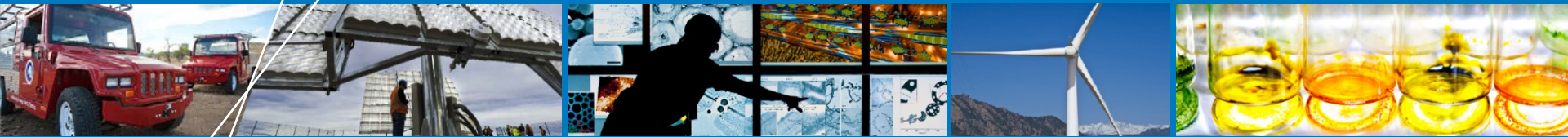


Hydrogen Station Data Collection and Analysis



**2014 DOE Annual Merit Review
and Peer Evaluation Meeting**

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

Project ID# TV017

June 19, 2014: Washington, DC

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

Project start date: Oct 2011

Project end date: Sep 2014*

Percent complete: ongoing

Budget

FY13 DOE Funding: \$285k

Planned FY14 DOE Funding: \$200k

Total Project Funding: \$485k

Barriers

- **Lack of current hydrogen refueling infrastructure performance and availability data**

Partners

- **Hydrogen Frontier**
- **CSULA**
- **CARB**
- **Shell**
- **Proton OnSite**
- **GTI**
- **Linde**

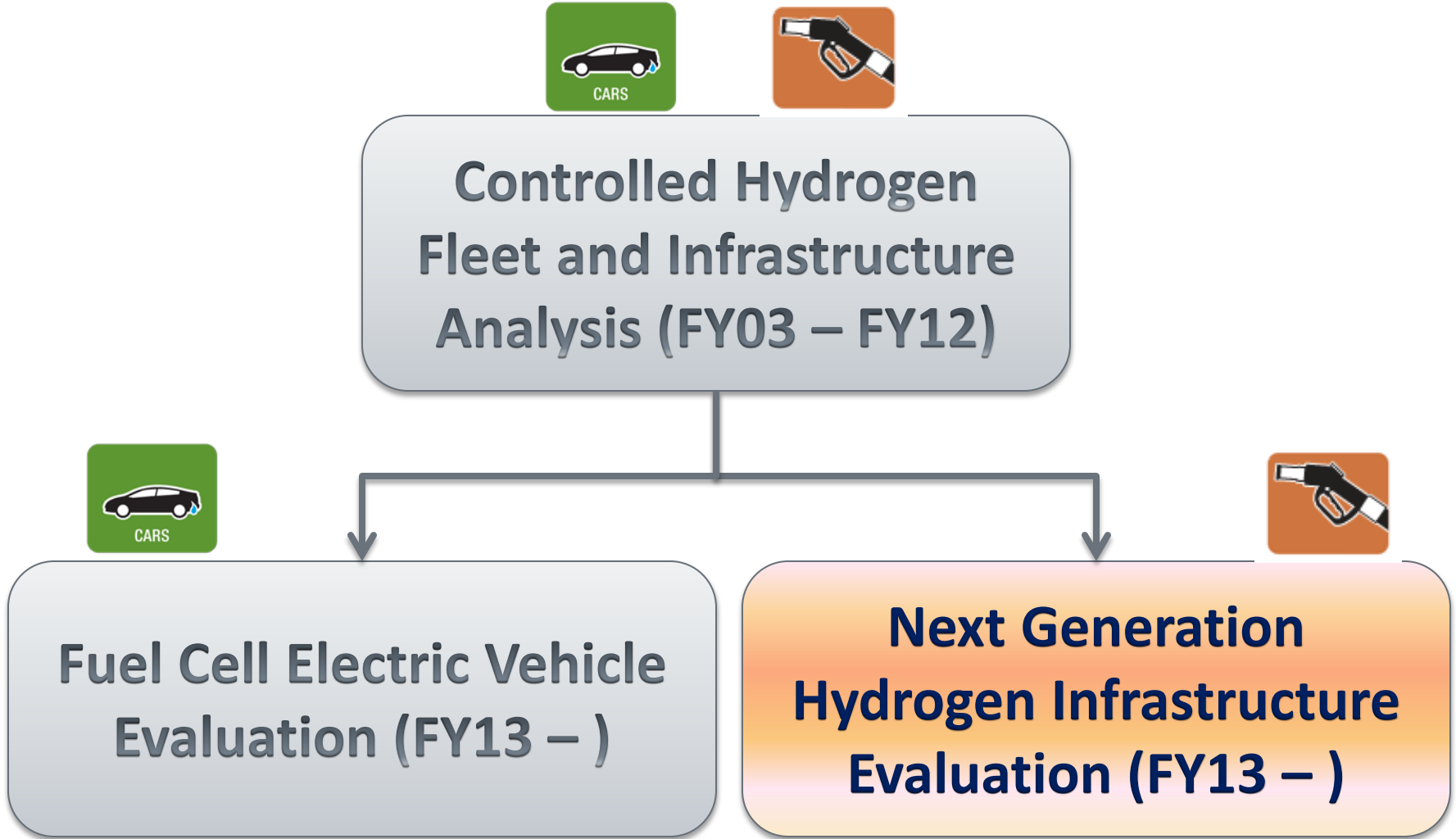
*Project continuation is determined annually by DOE

Relevance: Meeting Vehicle Needs

Use metrics to clearly evaluate progress toward challenges

- **Location/Capacity/Utilization**
 - **Challenge:** Stations need to provide coverage to meet the needs of vehicle drivers in the pre-commercial stage as well as have hydrogen availability with minimal wait time
 - **Metrics:** Station usage patterns and geographic locations
- **Fueling**
 - **Challenge:** Vehicles need to be fueled in an acceptable amount of time
 - **Metrics:** Fueling rates, times, amounts, back-to-back fills, communication...
- **Maintenance/Availability**
 - **Challenge:** Maintenance and other factors may cause station downtime and increase cost
 - **Metrics:** Maintenance patterns, reliability and availability of stations
- **Cost**
 - **Challenge:** Hydrogen cost is dependent on several factors including where produced, how delivered, efficiencies, and maintenance requirements
 - **Metrics:** Energy cost, maintenance cost...
- **Station Timing**
 - **Challenge:** Need enough lead time to build infrastructure to meet vehicle demand
 - **Metrics:** Permitting time, building time, commissioning time...

Approach: Relationship to Other Tech Val Projects



Approach: FOA-626 (H₂ Infrastructure Data)

Validation of Hydrogen Refueling Station Performance and Advanced Refueling Components

- **Objectives of FOA**

- Provide H₂ infrastructure data to NREL's National Fuel Cell Technology Evaluation Center (NFCTEC) for analysis and aggregation
- Test, demonstrate, and validate hydrogen technologies in real-world environments

Approach: FOA-626 Status (H₂ Infrastructure Data)

- 4 awardees announced July 18, 2012
- All awards completed
- Project kickoff Jan 2013
- Data starting to be delivered to NREL's NFCTEC
- Project to run for 4 years through 2 phases
- Will learn from state-of-the-art stations


Energy Department Investments to Advance Hydrogen Infrastructure and Fueling Technologies

Projects to Reduce Costs and Drive Higher Performance

July 18, 2012

As part of the Energy Department's commitment to give American businesses more options to cut energy costs and reduce reliance on imported oil, the Department today announced a \$2.4 million investment to collect and analyze performance data for hydrogen fueling stations and advanced refueling components. The five projects—located in California, Illinois, and Connecticut—will track the performance and technical progress of innovative refueling systems at planned or existing hydrogen fueling stations to find ways to lower costs and improve operation. These investments are part of the Department's commitment to support U.S. leadership in advanced hydrogen and fuel cell research and help industry bring hydrogen technologies into the marketplace at lower cost.

These new projects will collect data and monitor the performance of hydrogen fuel stations, advanced components and other innovative hydrogen technologies using renewable energy or natural gas. By analyzing performance in real-world environments, these projects will help hydrogen fueling equipment manufacturers improve the designs of existing systems to achieve higher efficiencies and test new system components. Additionally, this data will help focus future research and development efforts, driving American manufacturing competitiveness in the next generation of hydrogen and fuel cell technologies.

In addition, the Energy Department released today the [final report](#)  from a technology validation project that collected data from more than 180 fuel cell electric vehicles. Over six years, these vehicles made more than 500,000 trips and traveled 3.6 million

Approach: FOA-626 Winners Selected

Summary from press release (July 18, 2012)

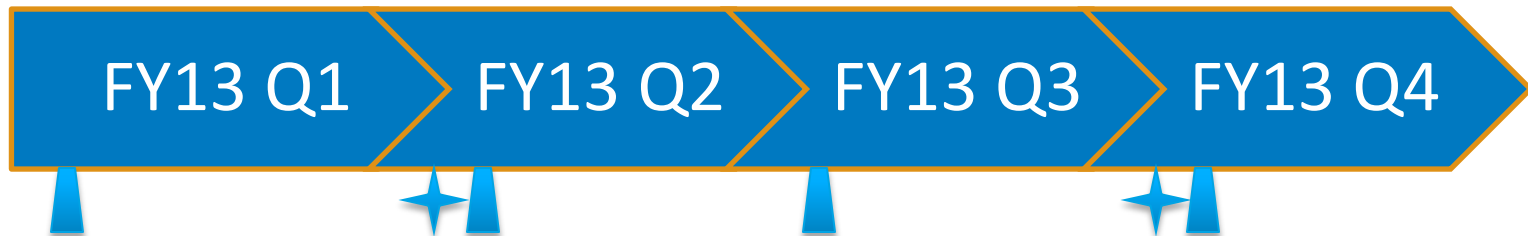
- **California Air Resources Board (Sacramento, California)**
 - 1 station with natural gas to hydrogen, 180 kg of storage, and 60 kg of back-to-back fills in under an hour (DOE Award: \$150,000)
- **California State University and Los Angeles Auxiliary Services, Inc. (Los Angeles, California)**
 - 1 station at CSULA with 24 hour public access and will fill up to 20 hydrogen powered vehicles daily (DOE Award: \$400,000)
- **Gas Technology Institute (Des Plaines, Illinois)**
 - 5 stations with their compressor technology, public access, and will analyze operational, transactional, safety, and reliability data (DOE Award: \$400,000)
- **Proton Energy Systems (Wallingford, Connecticut)**
 - 2 stations that generate hydrogen from water through onsite solar-powered electrolysis and will collect data on operation, maintenance and energy consumption (DOE Award: \$400,000)
 - Also, second project to deploy an advanced high-pressure electrolyzer at a station and nearly double the dispensing capacity of its storage tanks (DOE Award: \$1 million)

Approach: Analysis Objectives

Analyze operational data on existing hydrogen stations to provide status and feedback in the following areas:

- Capacity
- Utilization
- Station build time
- Maintenance/availability
- Fueling
- Geographic coverage

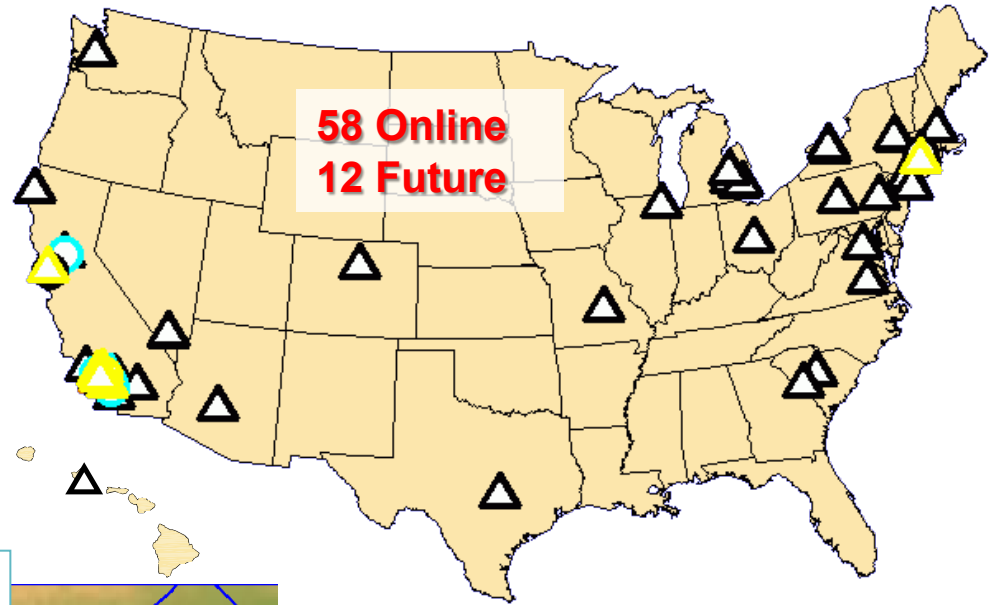
Approach and Accomplishments: Milestones



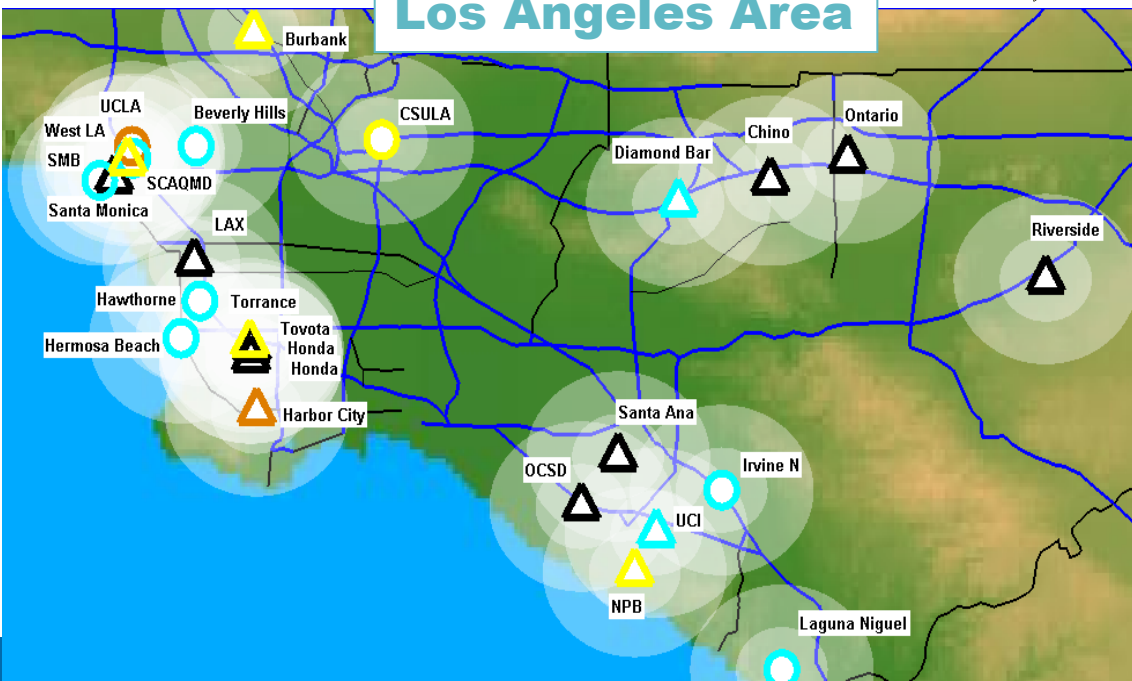
- ▲ Quarterly data analysis (based on available data)
- ★ Publication of composite data products

Approach: Station Locations

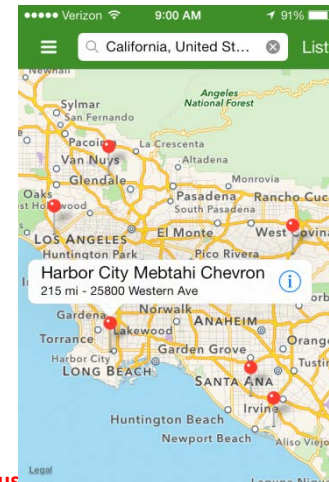
- Maintain database of current stations in the U.S.
- Sync data with Alt Fuels Data Center (AFDC)
- Station coverage



Los Angeles Area

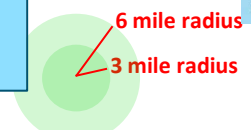


Hydrogen Station Location Data Available through AFDC Mobile App (iPhone)

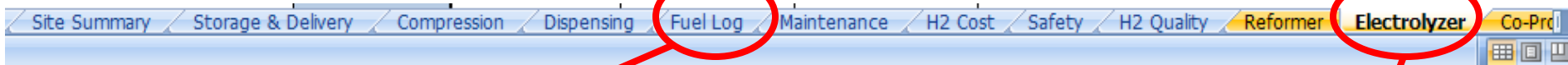


Legend

- △ Online
- Future
- Current Project
- CEC
- CARB
- Other



Accomplishment: Infrastructure Data Templates



Templates enable collection of similar data from all the stations

- Aggregated results from data collected
- Templates distributed to project partners for data collection and feedback
- Templates provided to CEC for inclusion in Hydrogen Station Program Opportunity Notices (PONs)

Fuel Log

Date/Time (m/d/yy HH:MM:SS)	(\$/kg)	multiple)	(kg)	Fill Time (s)	(bar)	Fill Type	Type	Comments	(kg H2/Fill Time)
5/1/01 15:30:24	\$5.00	Disp350A	2.5	180	350	Communication	ECO-FCV01		0.8
5/1/01 15:30:24	\$5.00	Disp700B	15	480	700	Non-Communication	BusCo-Transit Bus	Bus Demo	1.9
5/1/01 15:30:24	\$5.00	Disp350B							

Electrolyzer

Template last updated on December 02, 2011 (NREL)

Calendar Quarter (ex. 2011Q2)	insert calendar quarter
Site Name	insert site name
Electrolyzer Type	e.g., PEM, Solid Oxide, etc.
Electricity Source	e.g., Gnd, Wind, PV, etc.

Data should be from reporting quarter

Category	Units	Month		
		Month1	Month2	Month3
Hydrogen Produced	kg	450		
Operation Time	hours	400		
Water Consumed, Directly				
Converted + Waste + Other	gallons	4140		
Electricity Used	kWhr	6000		
Electricity Cost (ex. monthly bill)	dollars	\$300		
Total Energy Consumed in Conversion (1) (Electrical, Thermal,				

Approach: Station Data (Continual Collection)

- **H₂ produced or delivered by month**
- **On-site efficiency, conversion efficiency, compression energy, storage and dispensing energy**
- **Maintenance**
- **Safety**
- **Hydrogen quality**
- **Fueling**
- **Cost of non-H₂ energy for compression, dispensing, conversion**
- **Cost items (by month)**

Approach: Station Data (Site Summary)

- **Station description**
- **Production capacity**
- **Dispensing capacity**
- **Survivability (max/min temperature)**
- **Nominal pre-cooling temp and SAE 2601 type**
- **Storage type(s) and capacities and at what pressure(s)**
- **Number of dispensers at what pressure(s)**
- **Compressor(s) information**
- **Time to design, permit, construct, and commission**
- **Footprints: storage, production, dispensing**

Approach: National Fuel Cell Technology Evaluation Center (NFCTEC)

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly

NREL's National Fuel Cell Technology Evaluation Center

Results

DDPs

Confidential

Public

CDPs

Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months¹

Composite Data Products (CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months²

1) Data exchange may happen more frequently based on data, analysis, and collaboration

2) Results published via NREL Tech Val website, conferences, and reports

Accomplishment: Analysis

- **NREL Fleet Analysis Toolkit (NRELFAT)**
 - Developed first under fuel cell vehicle Learning Demonstration
 - Restructured architecture and interface to effectively handle new applications and projects and for analyses flexibility
 - Leverage analysis already created
- **Publish results**
 - Detailed and composite results
 - Target key stakeholders such as fuel cell and hydrogen community and end users



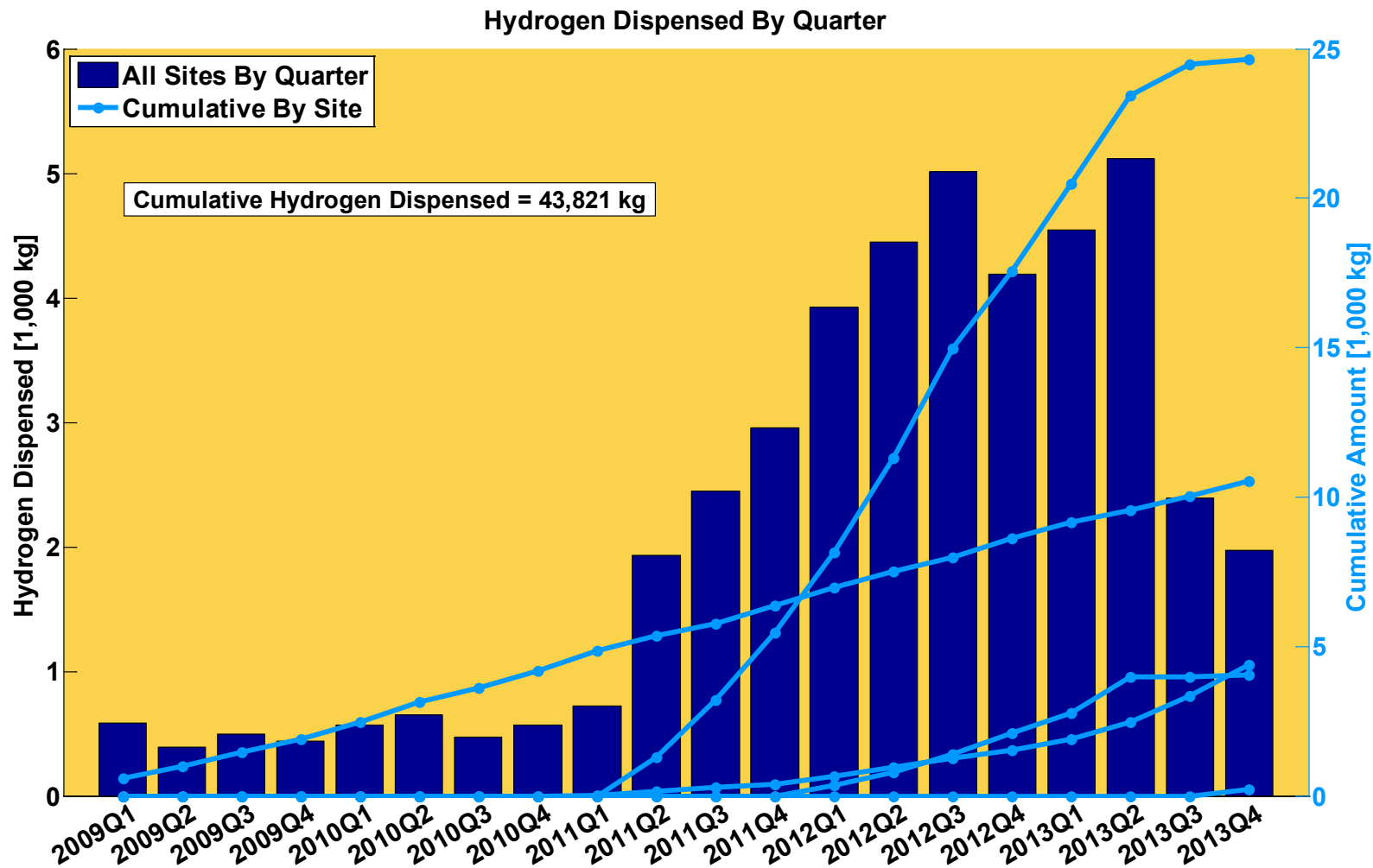
Leveraged analysis code from previous projects and created new code useful for other projects such as material handling equipment.

Accomplishments

- Analyzed data for station(s) providing data through CY2013Q4
- Visited several current stations
- Published new Fall 2013 and Spring 2014 CDPs
- Tracked current stations in database and synced with Alt Fuels Data Center database of stations

Spring 2014 Composite Data Products

Hydrogen Dispensed by Quarter

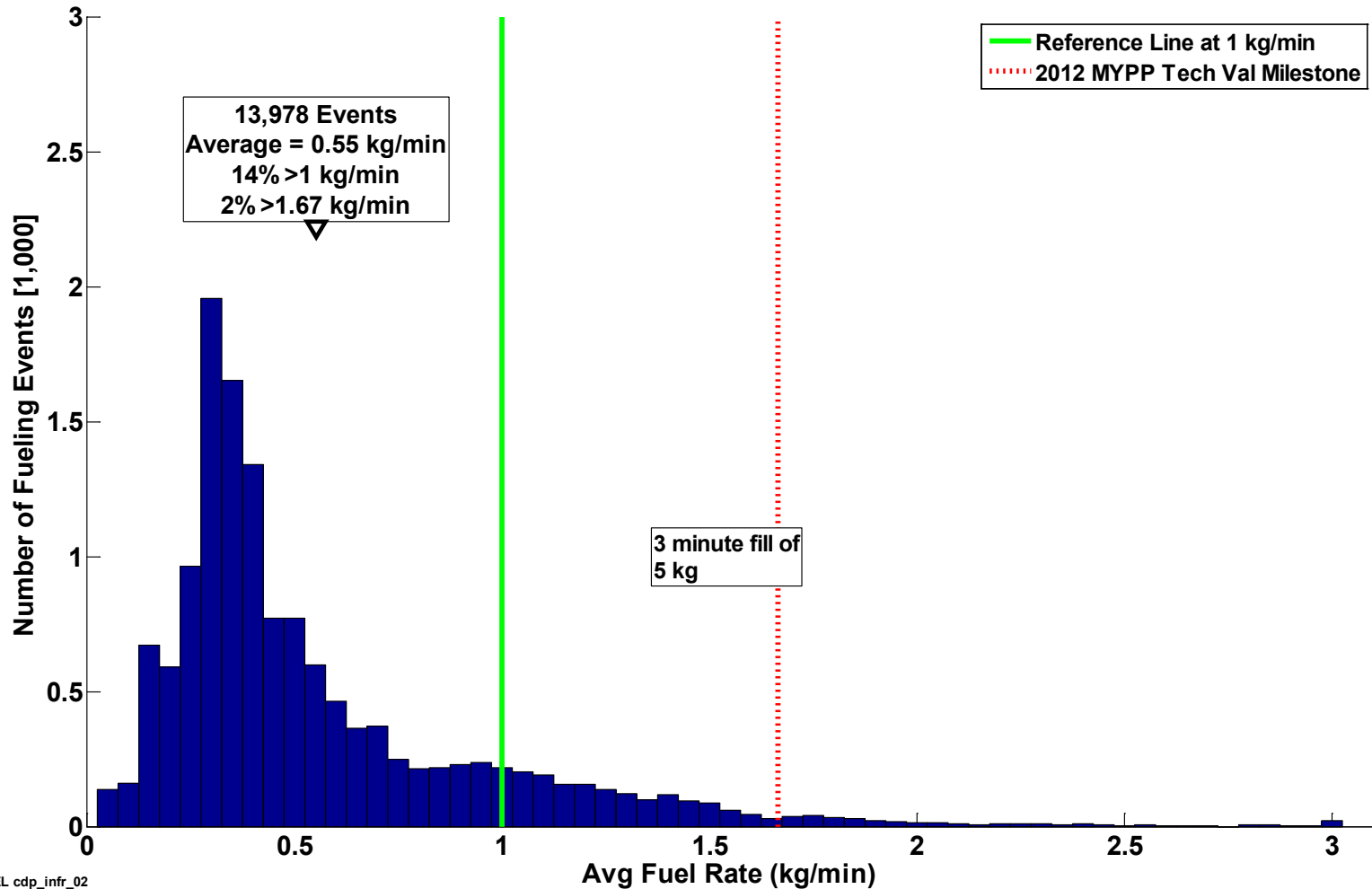


NREL cdp_infr_01

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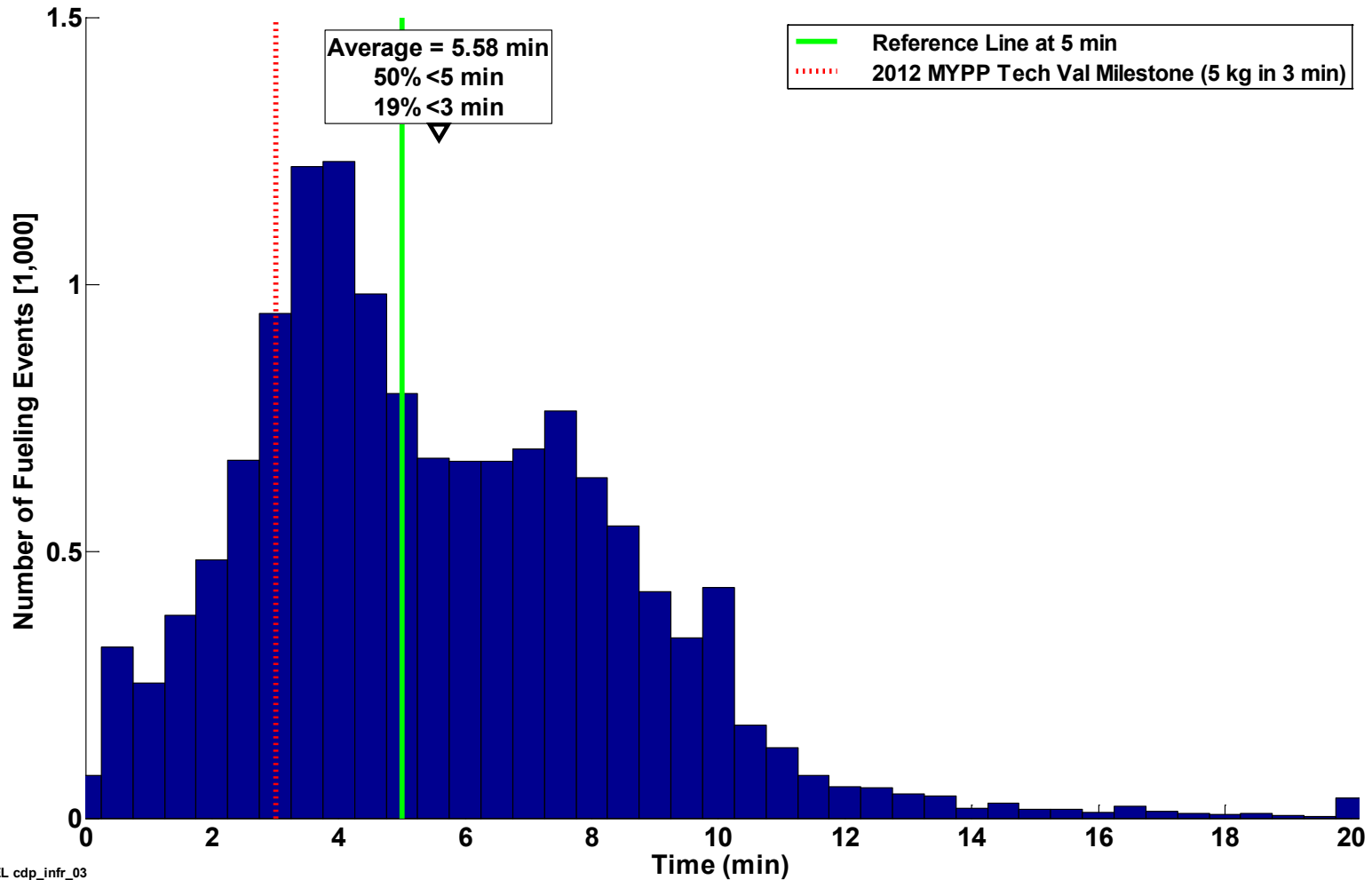
Histogram of Fueling Rates

Histogram of Fueling Rates

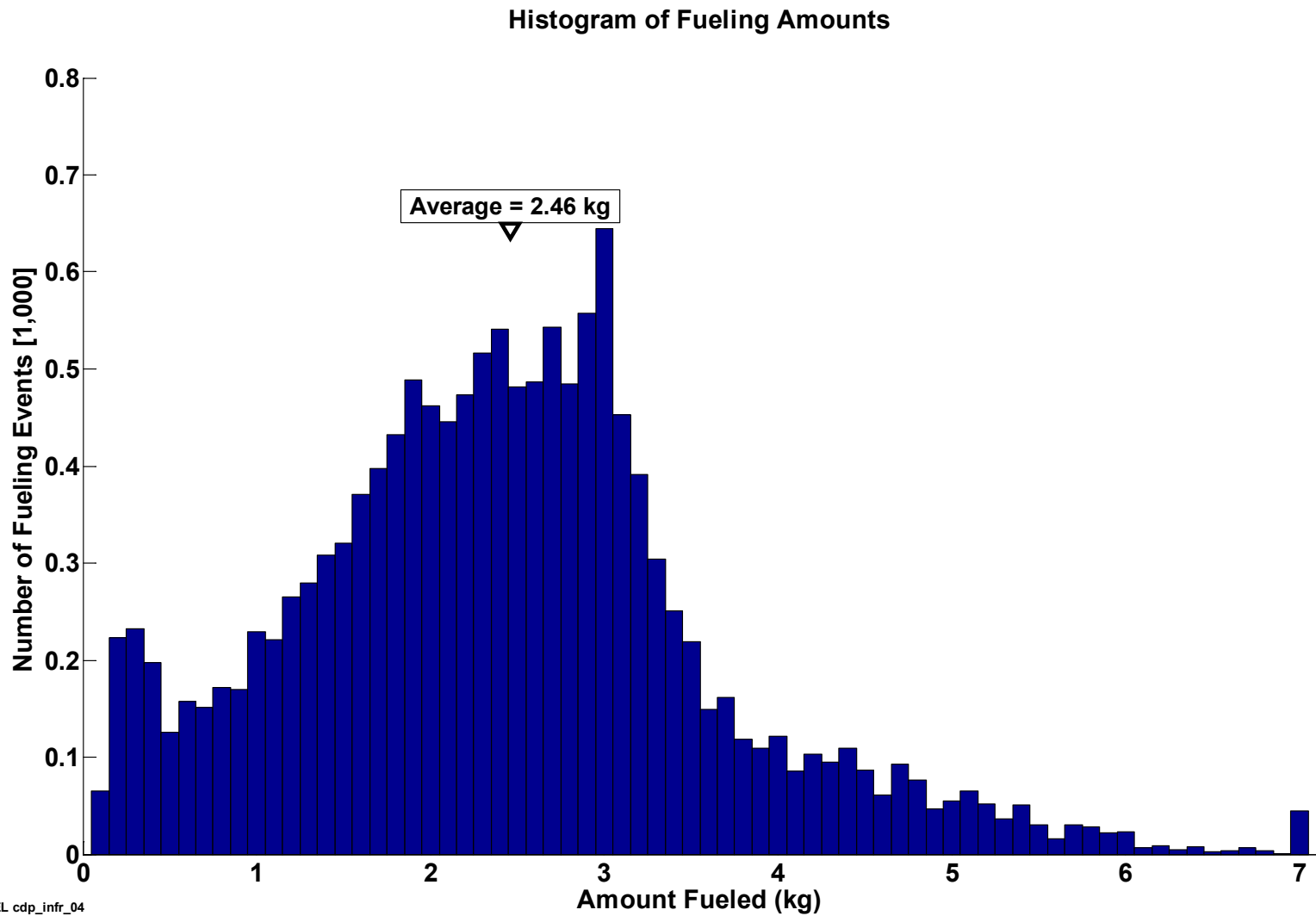


Histogram of Fueling Times

Histogram of Fueling Times



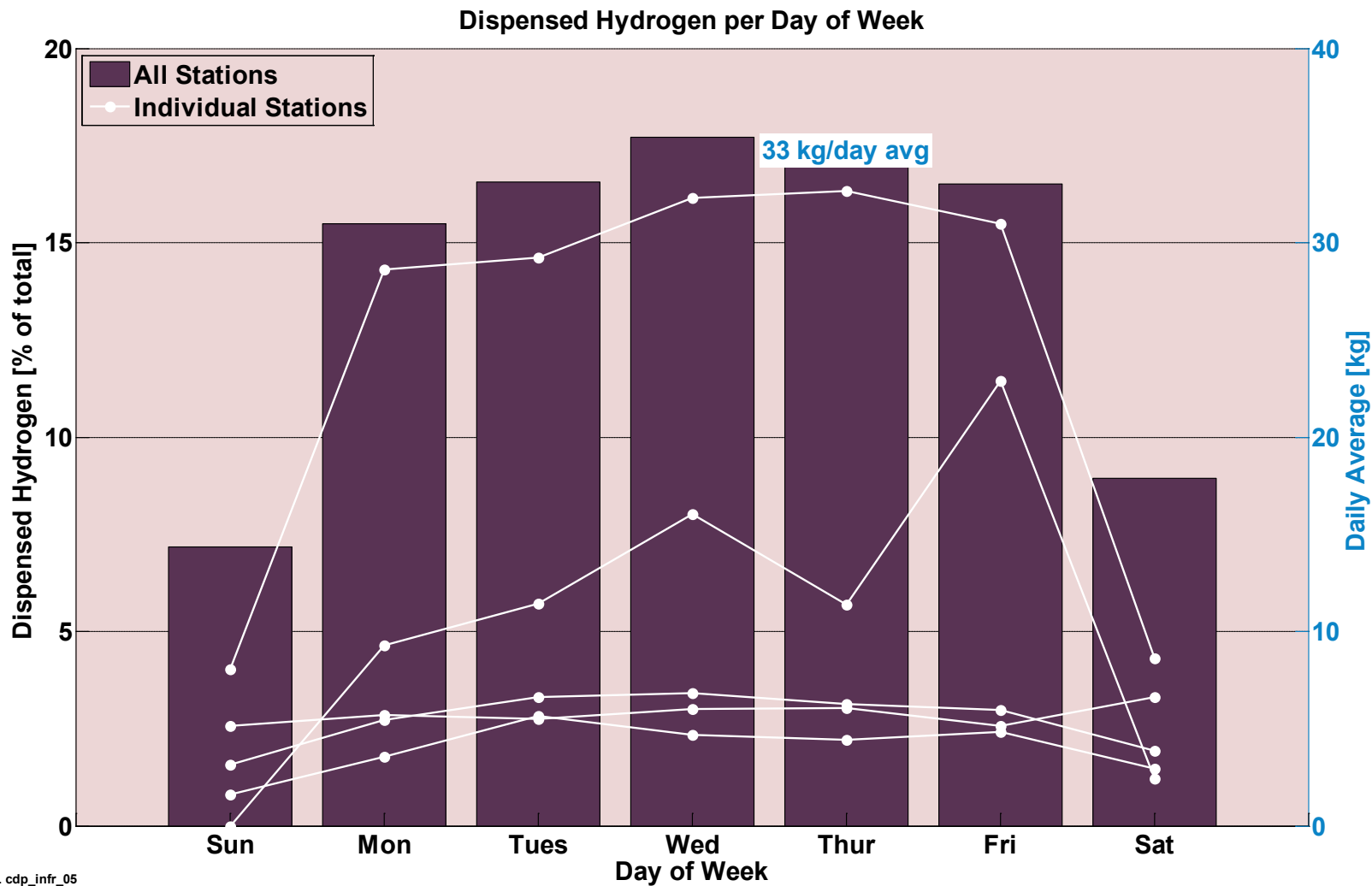
Histogram of Fueling Amounts



NREL cdp_infr_04

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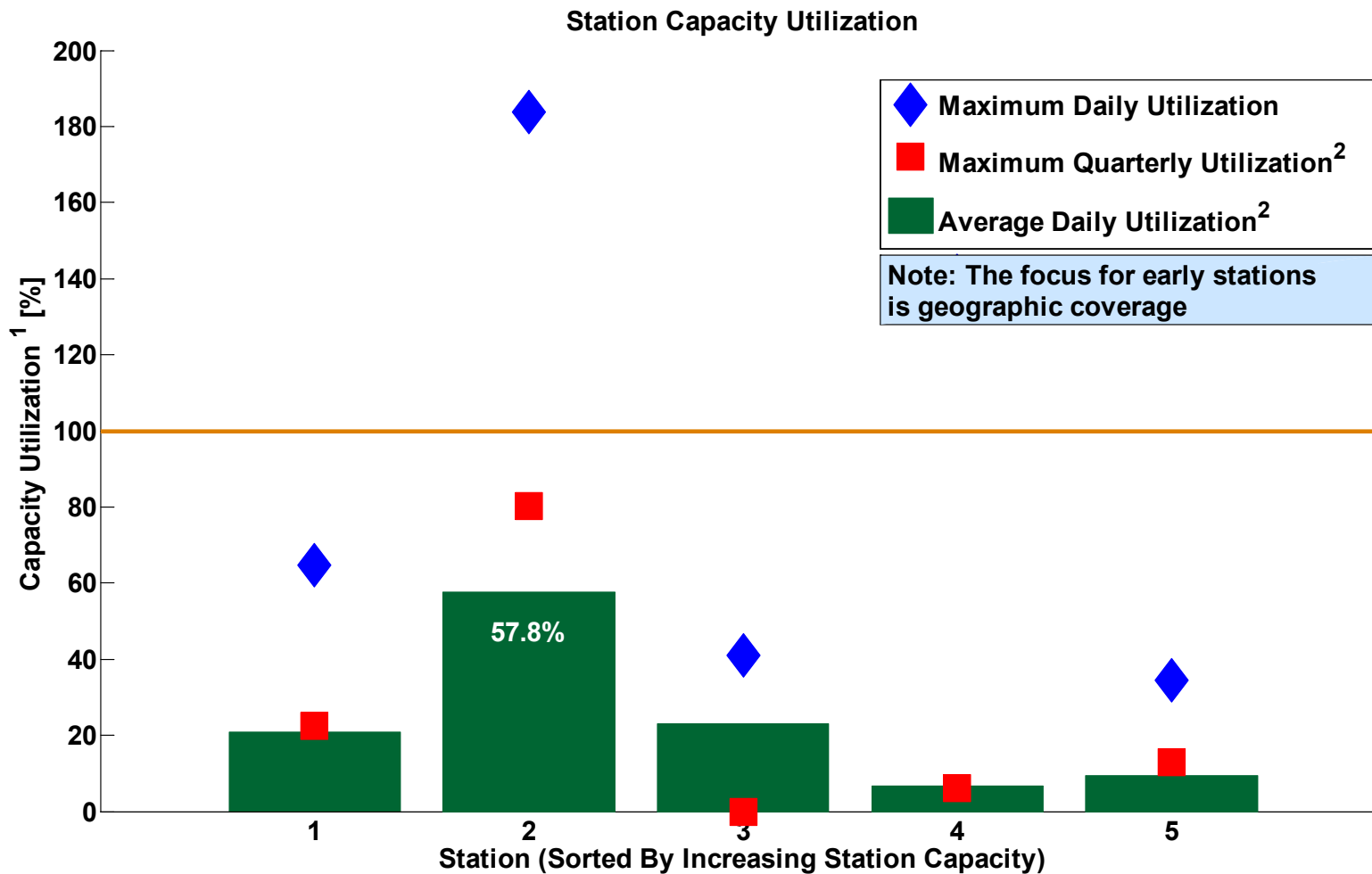
Dispensed Hydrogen per Day of Week



NREL cdp_infr_05

Created: Apr-07-14 4:32 PM | Data Range: 2009Q1-2013Q4

Station Capacity Utilization

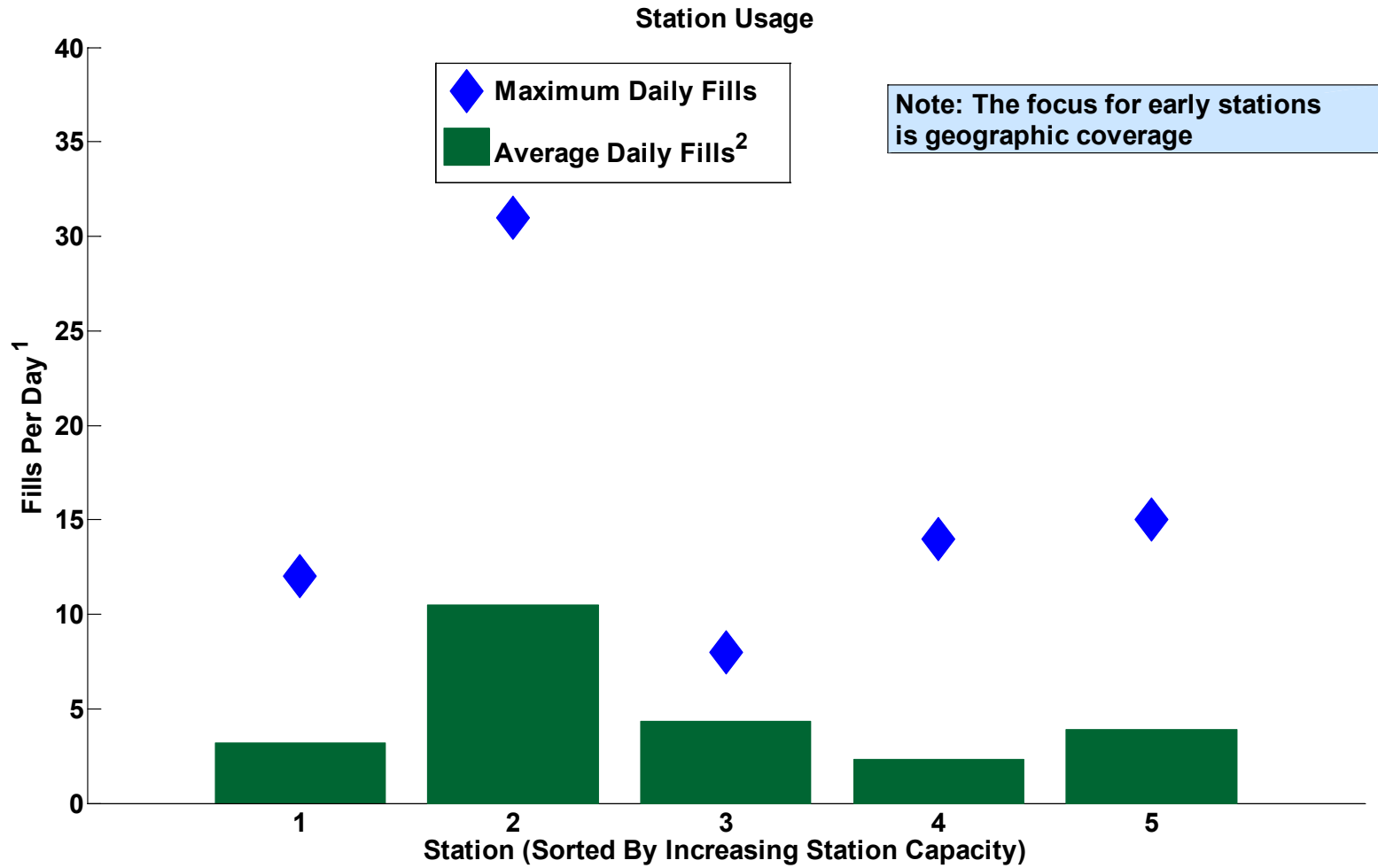


¹ Station nameplate capacity reflects a variety of system design considerations including system capacity, throughput, system reliability and durability, and maintenance. Actual daily usage may exceed nameplate capacity.

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

CDP-INFR-07

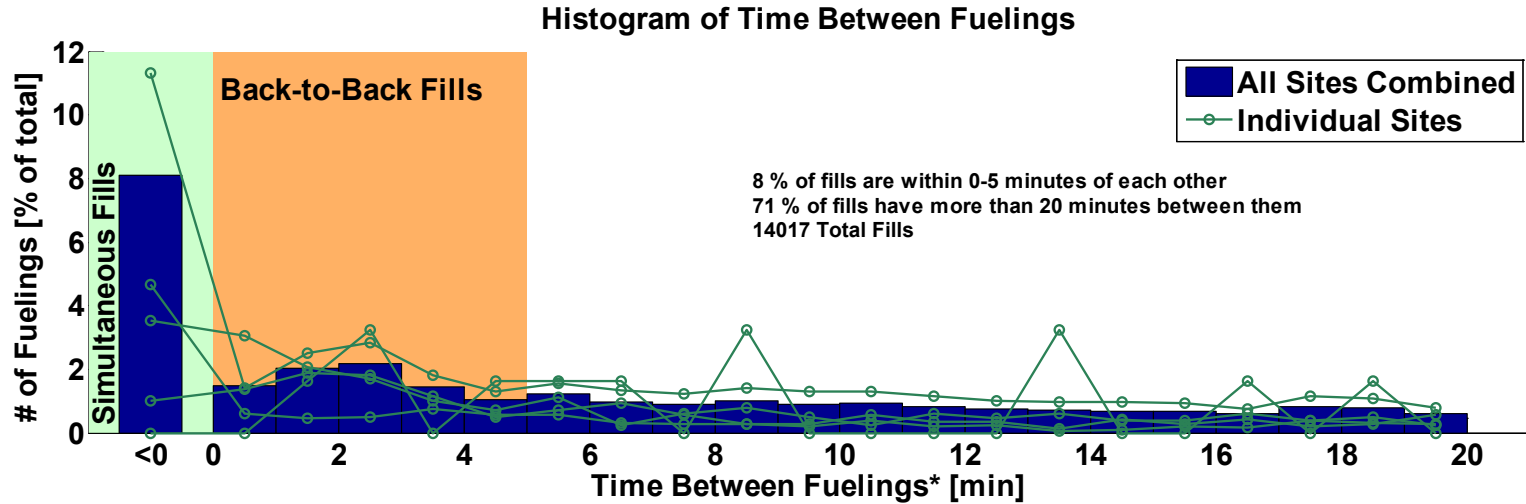
Station Usage



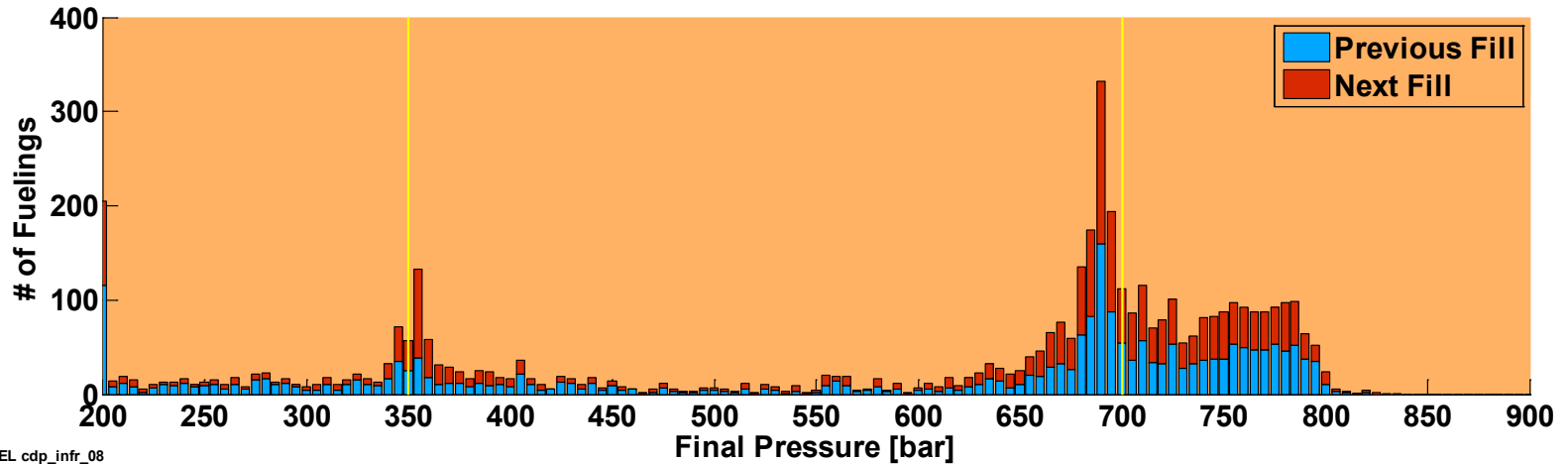
¹Excludes hydrogen fills of < 0.5 kg

²Average daily fills considers only days when at least one fill occurred

Time Between Fueling



Final Pressures for Fills with <5 Minutes in Between

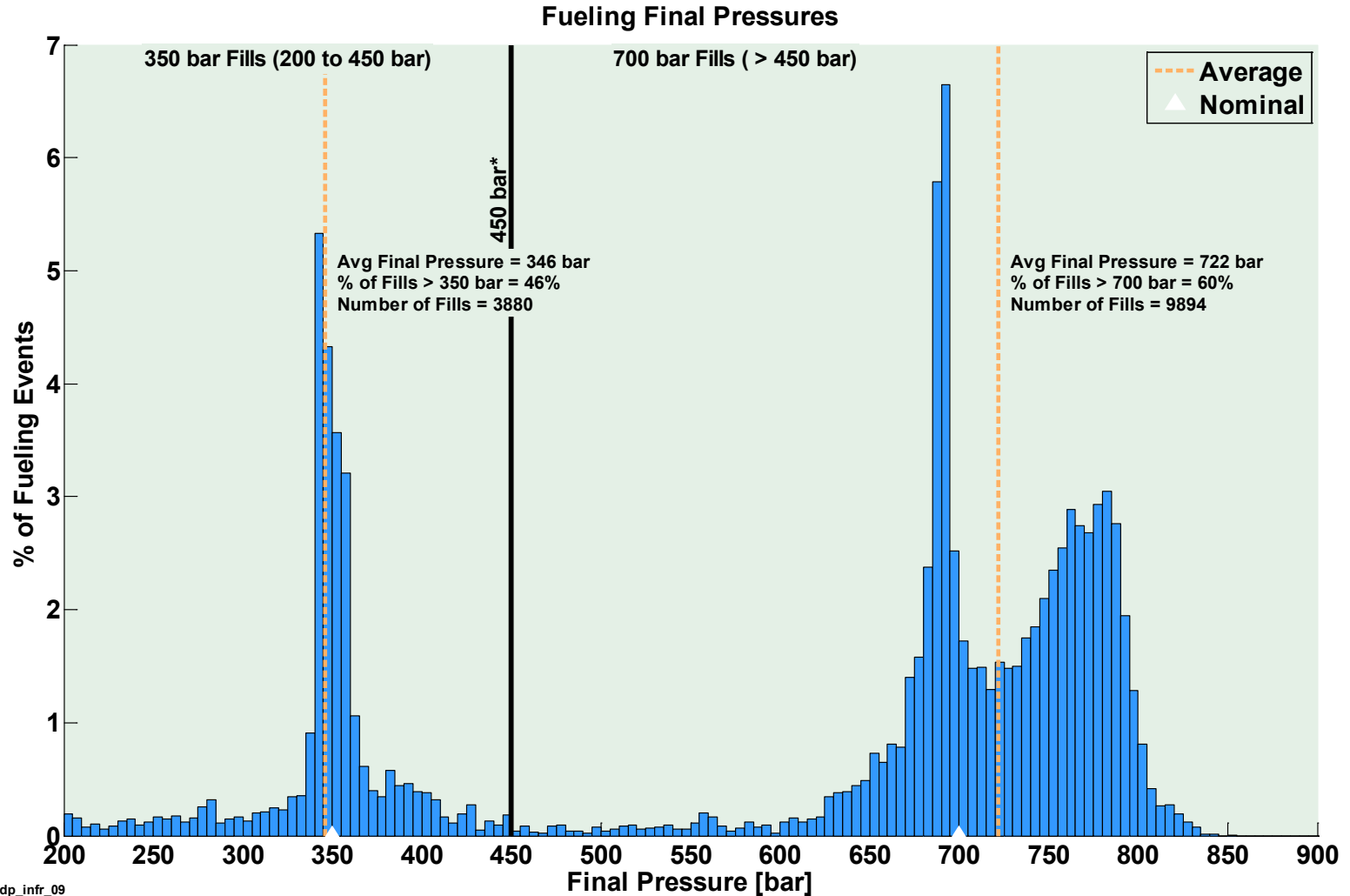


NREL cdp_infr_08

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

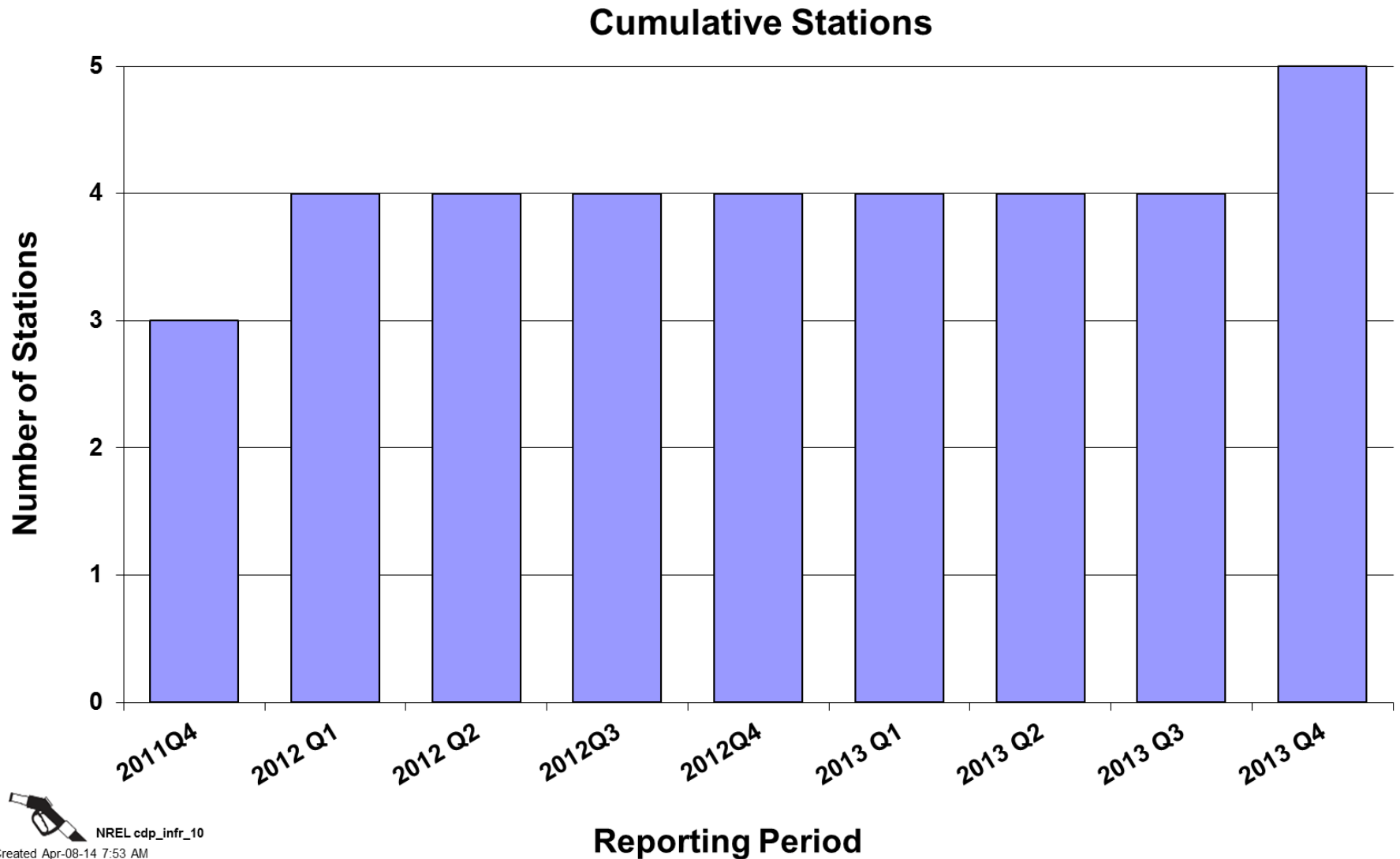
Fueling Final Pressures



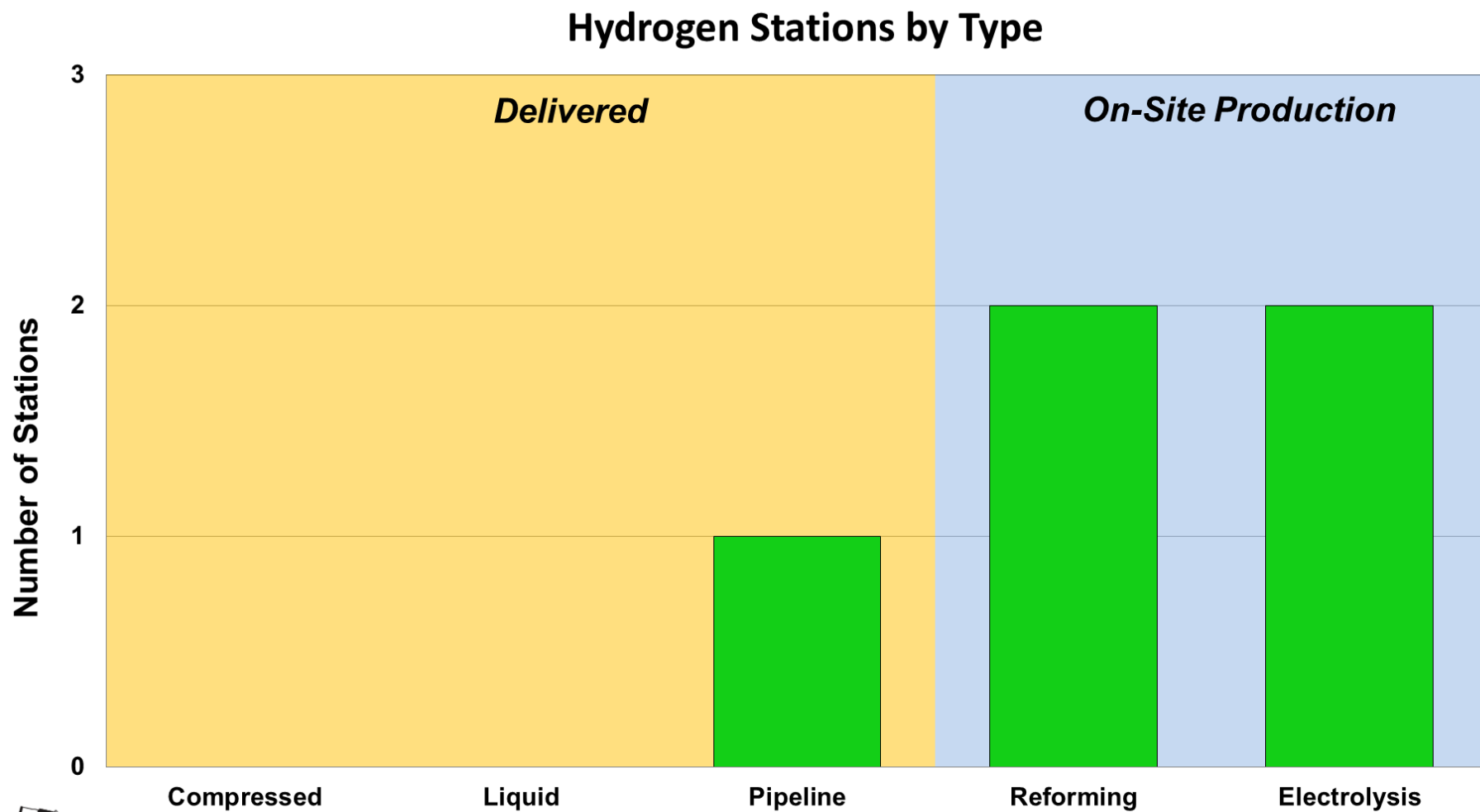
NREL cdp_infr_09

Created: Apr-24-14 2:09 PM | Data Range: 2009Q1-2013Q4

*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.

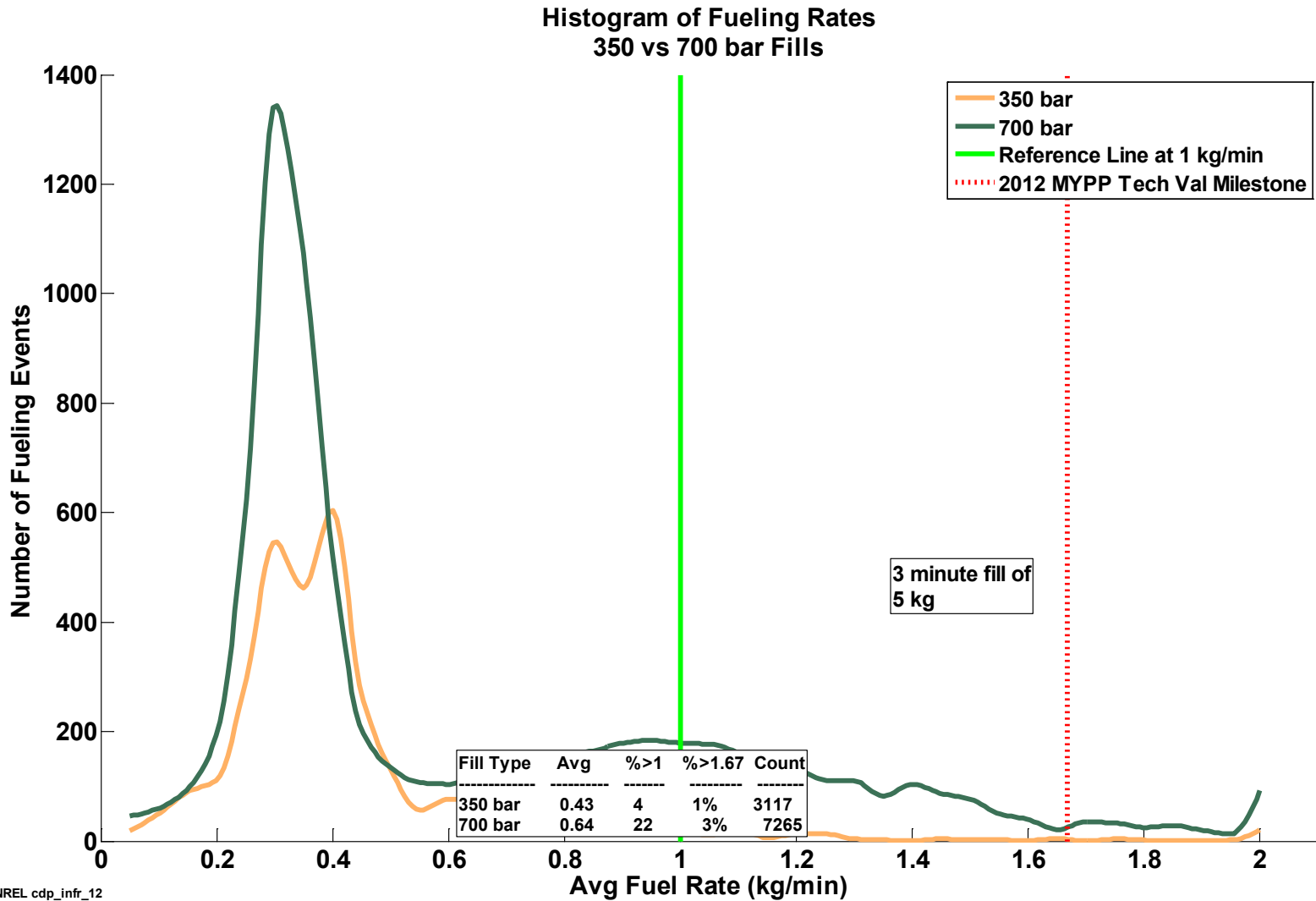


Hydrogen Stations by Type



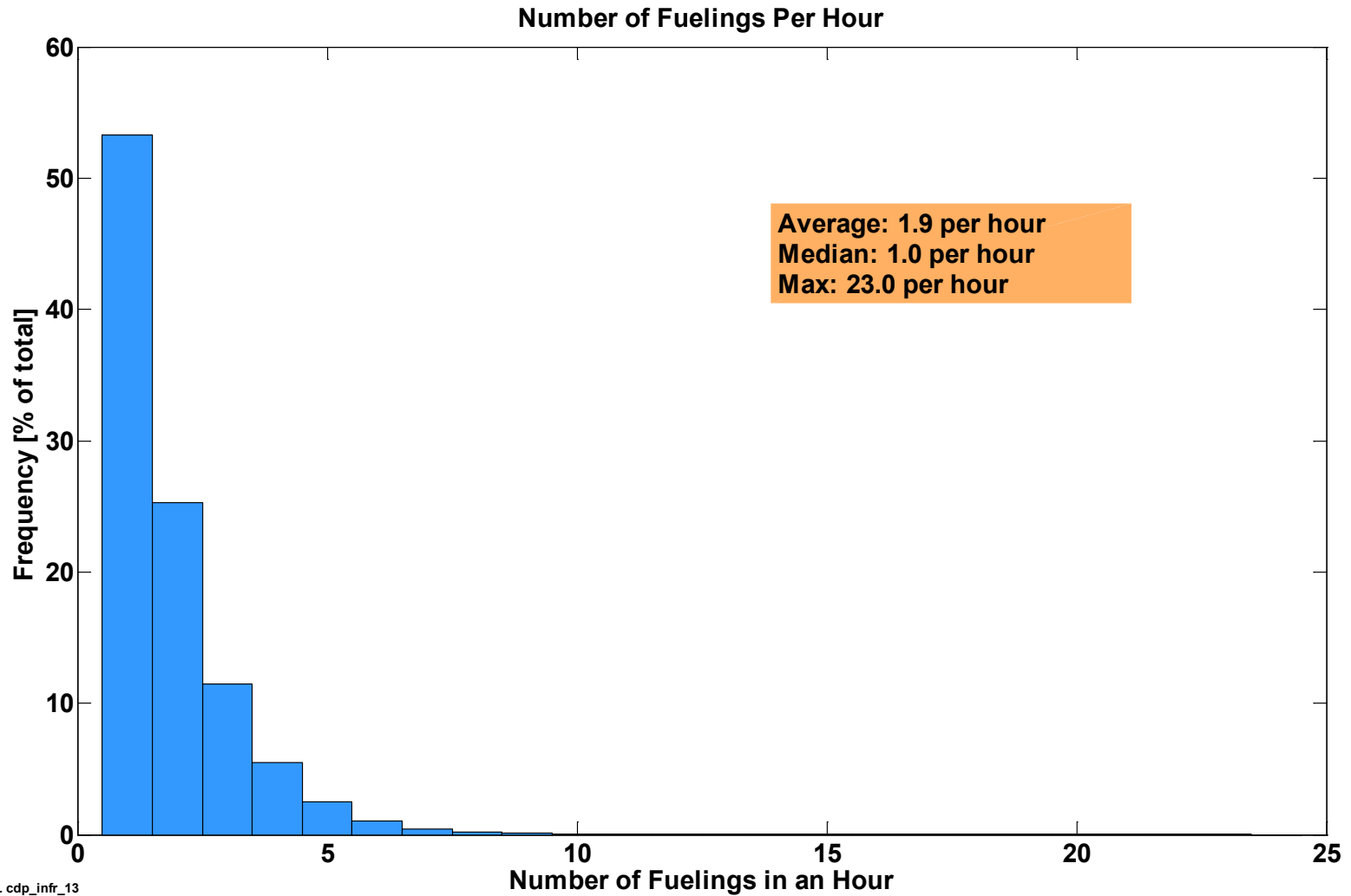
CDP-INFR-12

Fueling Rates 350 Vs. 700 bar



CDP-INFR-13

Number of Fueling Events per Hour

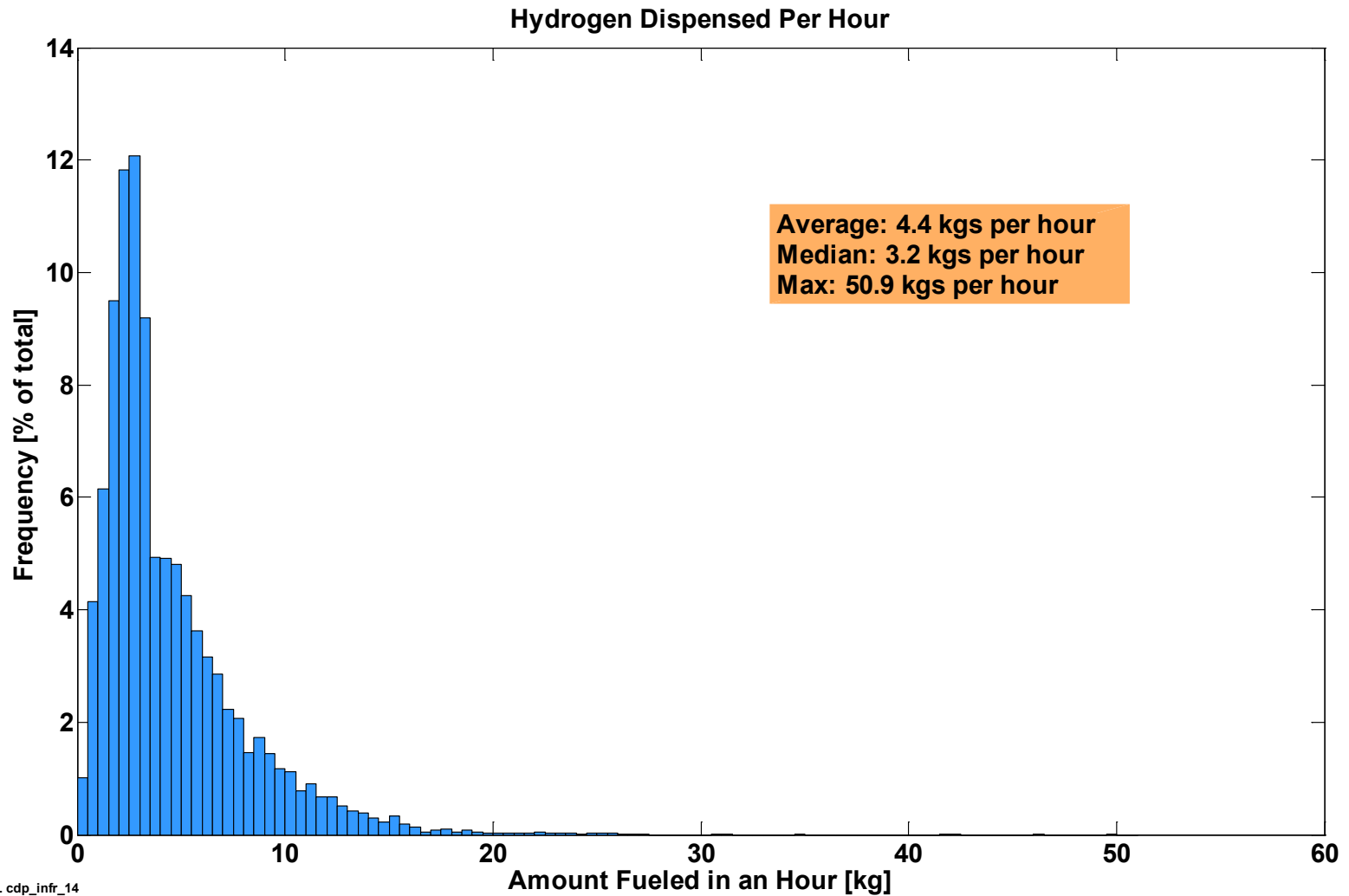


NREL cdp_infr_13

Created: Apr-07-14 4:38 PM | Data Range: 2009Q1-2013Q4

CDP-INFR-14

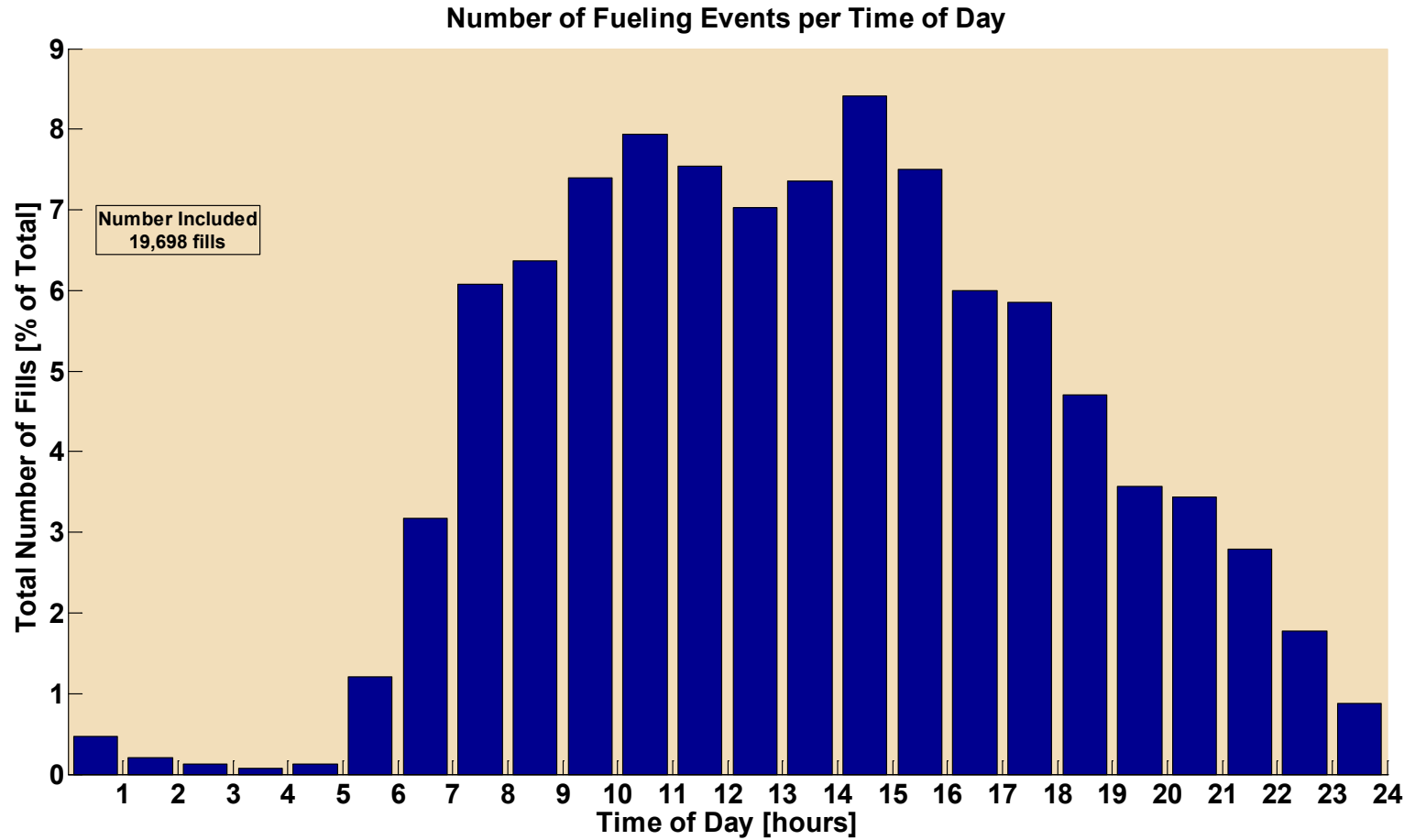
Hydrogen Dispensed per Hour



NREL cdp_infr_14

Created: Apr-07-14 4:39 PM | Data Range: 2009Q1-2013Q4

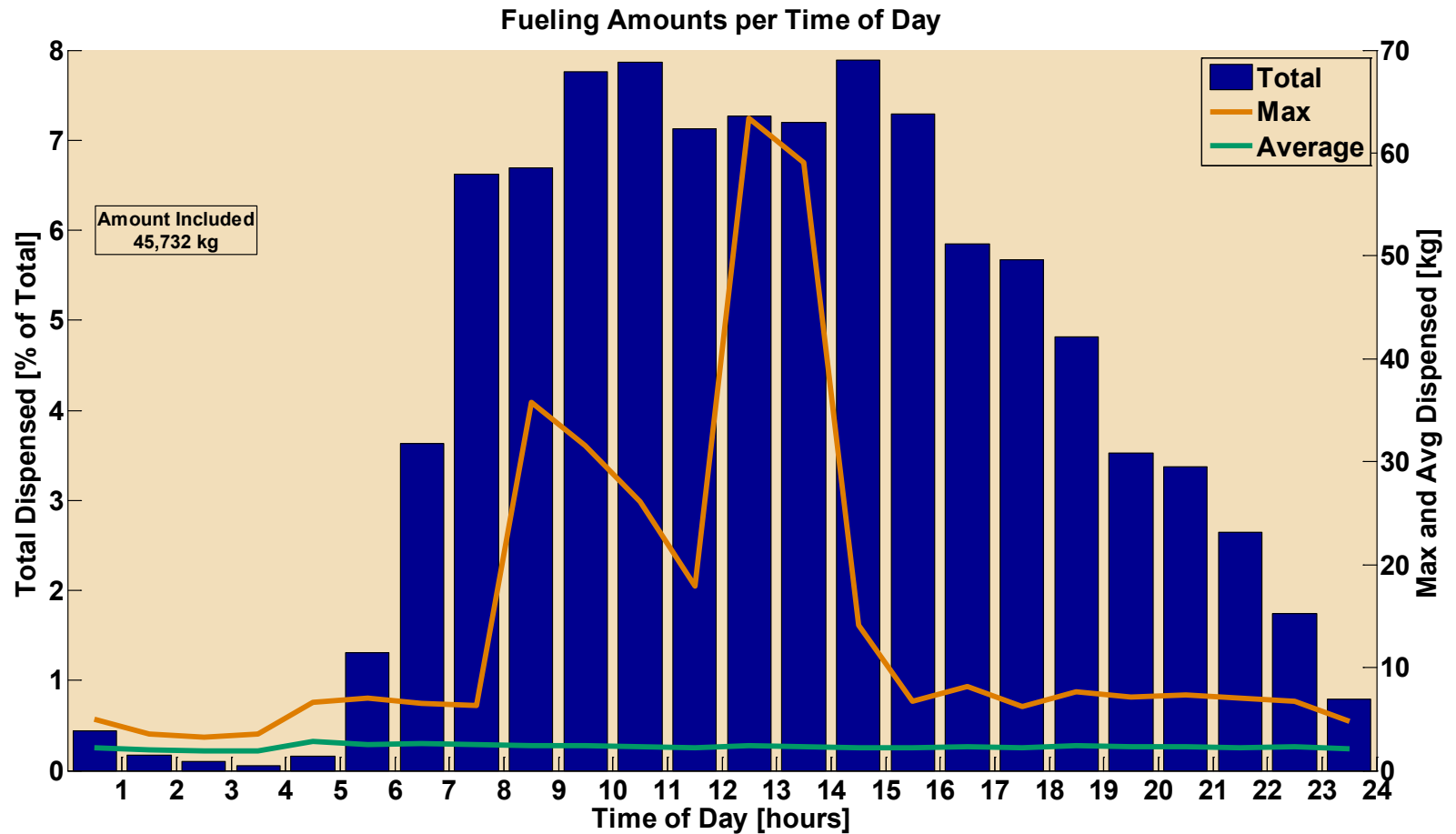
Number of Fills by Time of Day



NREL cdp_infr_15

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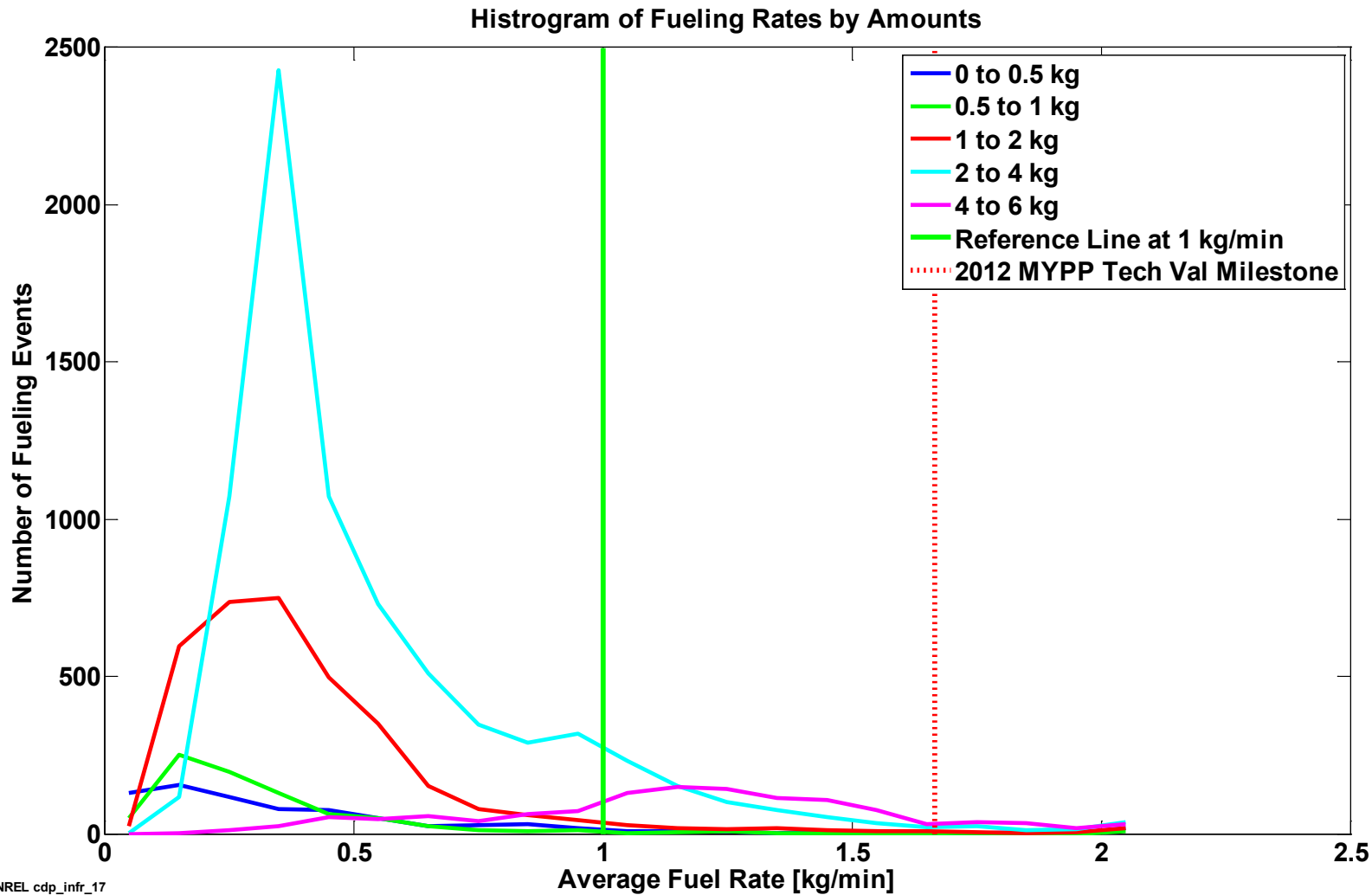
Fueling Amounts per Time of Day



NREL cdp_infr_16

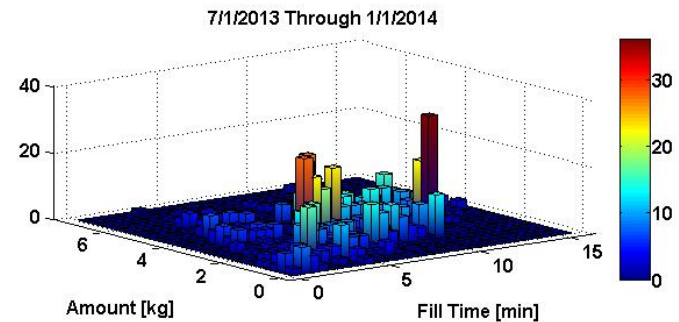
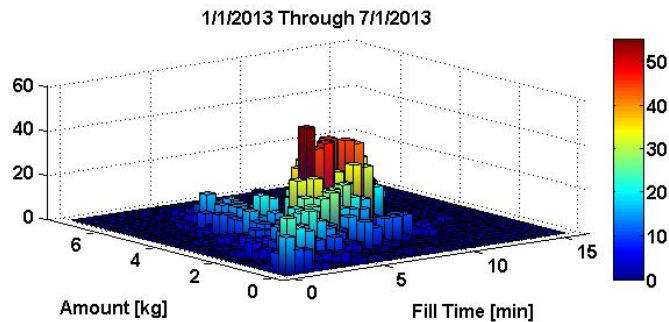
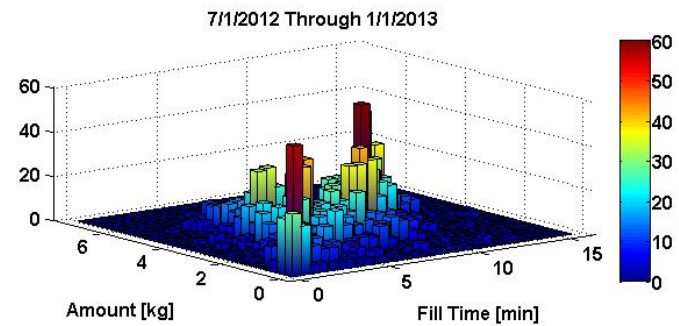
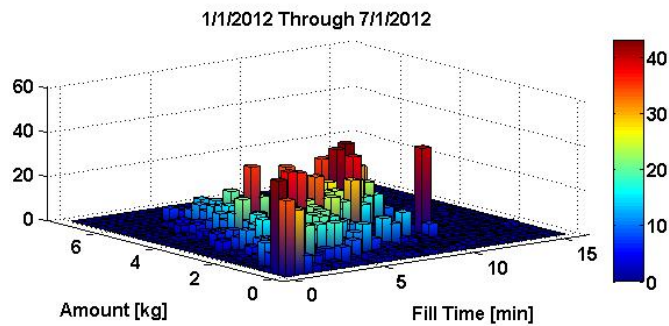
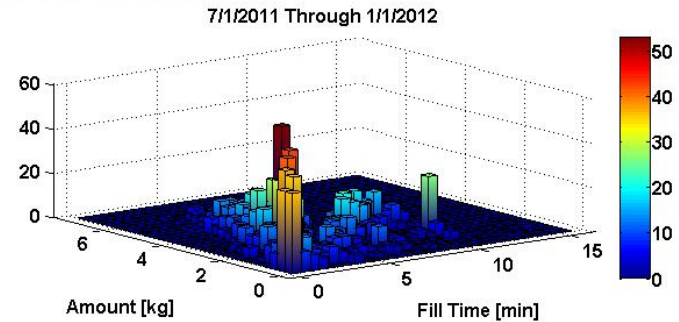
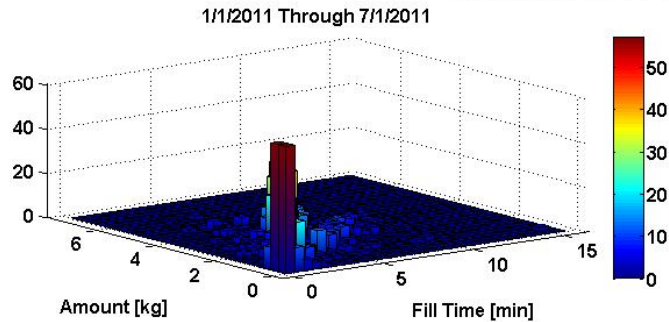
Created: Apr-07-14 4:41 PM | Data Range: 2009Q1-2013Q4

Fueling Rates by Amount Filled



Fueling Amount vs. Time to Fill

Histogram of Fueling Amount Vs Time

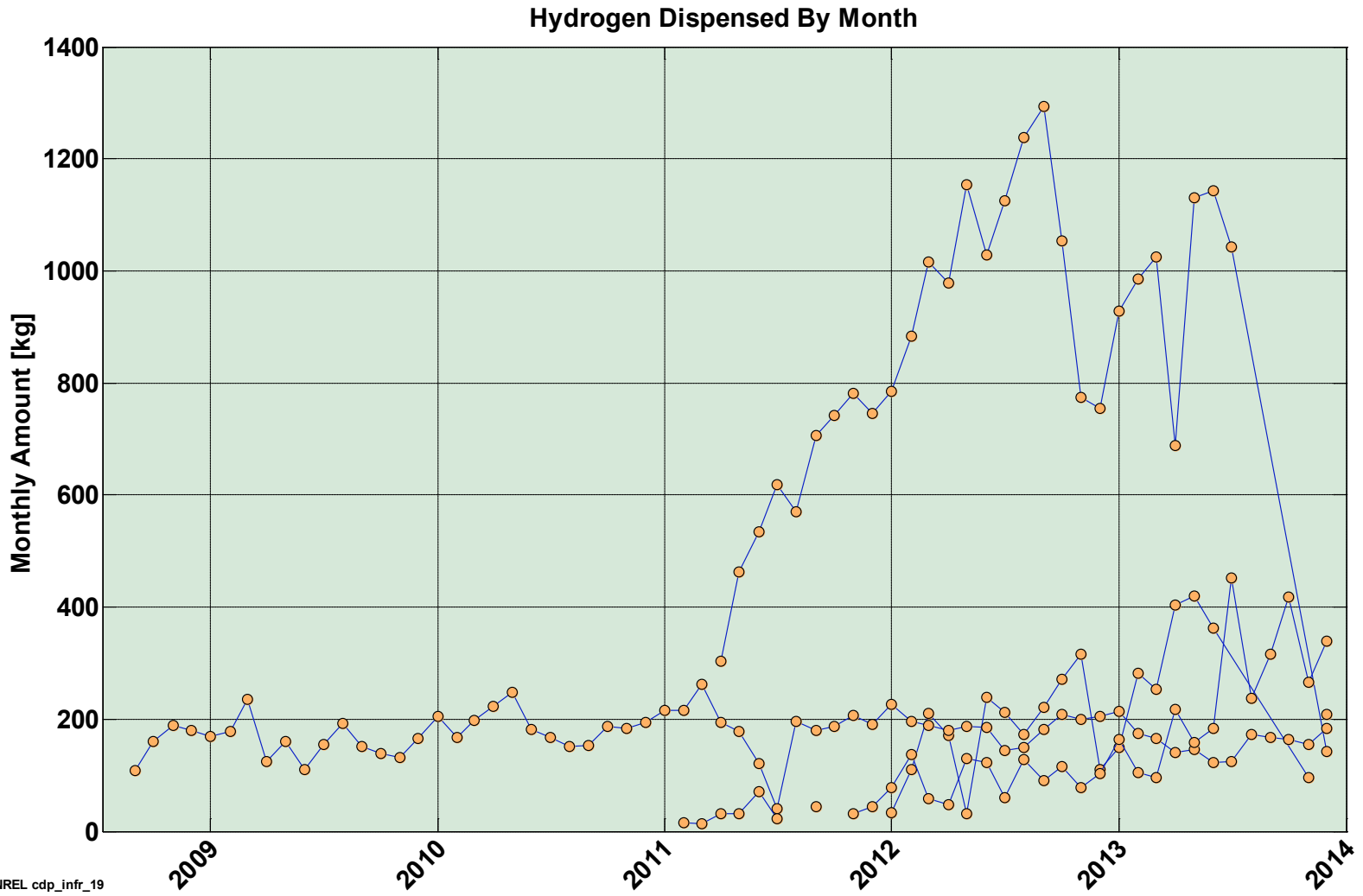


NREL cdp_infr_18

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CDP-INFR-19

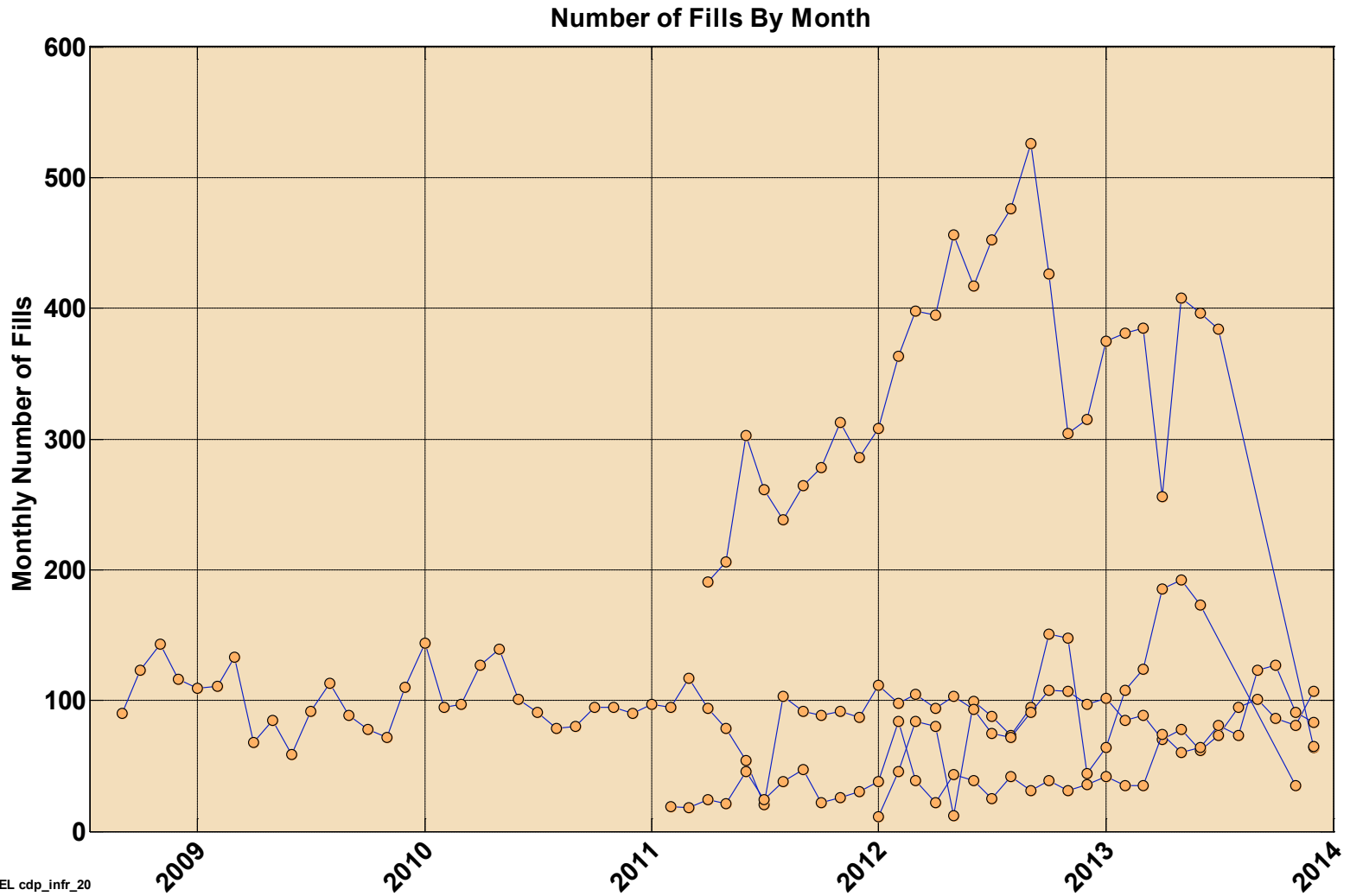
Hydrogen Dispensed by Month




NREL cdp_infr_19

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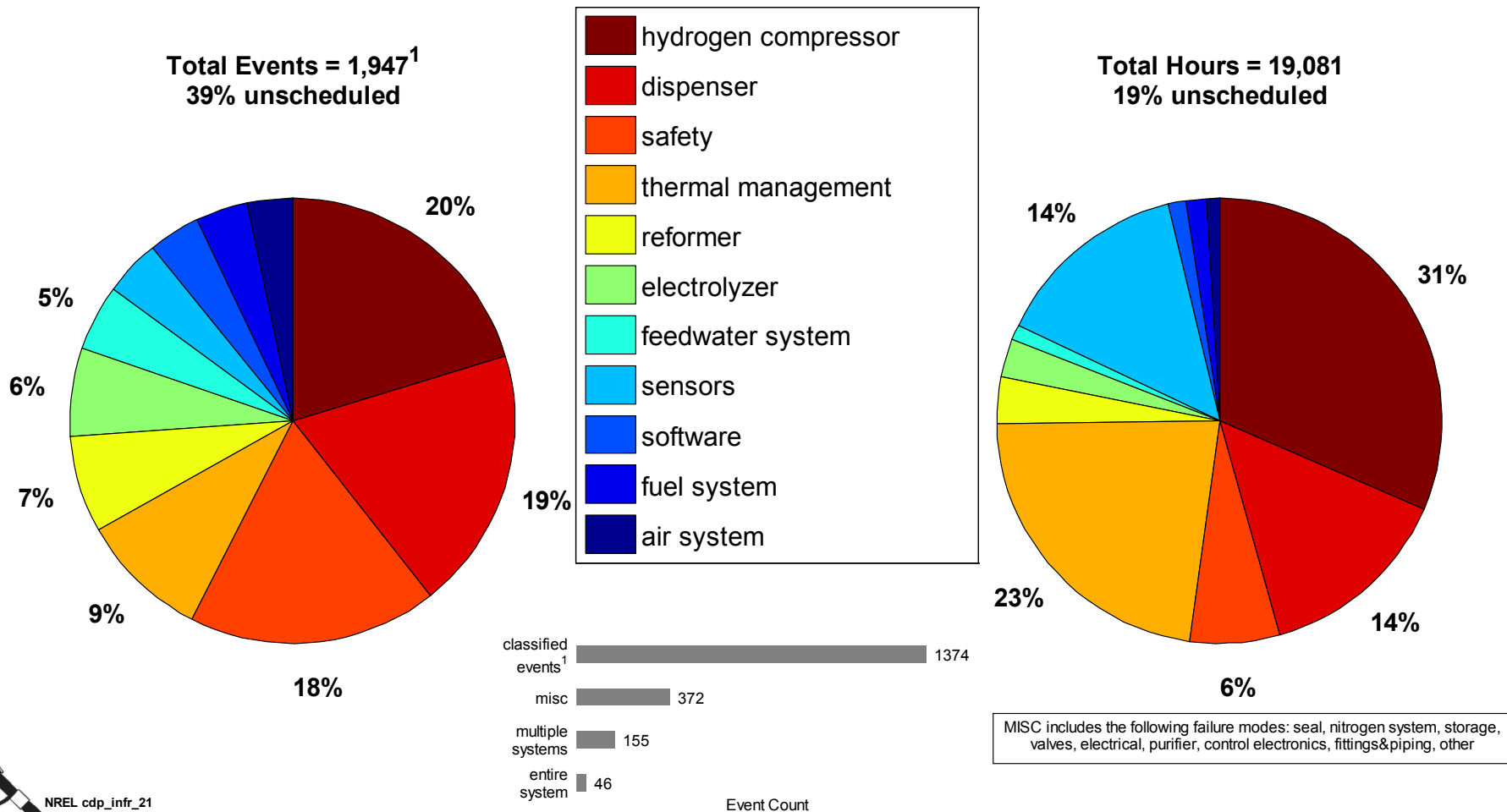
Number of Fills by Month



 NREL cdp_infr_20
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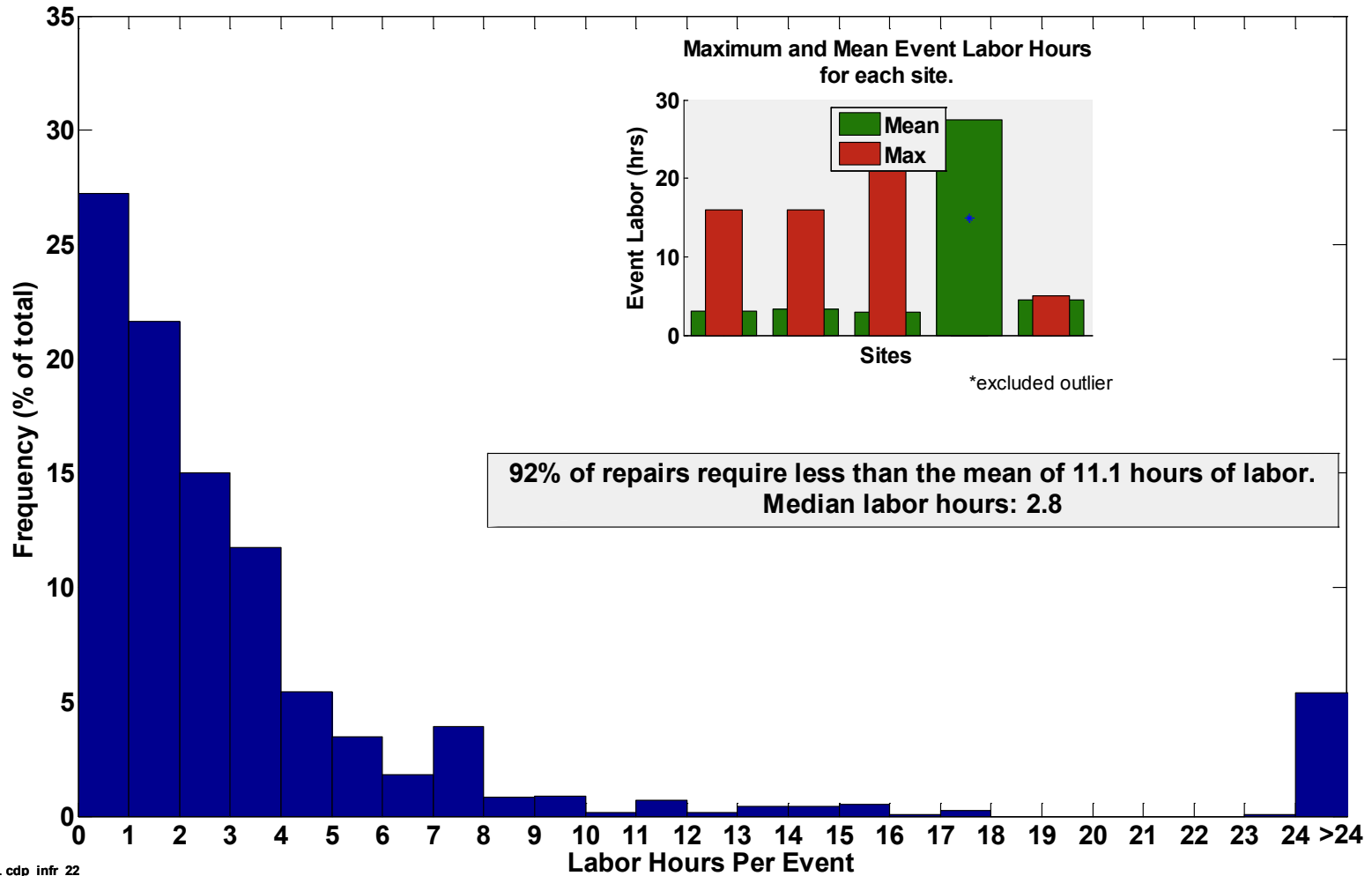
Maintenance by Equipment Type

Maintenance by Equipment Type



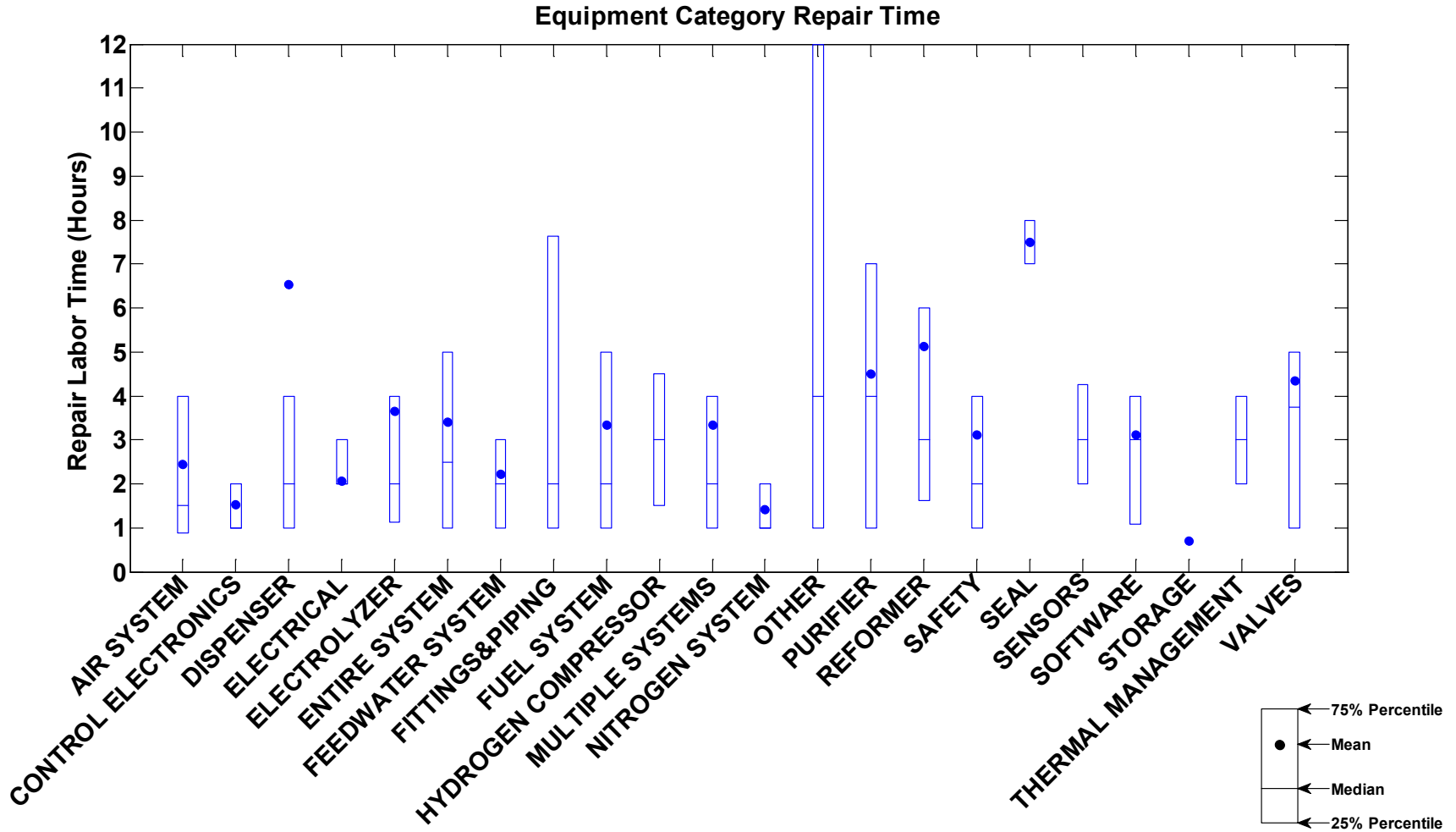
Maintenance Labor Hours Breakdown

Infrastructure Maintenance Labor Hours Breakdown



CDP-INFR-23

Equipment Category Repair Time

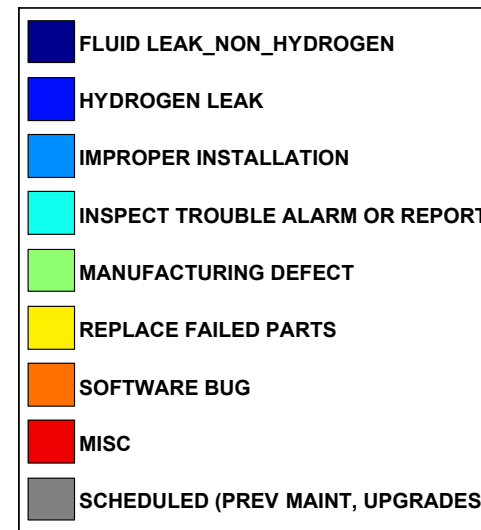
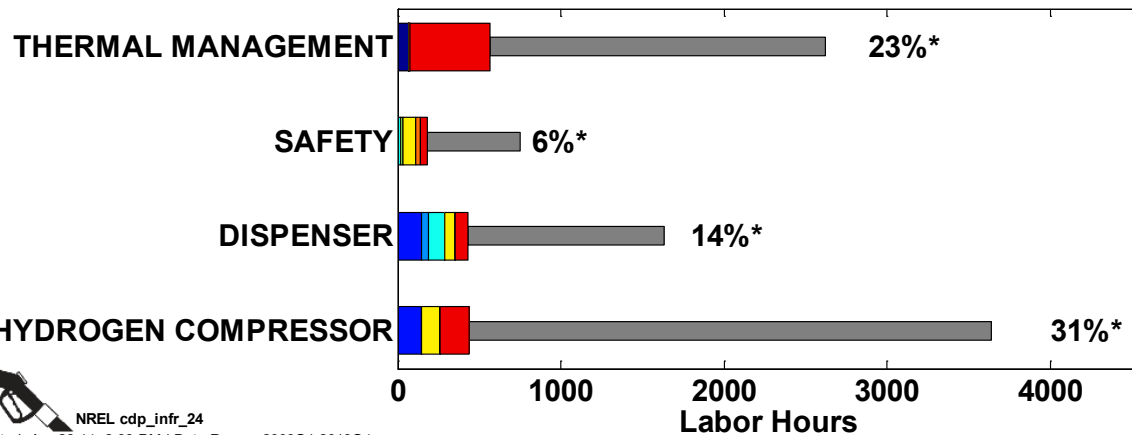
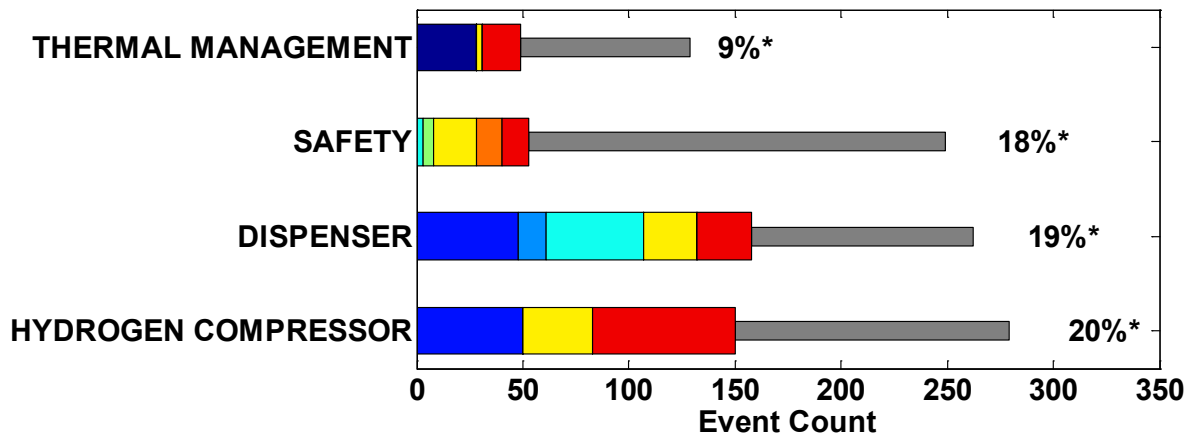


NREL cdp_infr_23

Created: Apr-10-14 4:20 PM | Data Range: 2009Q1-2013Q4

Failure Modes for Top Equipment Categories

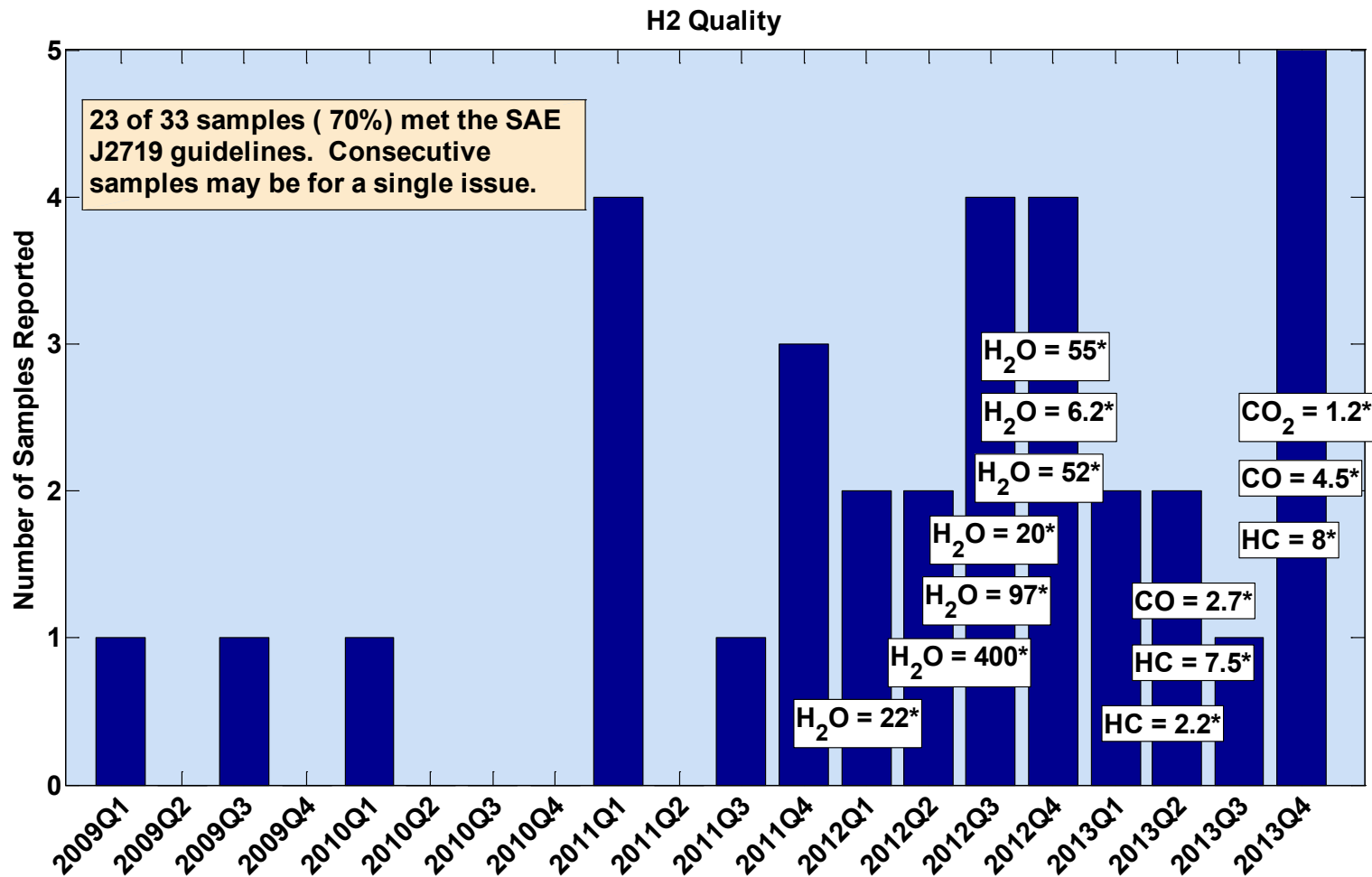
Failure Modes for Top Equipment Categories



MISC includes the following failure modes: flow low, inspect trouble alarm or report, other, out of calibration, pressure high, software bug, other

* Percentage of total events or hours.

H2 Quality



* Values are in micromole/mole. Only values that exceed SAE J2719 guideline are shown in text.



NREL cdp_infr_25

Created: Apr-24-14 4:13 PM | Data Range: 2009Q1-2013Q4

Collaborations

- **Station Operators**

- Gas Technologies Institute (GTI)
- Linde
- Hydrogen Frontier
- Shell
- California State University Los Angeles (CSULA)
- Proton OnSite

- **Organizations**

- California Fuel Cell Partnership (CaFCP)
- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- H2USA – Station Working Group

Collaborations: CaFCP Working Group

- **Participate in CaFCP working group meetings and station implementation team toward:**
 - Developing recommendations for future stations
 - Staying current with California hydrogen activities and needs

Future CDPs Planned

- **Separate out fueling events (rates, etc.) by topic (as data allow)**
 - Pre-cooling temp
 - Amount filled
 - Simultaneous fueling
 - Back-to-back
- **Maintenance**
 - Frequency, MTBF, most frequent, most costly...

Proposed Future Work

- Add stations to the analysis as they come online
 - FOA Station Status
 - Proton OnSite upgrades to Wallingford station (2014Q3)
 - Proton OnSite 2nd station (2014Q3)
 - GTI reporting on new Linde stations (2014Q4)
 - CARB Station measurement upgrades and data (2014Q3)
- Create new CDPs that describe the current state of pre-commercial stations
- Provide feedback on infrastructure status to stakeholders, continue collaborations, and seek feedback on important metrics
- Feed shortfalls back to developers, and track consumer behavior

Project Summary

- **Relevance:** Hydrogen stations need to be able to meet vehicle needs.
- **Approach:** Analyze station operational data, building upon tools and capabilities from Learning Demo.
- **Accomplishments and Progress:** Updated database of stations and completed analysis of current station data.
- **Collaborations:** Currently working with station operators and California organizations.
- **Future Work:** As new stations open and provide data, NREL will add them to the analysis to get a good picture of the current state of hydrogen infrastructure.