2009Q1-2014Q4

Station Costs by Daily Capacity



NREL cdp_infr_40

Created: May-05-15 4:38 PM | Data Range: 2009Q1-2014Q4

*Based on data that includes costs reported through 2014Q4 for projects at or near completion.

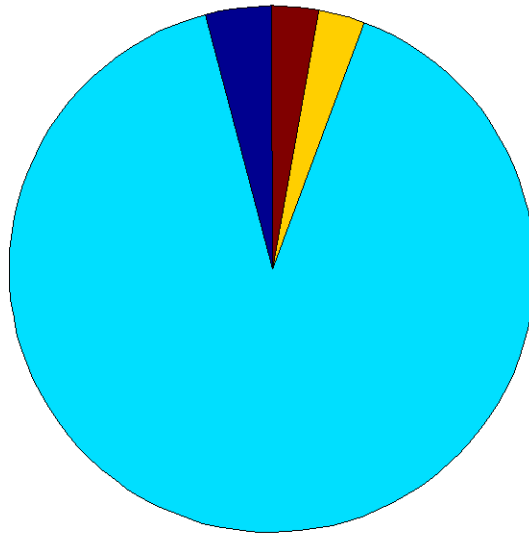
**Station with no cost share required.

Average Station Cost by Category

Average Station Cost by Category

Actual Costs* (Avg Total = \$1.42M)

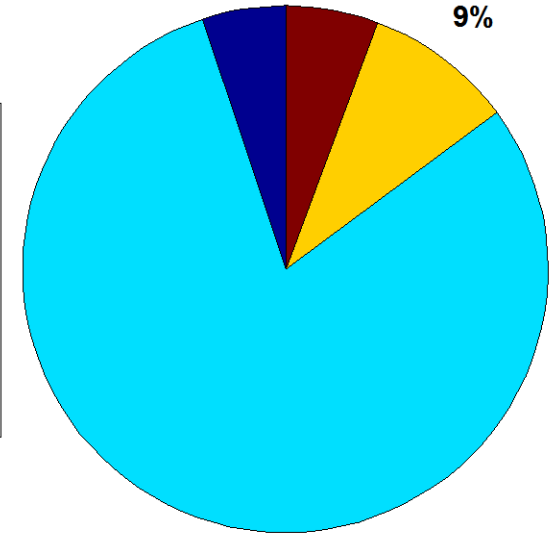
4% 3% 3%



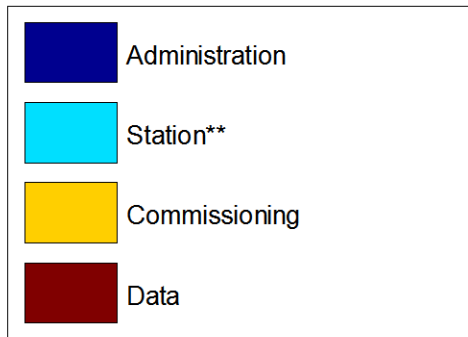
90%

Budget Amounts (Avg Total = \$2.14M)

5% 6%



80%

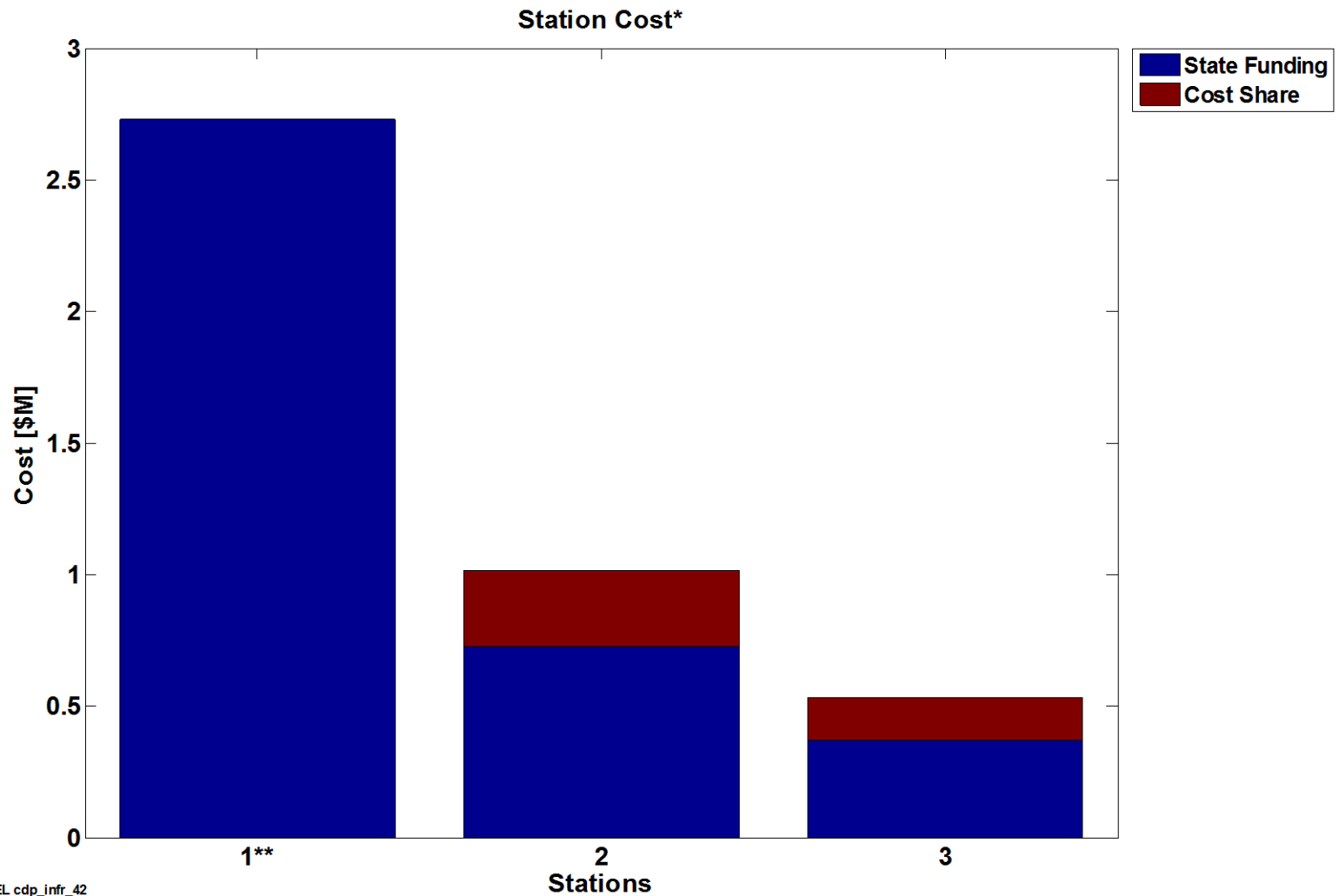



*Based on data that includes costs reported through 2014Q4 for projects at or near completion.

**Station includes: Hydrogen Equipment and Station Engineering, Design, Fabrication, Procurement, Site Preparation, Installation, and Construction

CDP-INFR-42

Station Costs



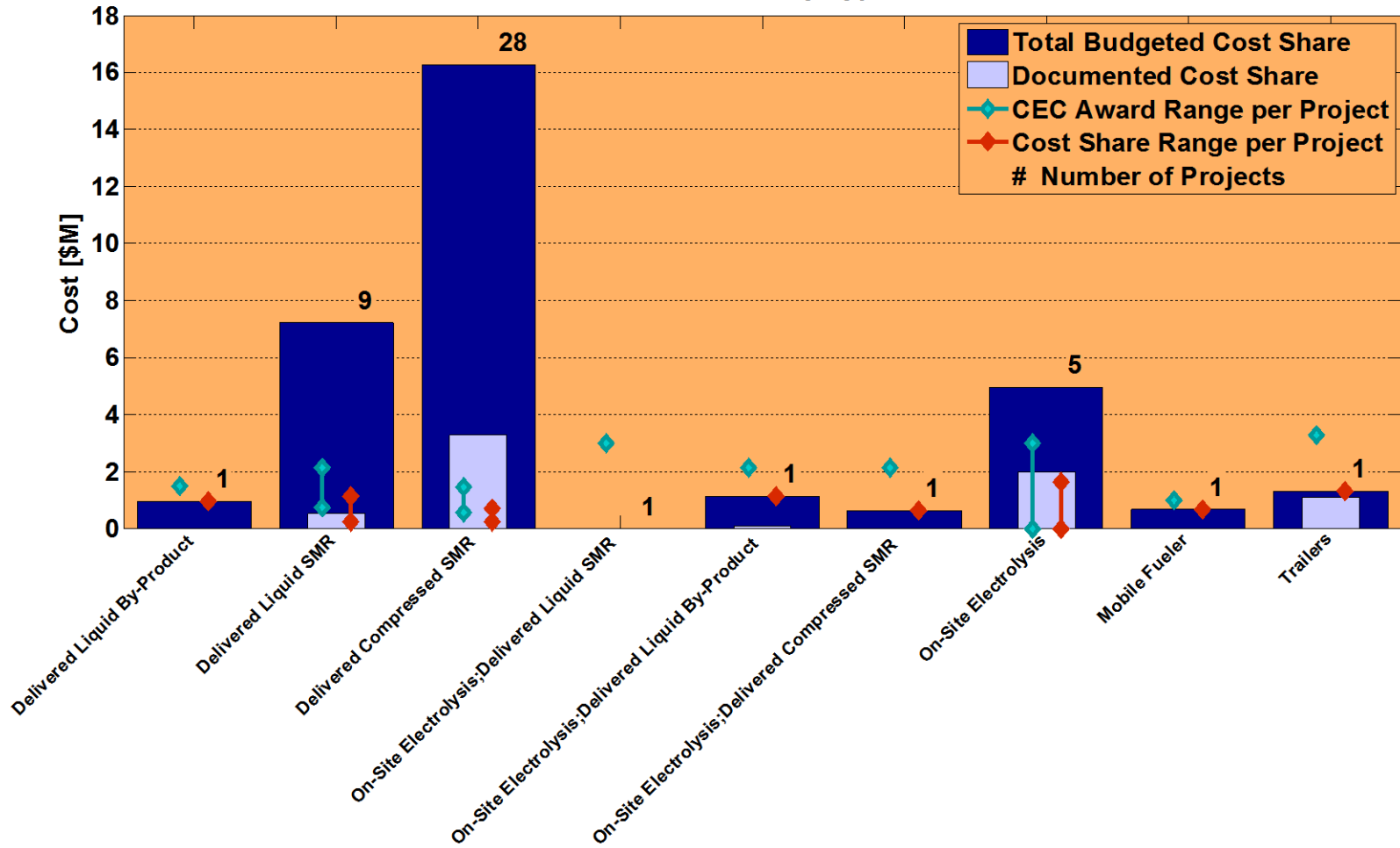
 NREL cdp_infr_42
Created: May-05-15 4:15 PM | Data Range: 2009Q1-2014Q4

*Based on data that includes costs reported through 2014Q4 for projects at or near completion.

**Station with no cost share required.

Station Cost by Type

Station Cost by Type*



*Based on California Energy Commission data that includes costs reported through 2014Q4.