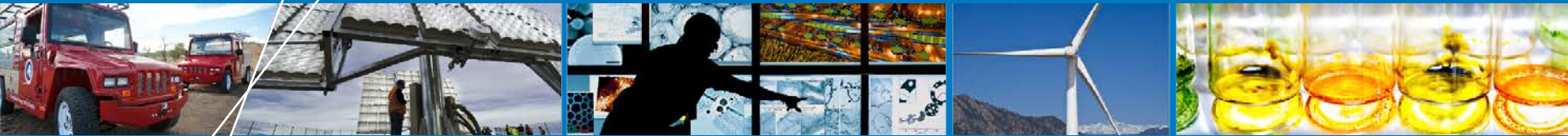


Next Generation Hydrogen Station Composite Data Products Data through Quarter 4 of 2015



**Sam Sprik, Jennifer Kurtz,
Chris Ainscough, Genevieve Saur,
Michael Peters, and Matthew Jeffers**

May 2016

H₂ Station Project Partners



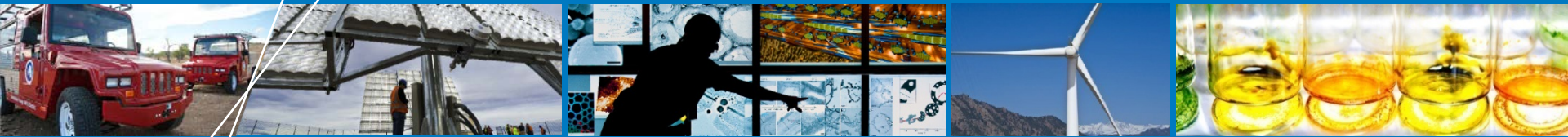
Current

- California Air Resources Board
- California Energy Commission
- California State University Los Angeles
- Gas Technologies Institute
- Linde
- H2 Frontier
- Proton OnSite
- Shell
- IPHE and HySUT

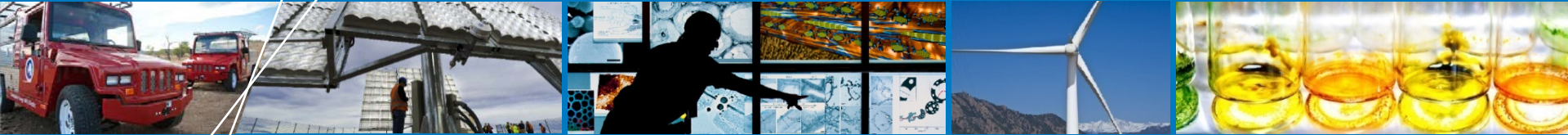


Analysis Categories





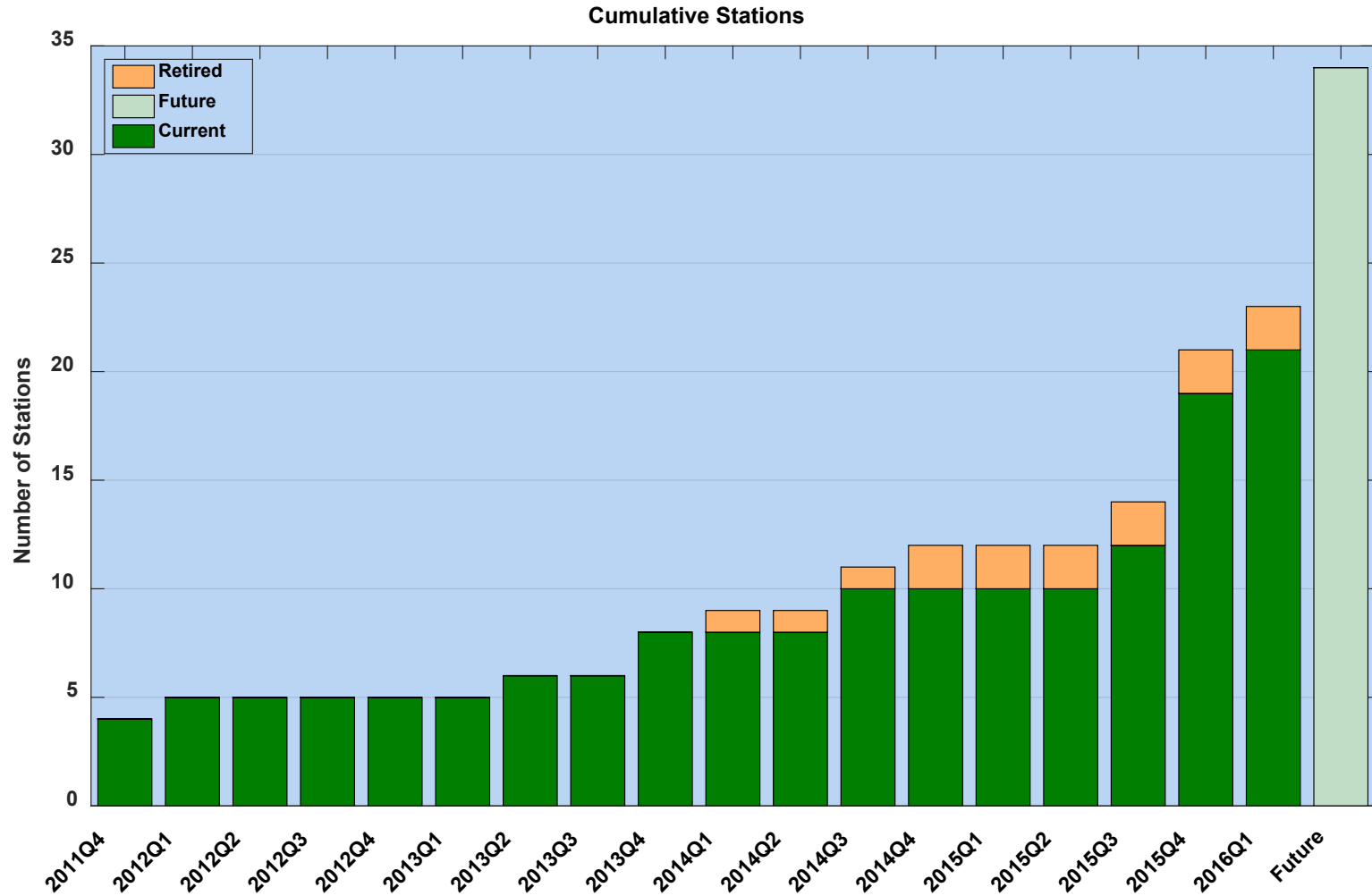
All Composite Data Products (CDPs)



Deployment

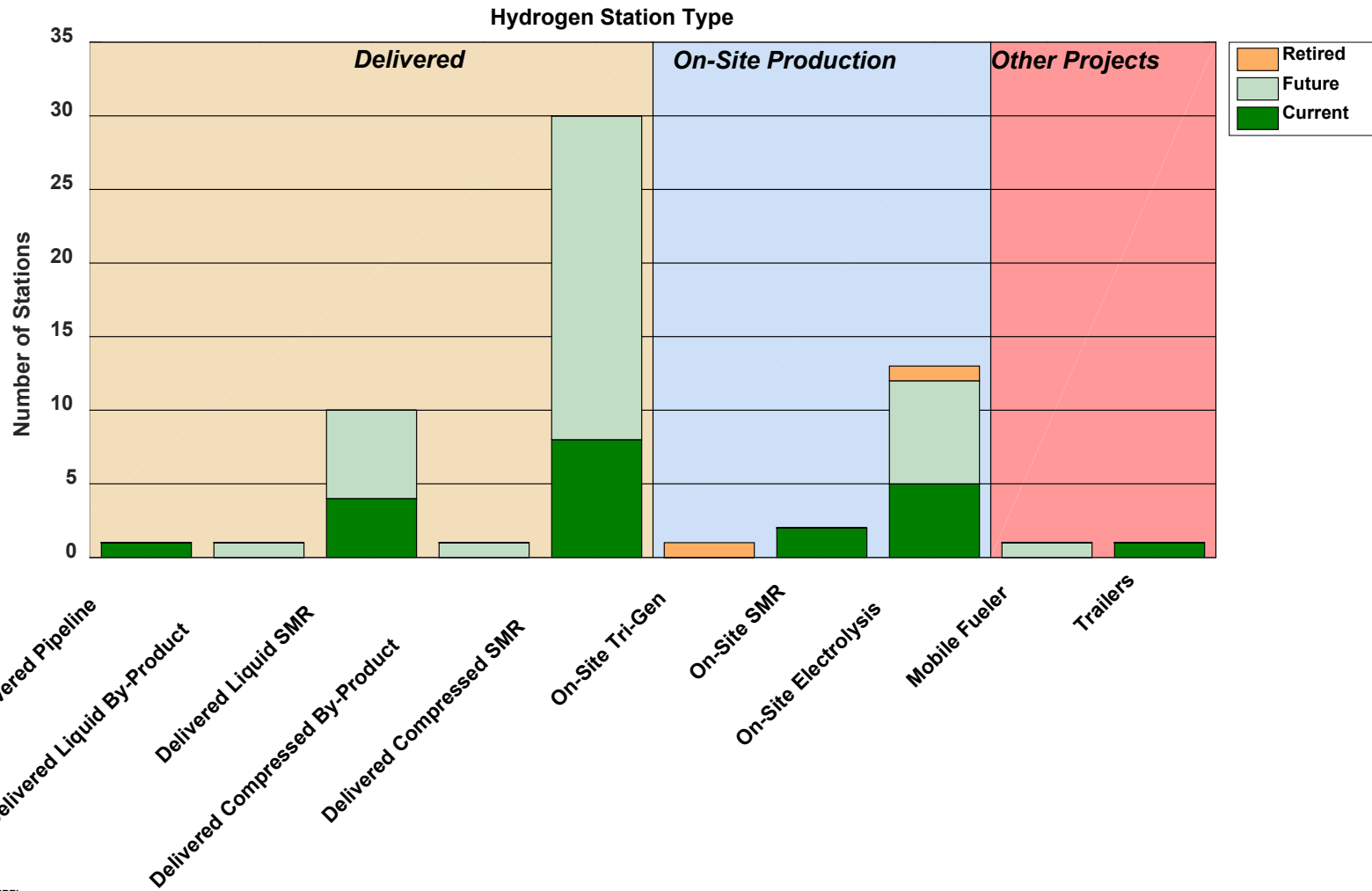
CDP-INFR-10

Cumulative Number of Stations

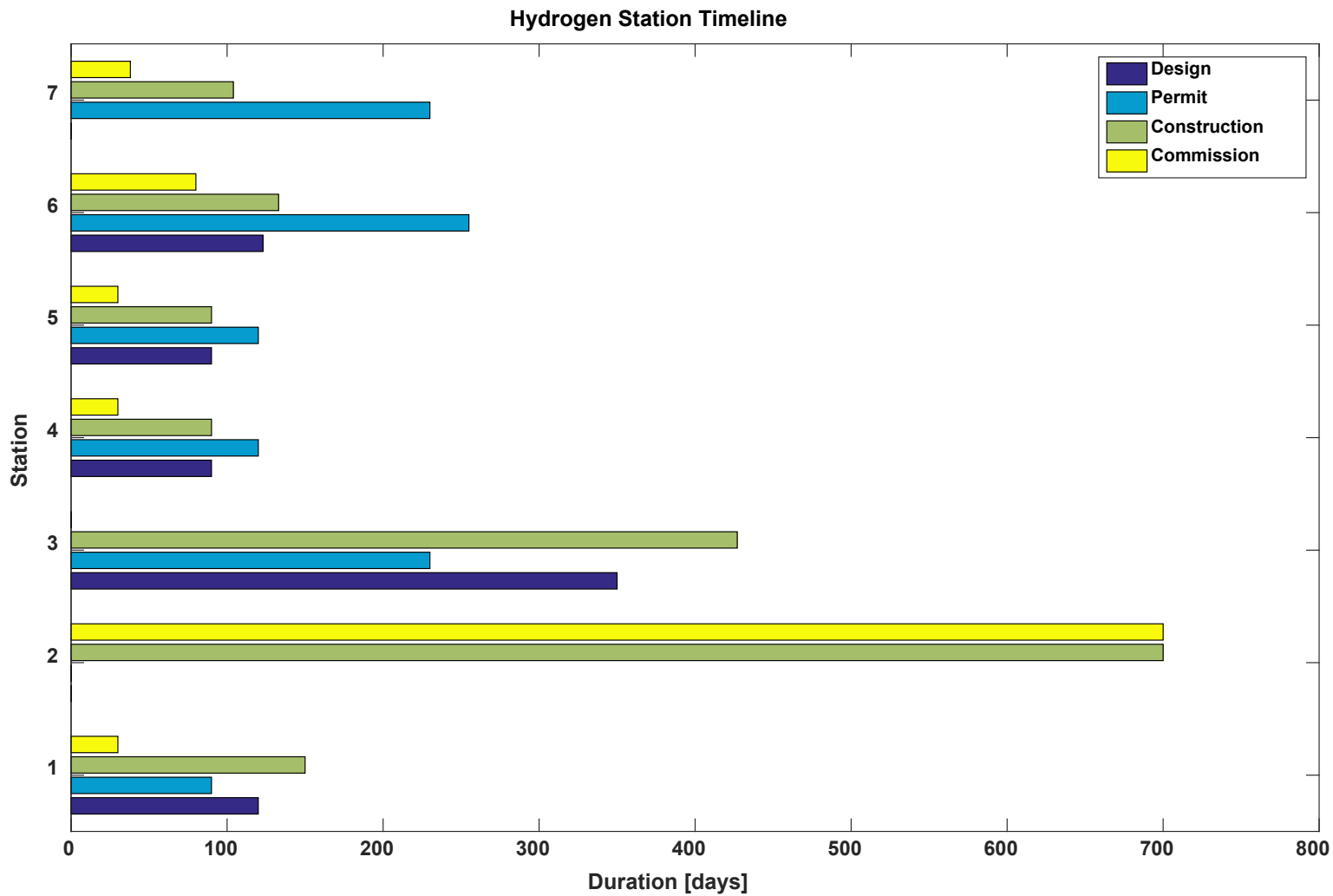


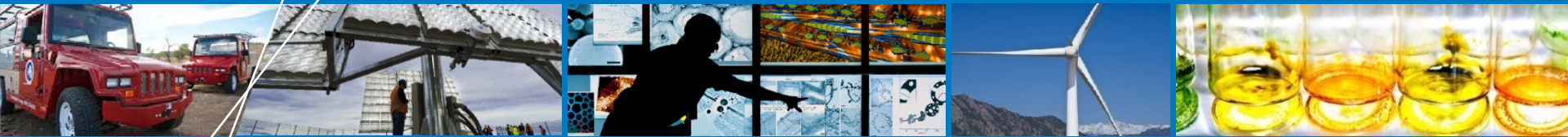
Created: Apr-11-16 5:07 PM

Hydrogen Stations by Type



Hydrogen Station Timeline





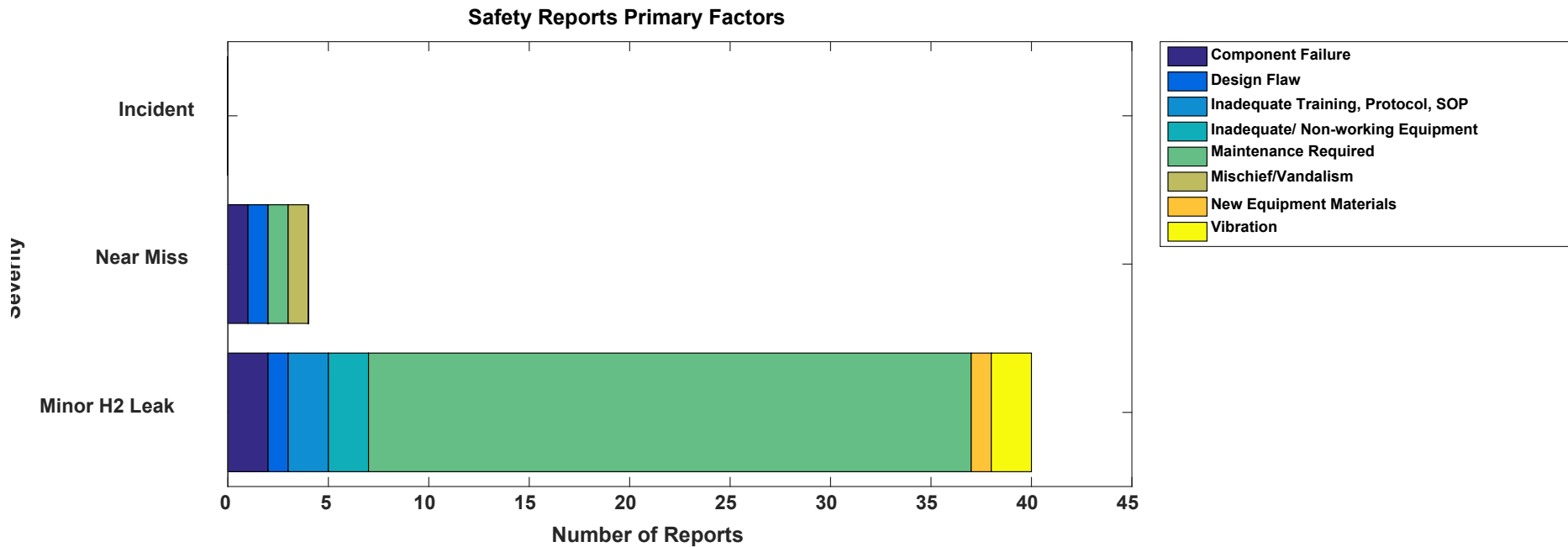
Safety

Safety (and Maintenance) Learnings

From Safety Reports Template

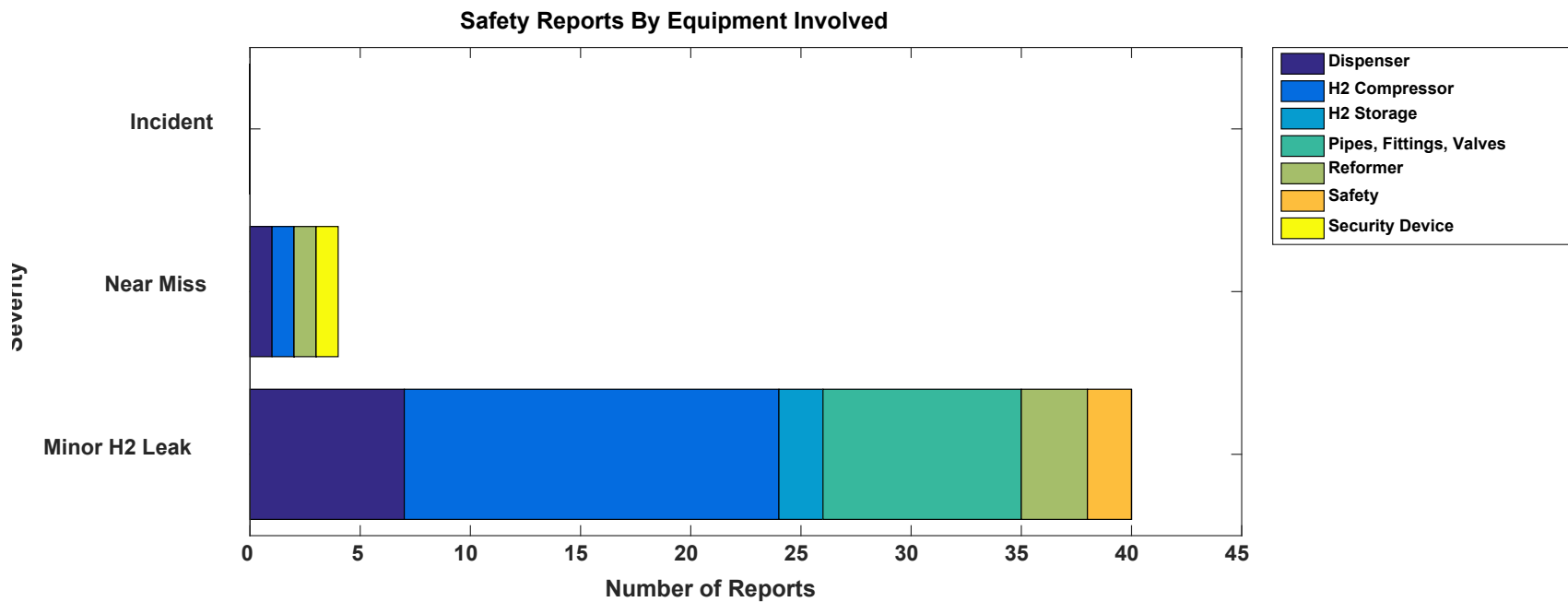
- Alarms not communicated
- Breakaway leak
- Check compressor oil filter
- Check integrity of delivered equipment
- Compressor leaking at startup normal?
- Does isolated leak need to shut down station?
- Electrical glitch
- Estop activated after hearing escaping gas-nitrogen
- Estop activated when nozzle stuck on car
- Estop activated without cause
- Estop flooded prevented restart
- False Alarm - No Fire
- Fill and leak check together caused shutdown - false leak alarm
- Filter to catch scrap from material processing
- Forgot to turn back on after maintenance
- Freezing and thawing caused moisture in communication connector
- Frozen cooling block - defrost
- HTO sensor fault
- Heat trace short caused false fire alarm
- Heavy rain triggered fire alarm
- Hose vent failure - nozzle stuck on car
- Loose wire intermittent problems
- Loud popping could be relief valve
- Mass balance alarm bug
- Mass balance alarm caused by high ambient temperature
- Power Issue - 3 Phase
- Predict service life better
- Proper installation prevents leaks
- Rain on sensor causing alarm
- Regular inspection of compressor valves
- Regular leak checks
- Regular station inspection
- Reset
- Spider web obscuring sensor
- Thermocouple failure shutdown station
- Vibration from normal activity shutdown dispenser
- Vibration isolation

Safety Reports Primary Factors

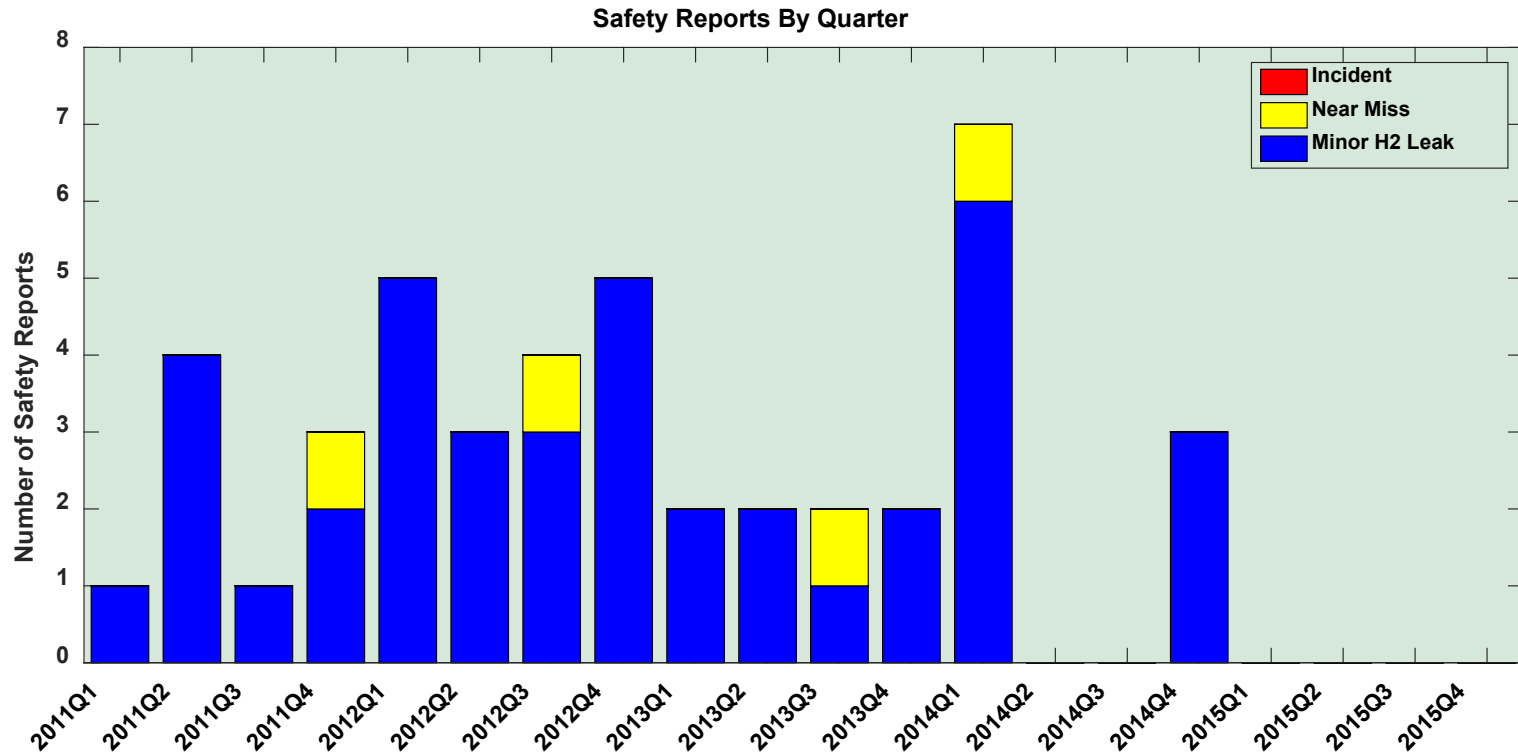


Created: May-01-16 11:40 J

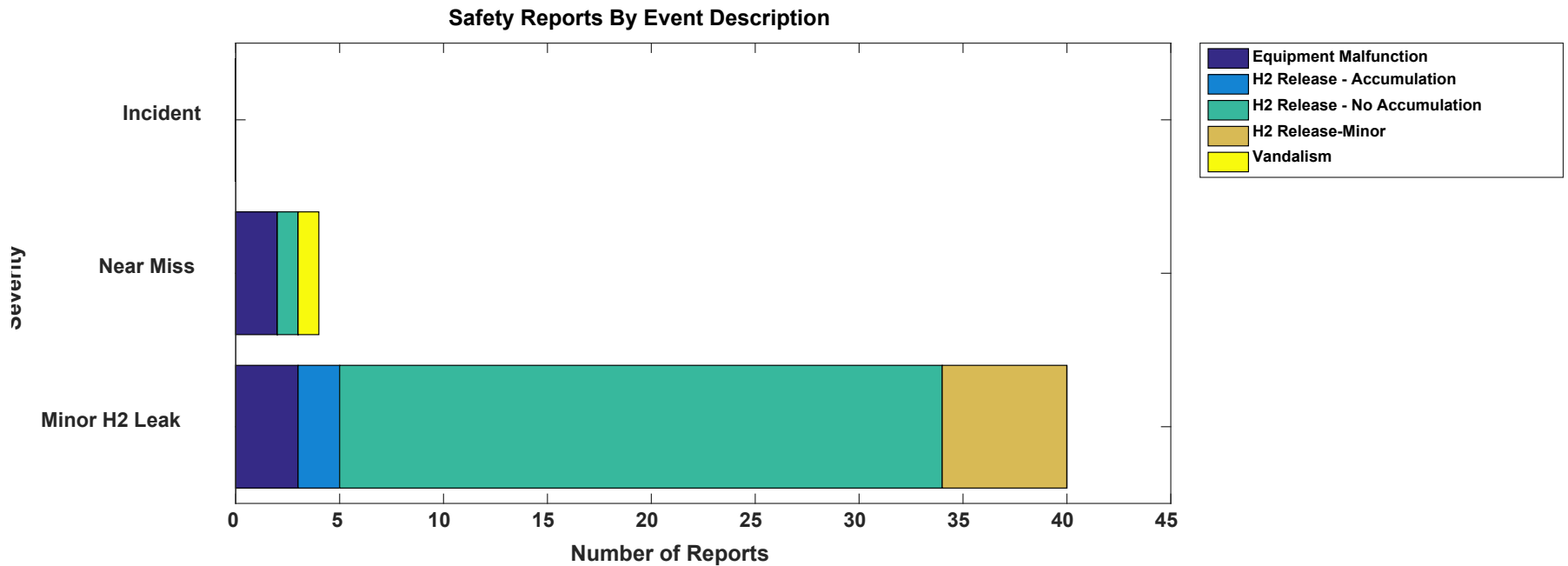
Safety Reports by Equipment Involved



Safety Reports by Quarter



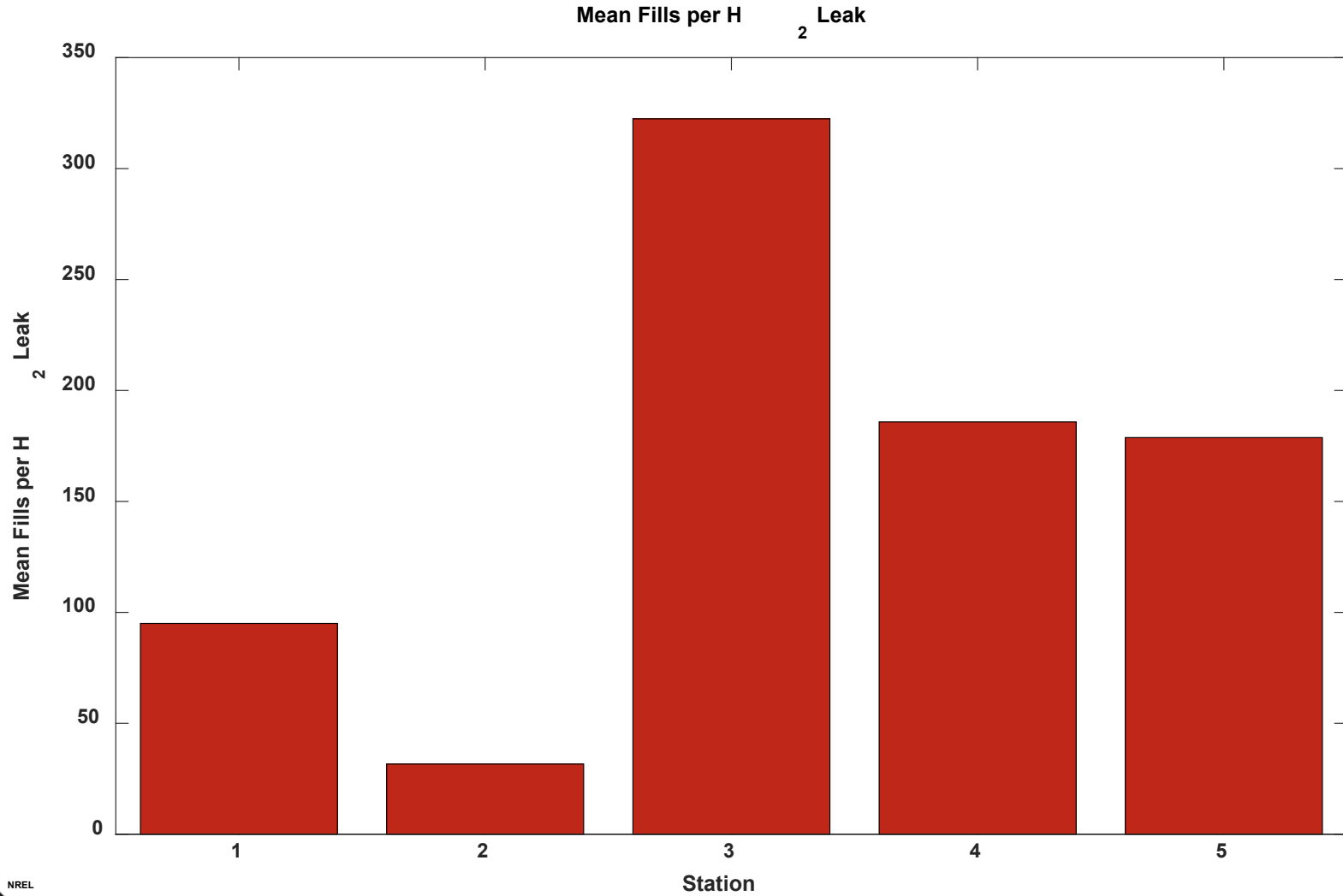
Safety Reports by Event Description



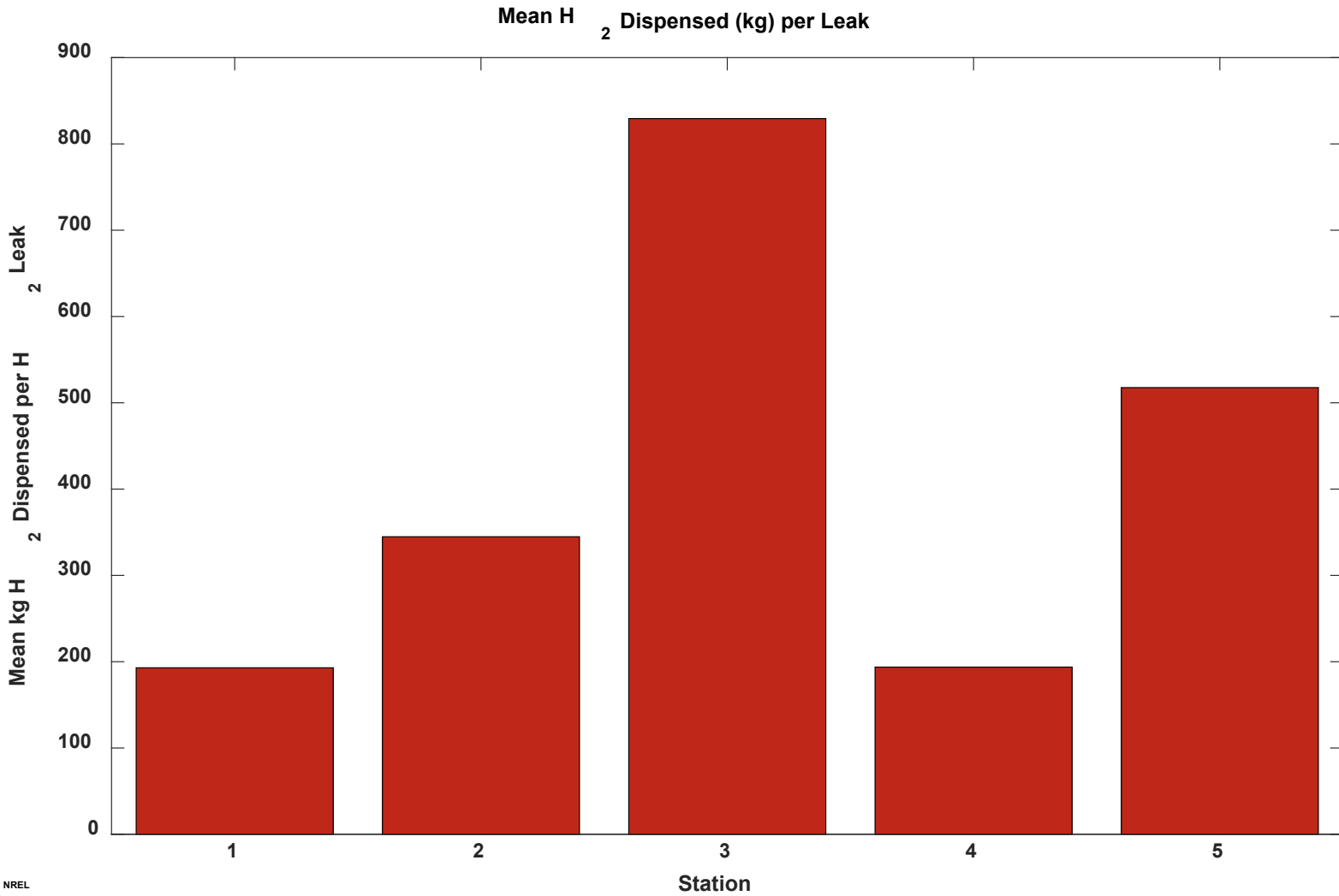
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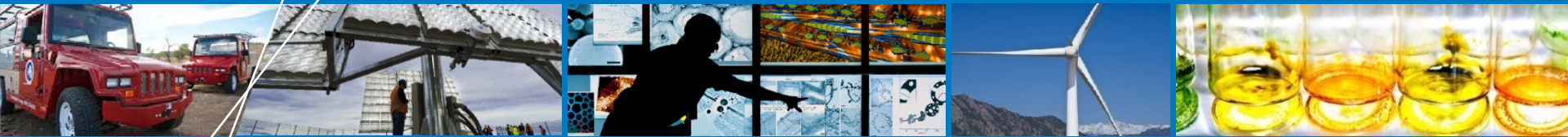
CDP-INFR-48

Mean Fills per Hydrogen Leak



Mean Hydrogen Dispensed per Hydrogen Leak

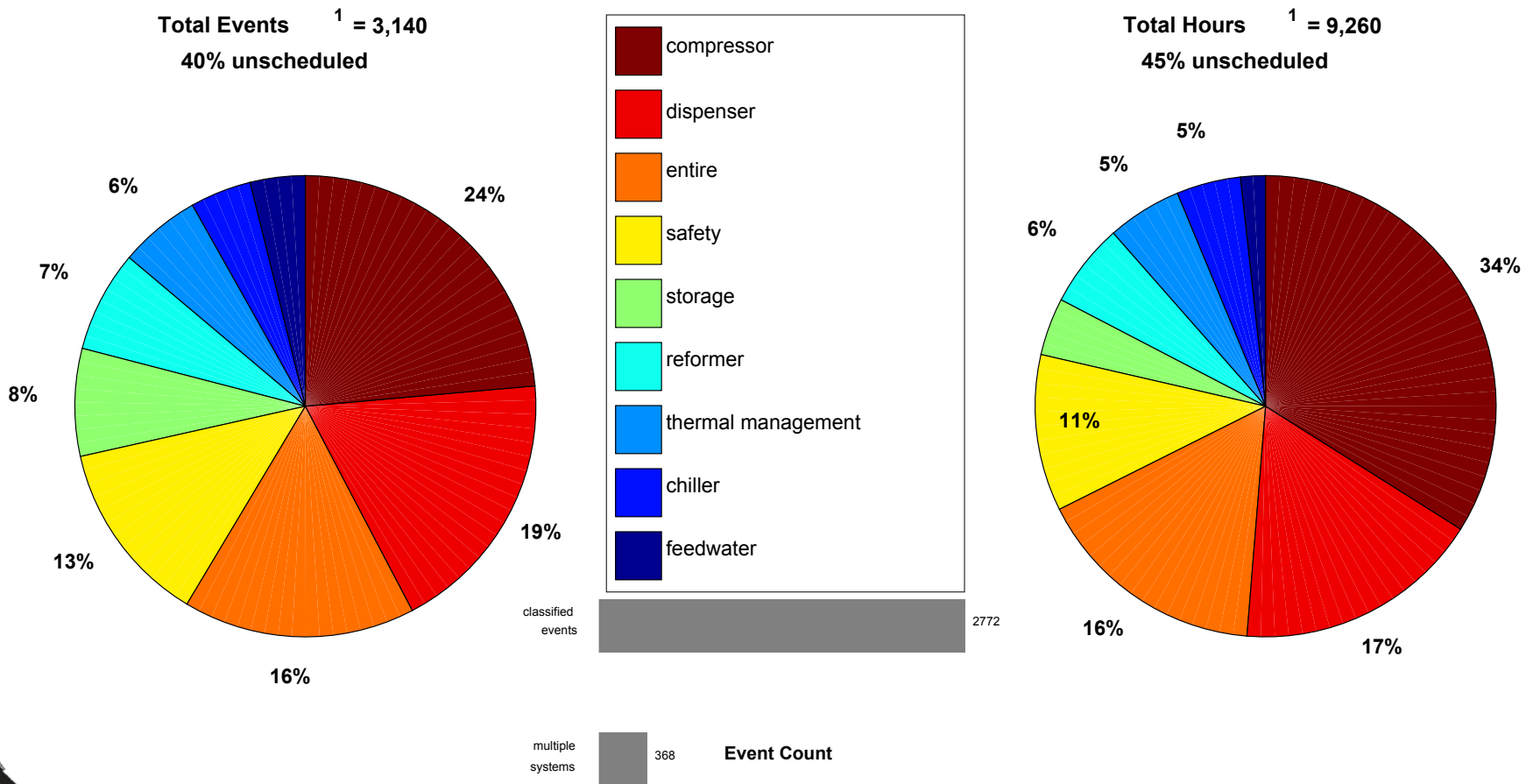




Maintenance and Reliability

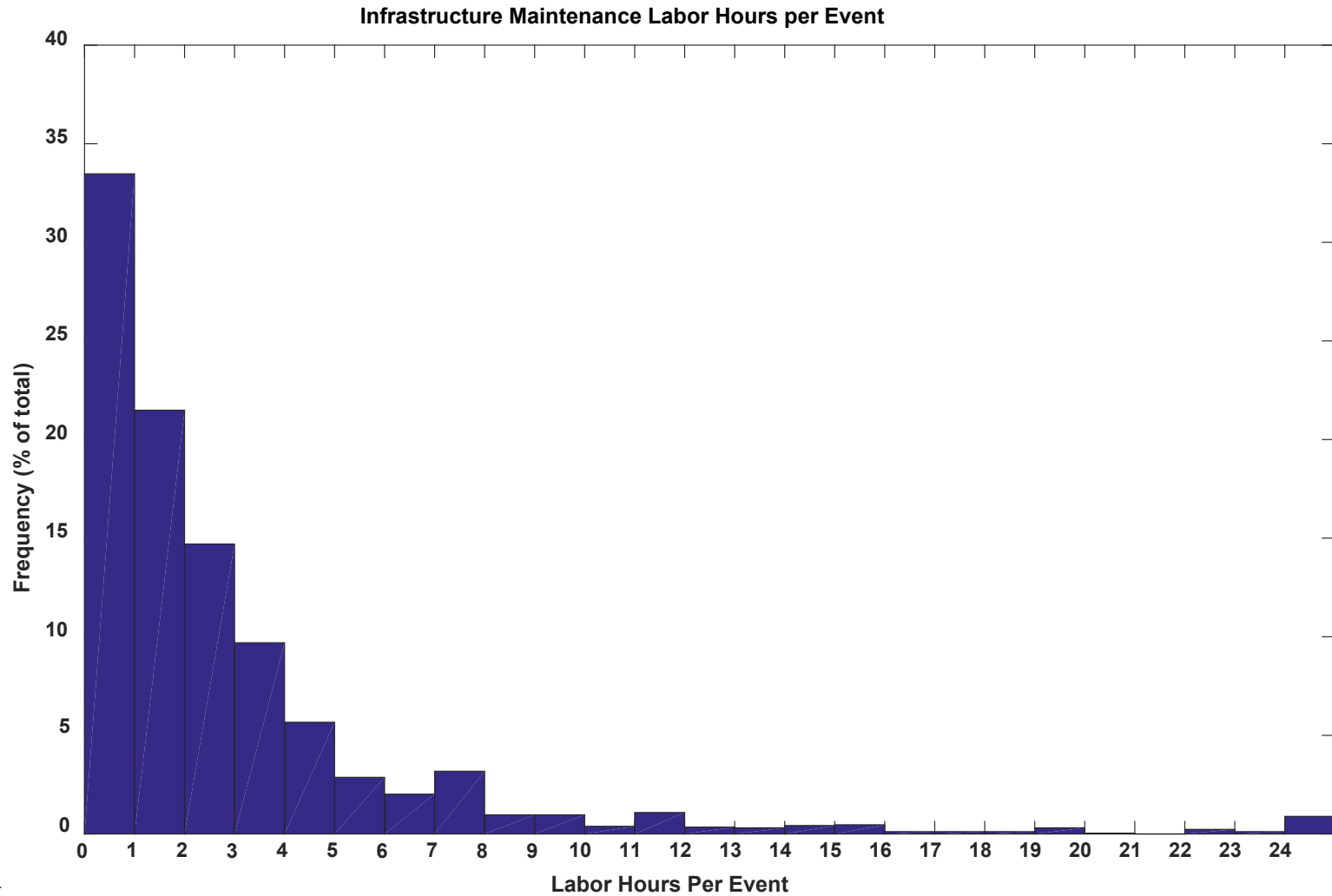
CDP-INFR-21

Maintenance by Equipment Type

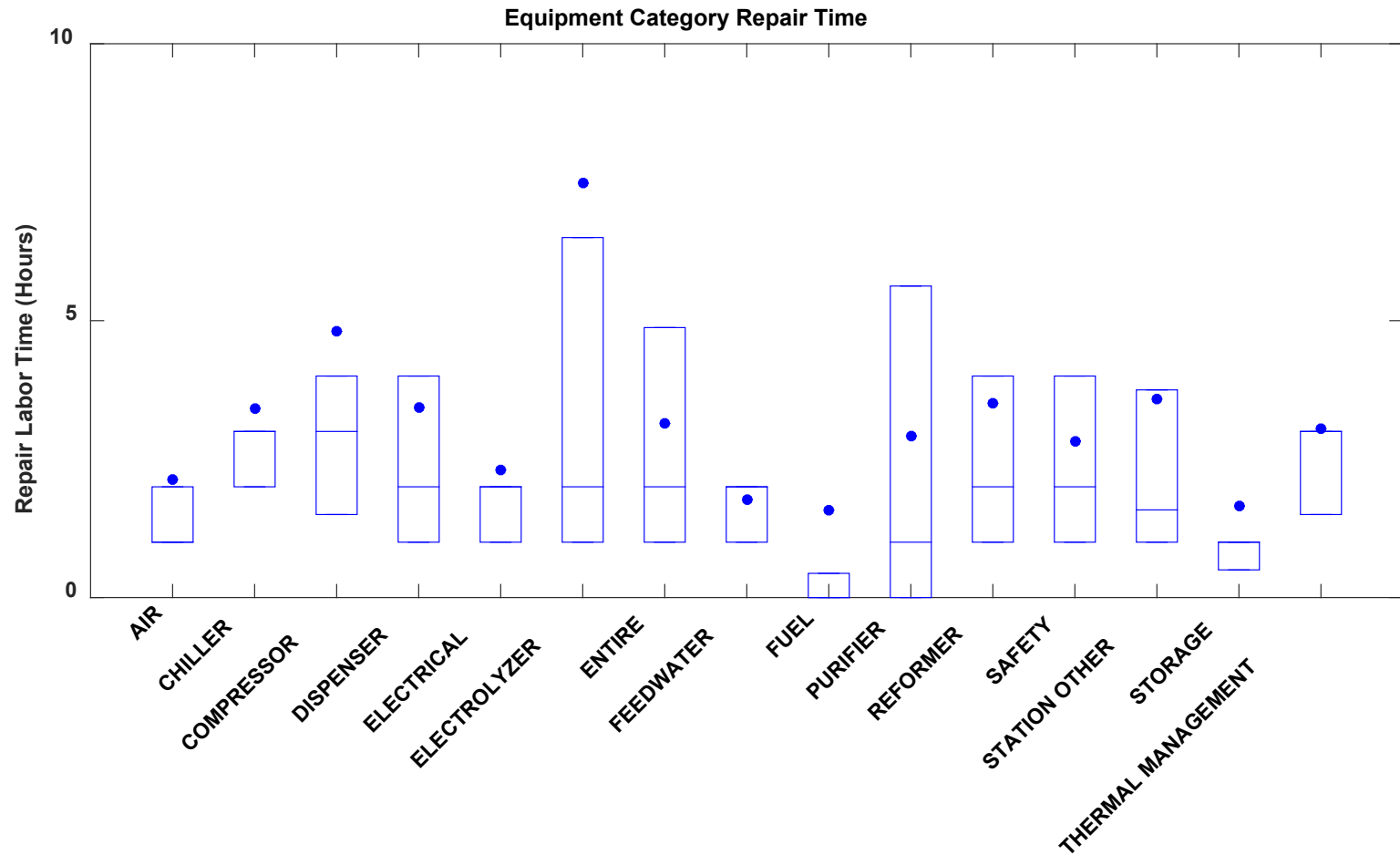


Created: Apr. 25, 16 9:18 PM

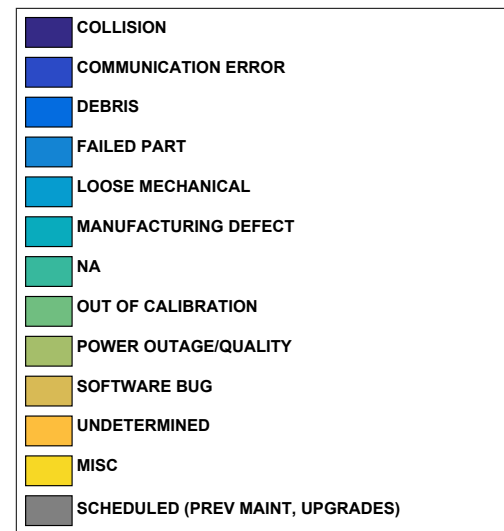
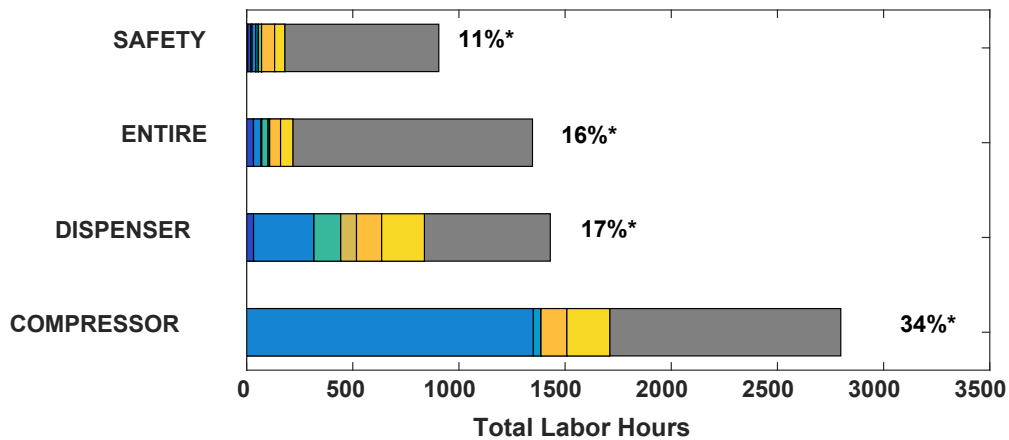
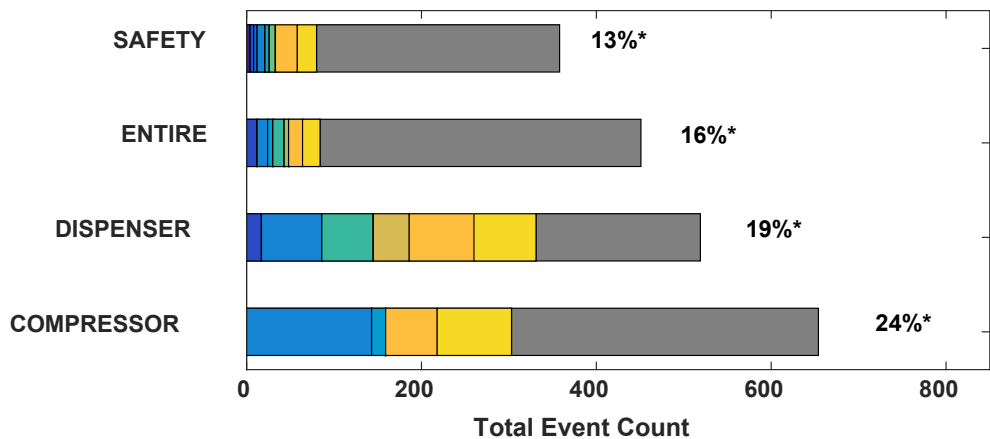
Maintenance Labor Hours per Event



Equipment Category Repair Time



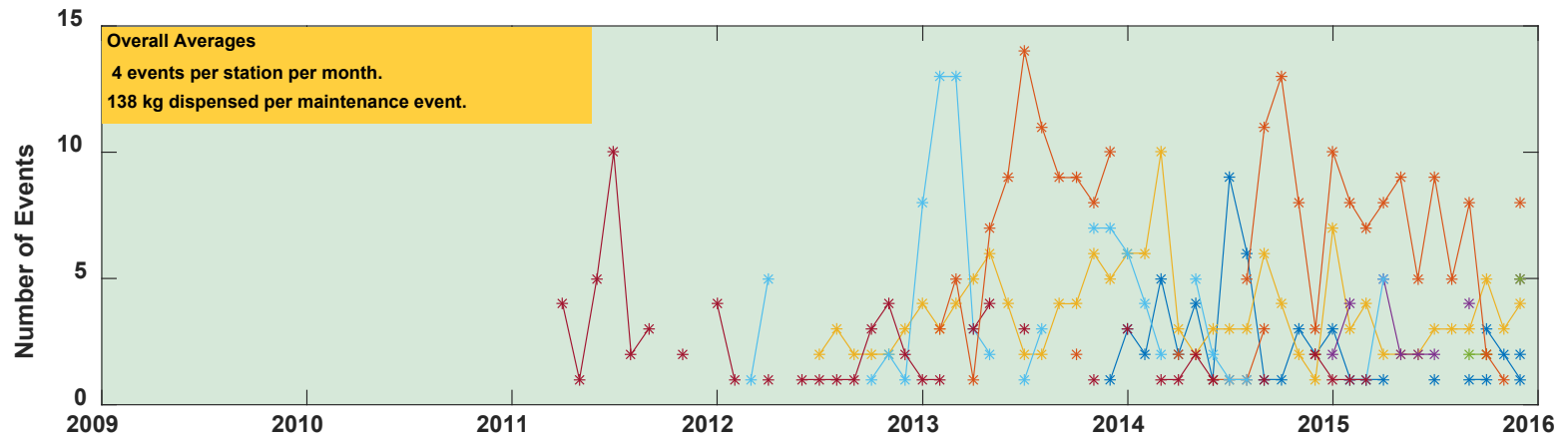
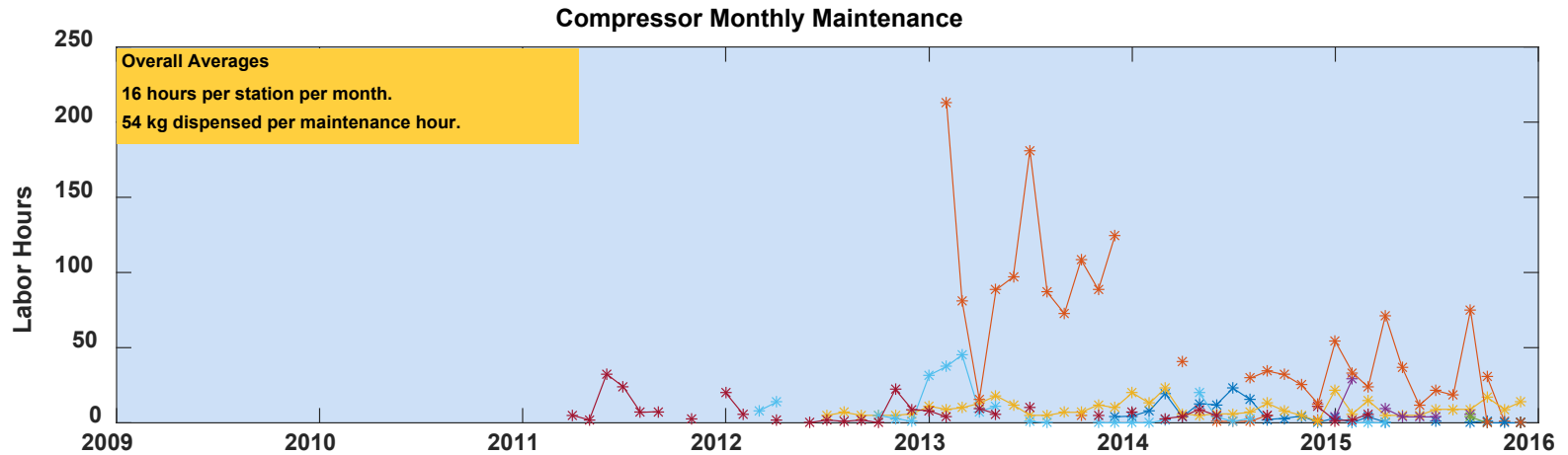
Failure Modes for Top Equipment Categories



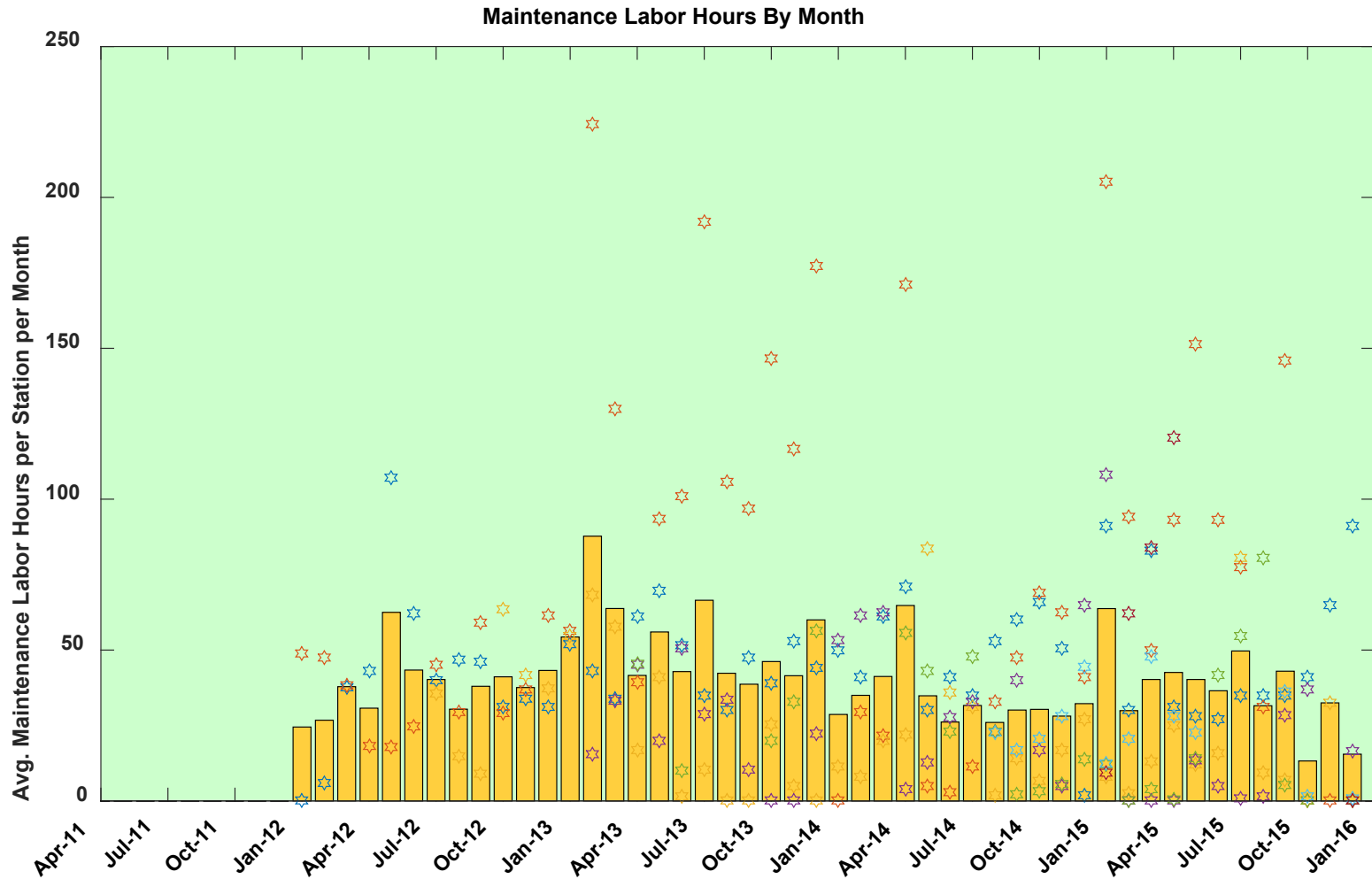
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CDP-INFR-26

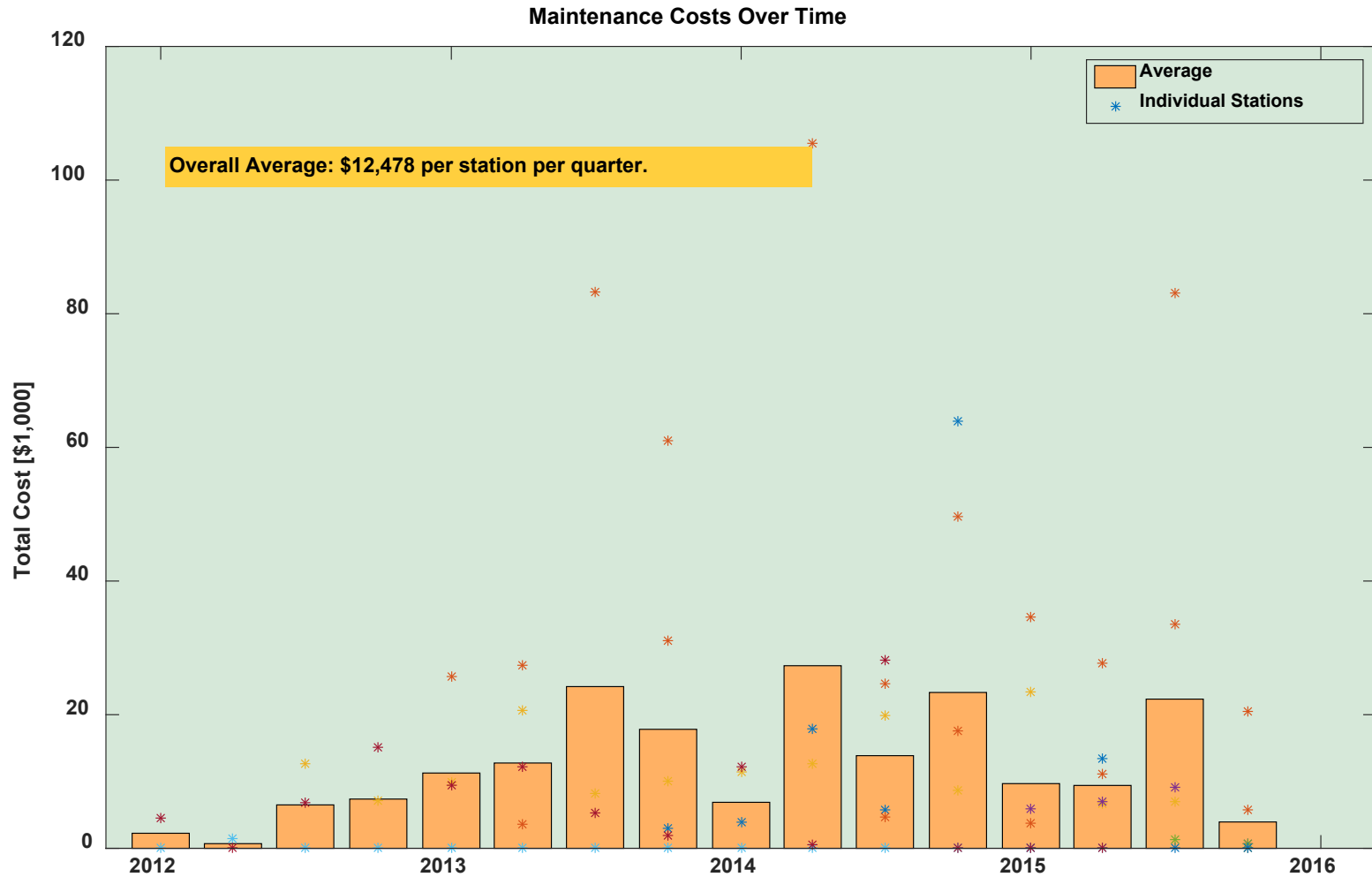
Compressor Monthly Maintenance



Maintenance Labor Hours by Month

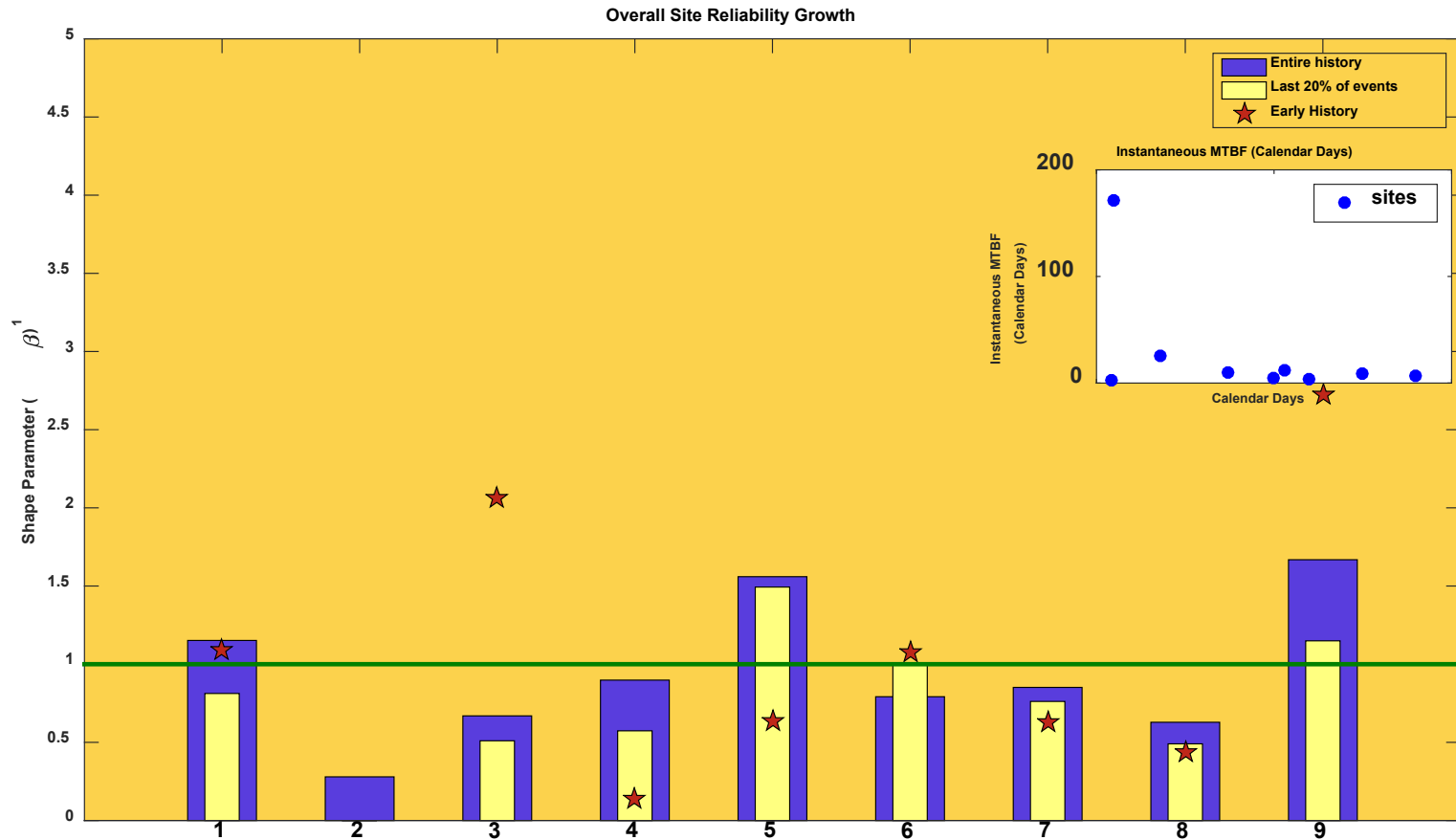


Maintenance Costs Over Time



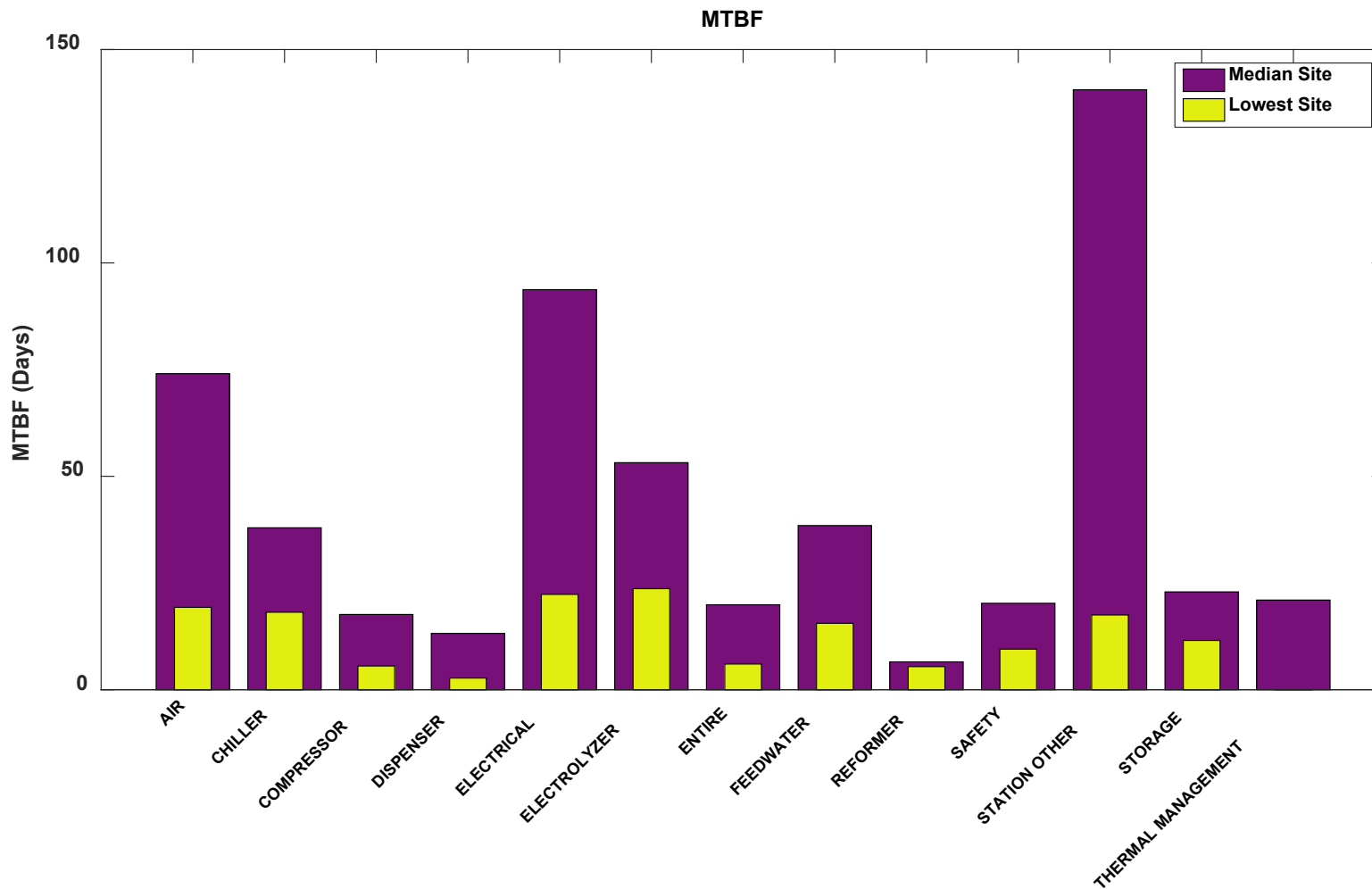
CDP-INFR-37

Reliability Growth

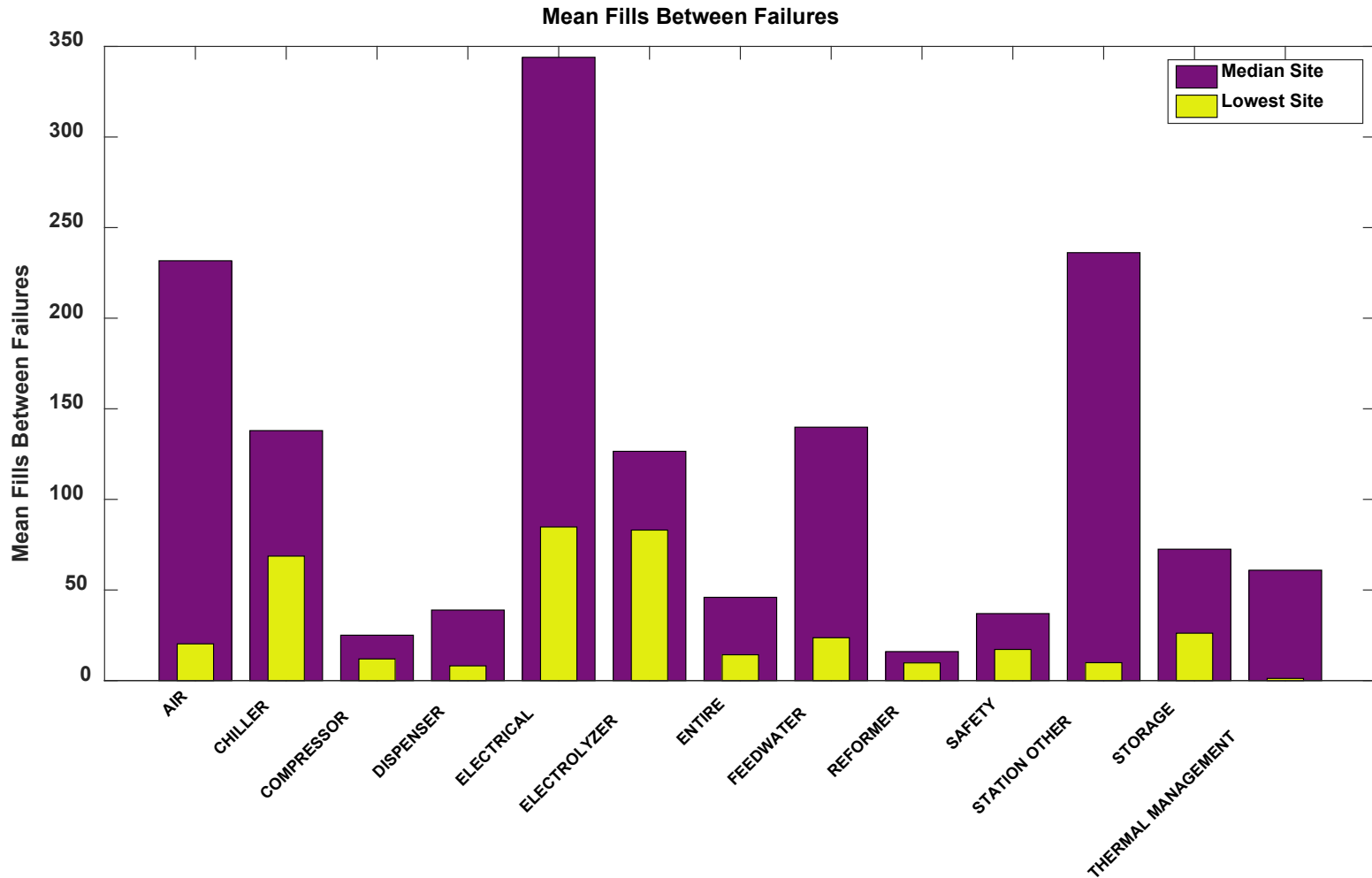


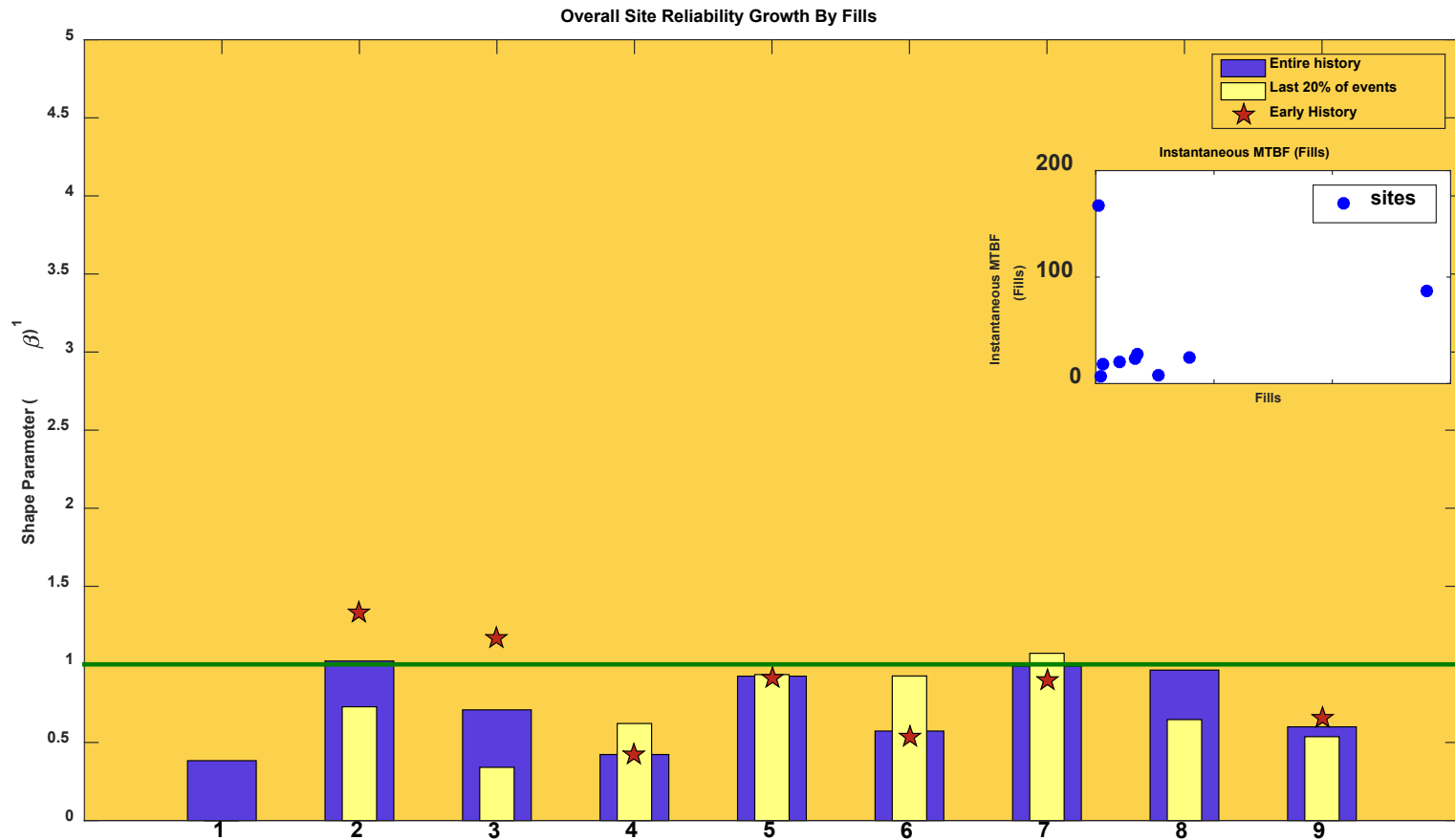
1. IEC 61164:2004(E), Reliability Growth - Statistical Test and Evaluation Methods, IEC, 2004.
2. % change in instantaneous mean Calendar Days between failures
3. Some sites are no longer active. Final results are shown for those sites.

Mean Time Between Failures (MTBF)



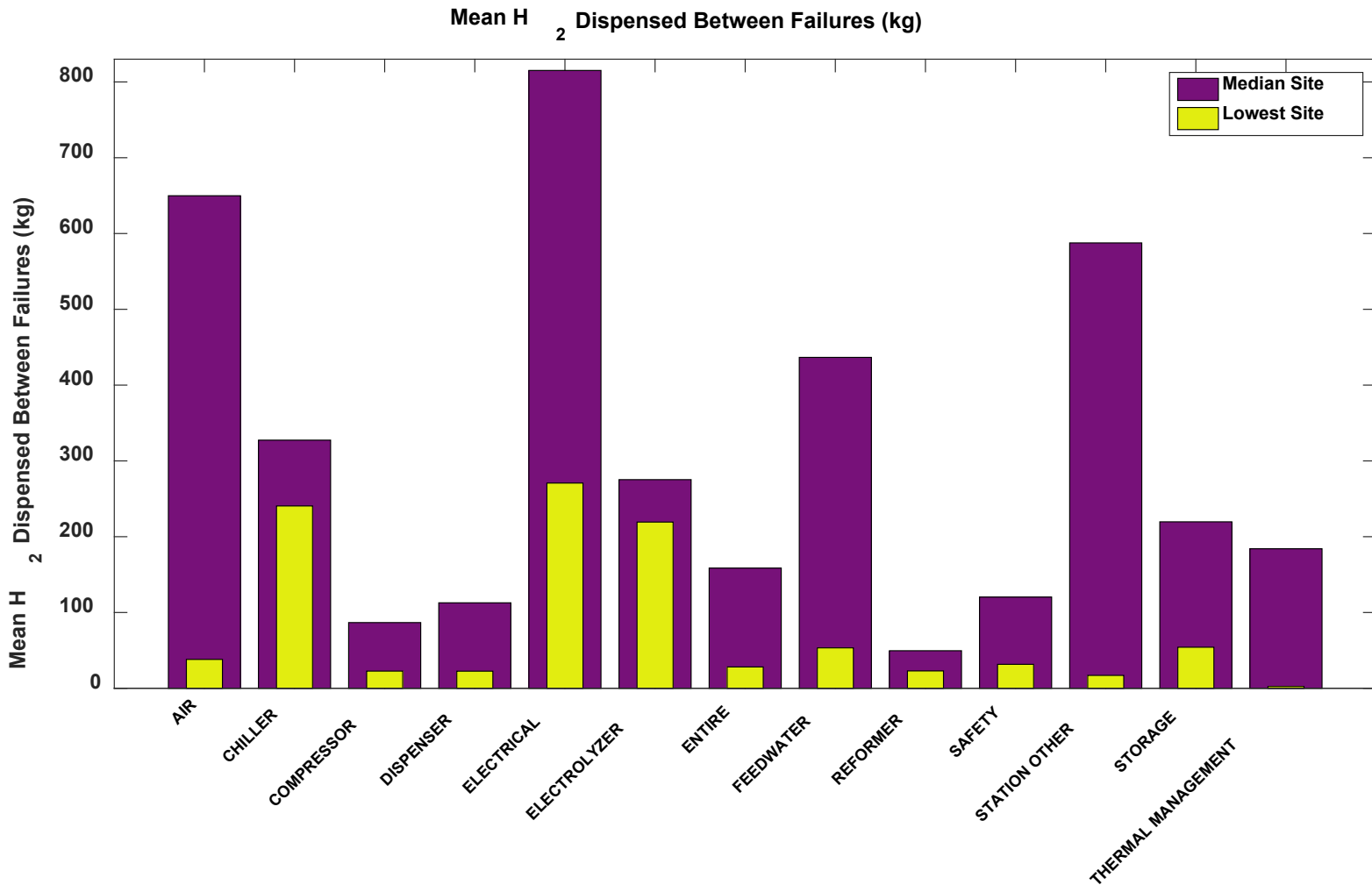
Mean Fills Between Failures



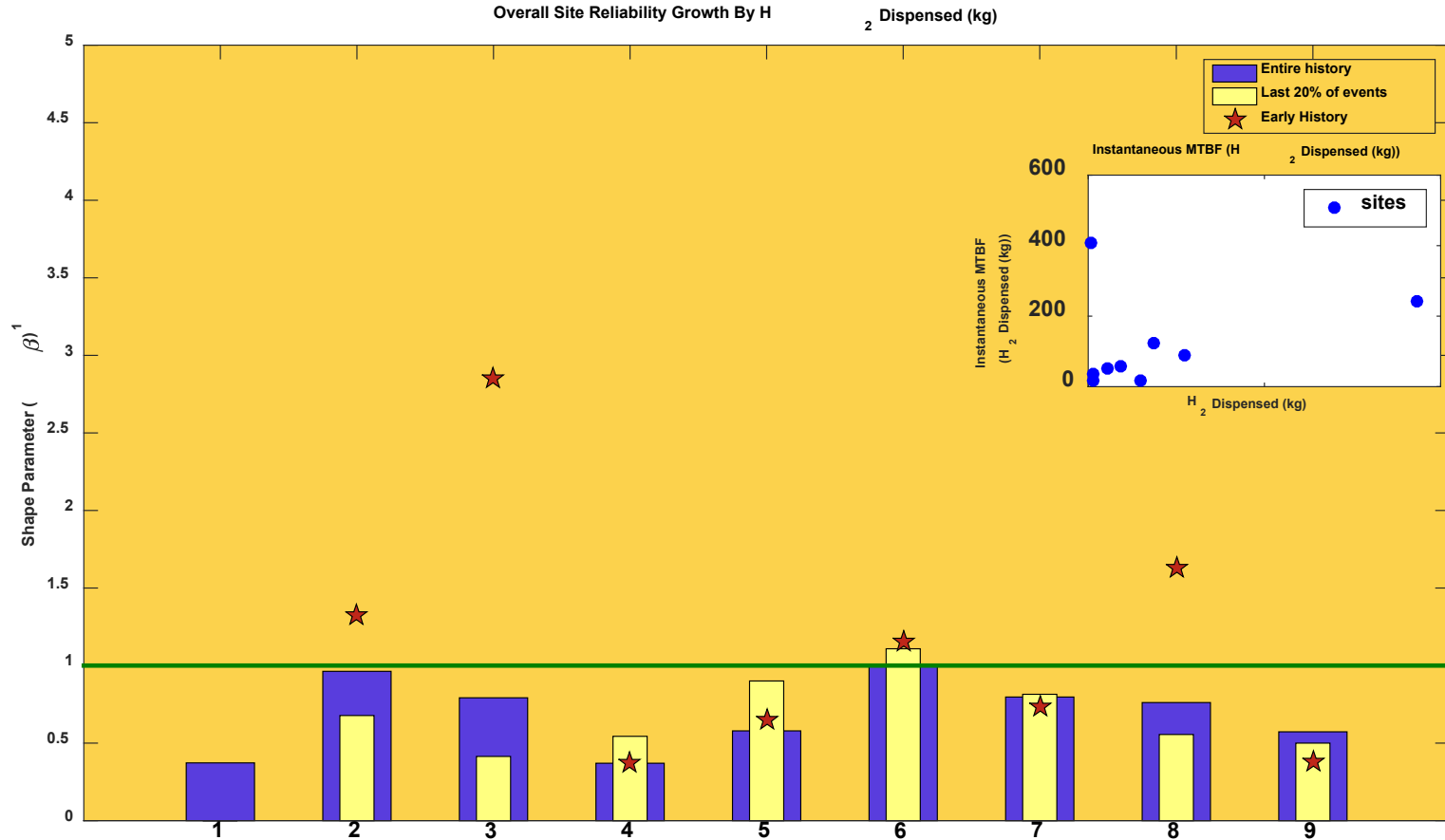


1. IEC 61164:2004(E), Reliability Growth - Statistical Test and Evaluation Methods, IEC. 2004.
- 2.% change in instantaneous mean Fills between failures
3. Some sites are no longer active. Final results are shown for those sites.

Mean Amount Dispensed Between Failures



Reliability Growth by Amount Dispensed

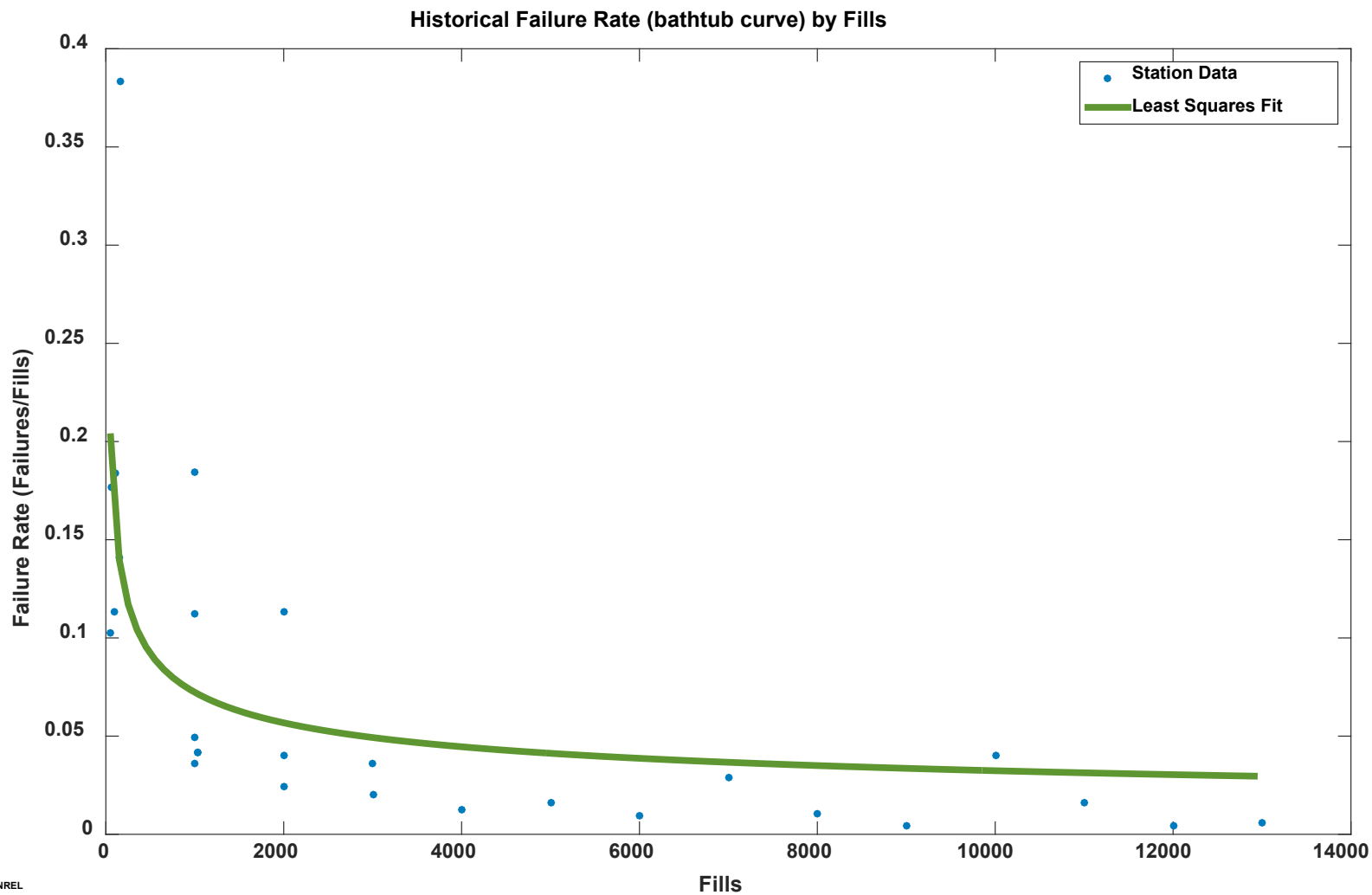


1. IEC 61164:2004(E), Reliability Growth - Statistical Test and Evaluation Methods, IEC, 2004.

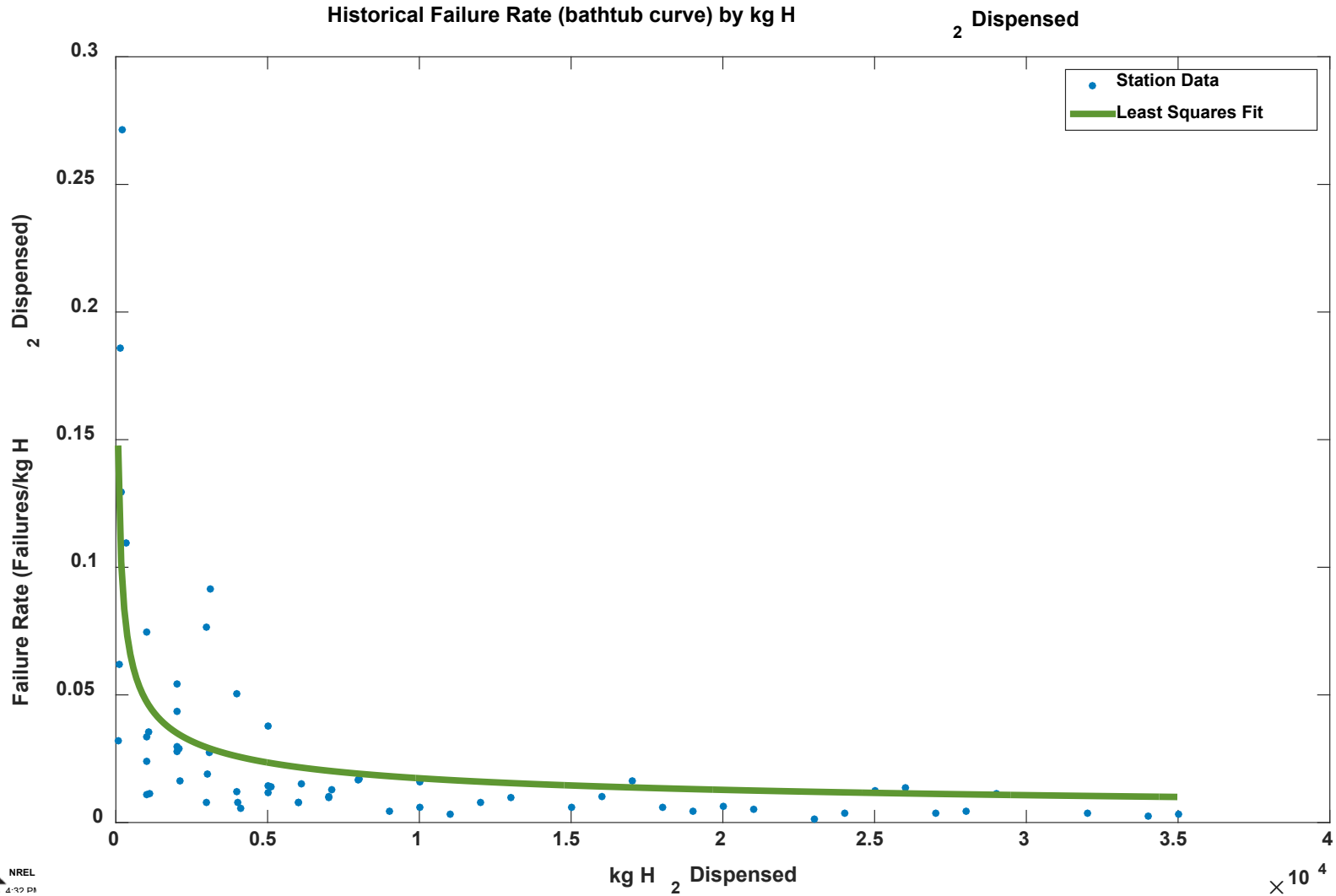
2.% change in instantaneous mean H₂ Dispensed (kg) between failures

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

Historical Failure Rate by Fills

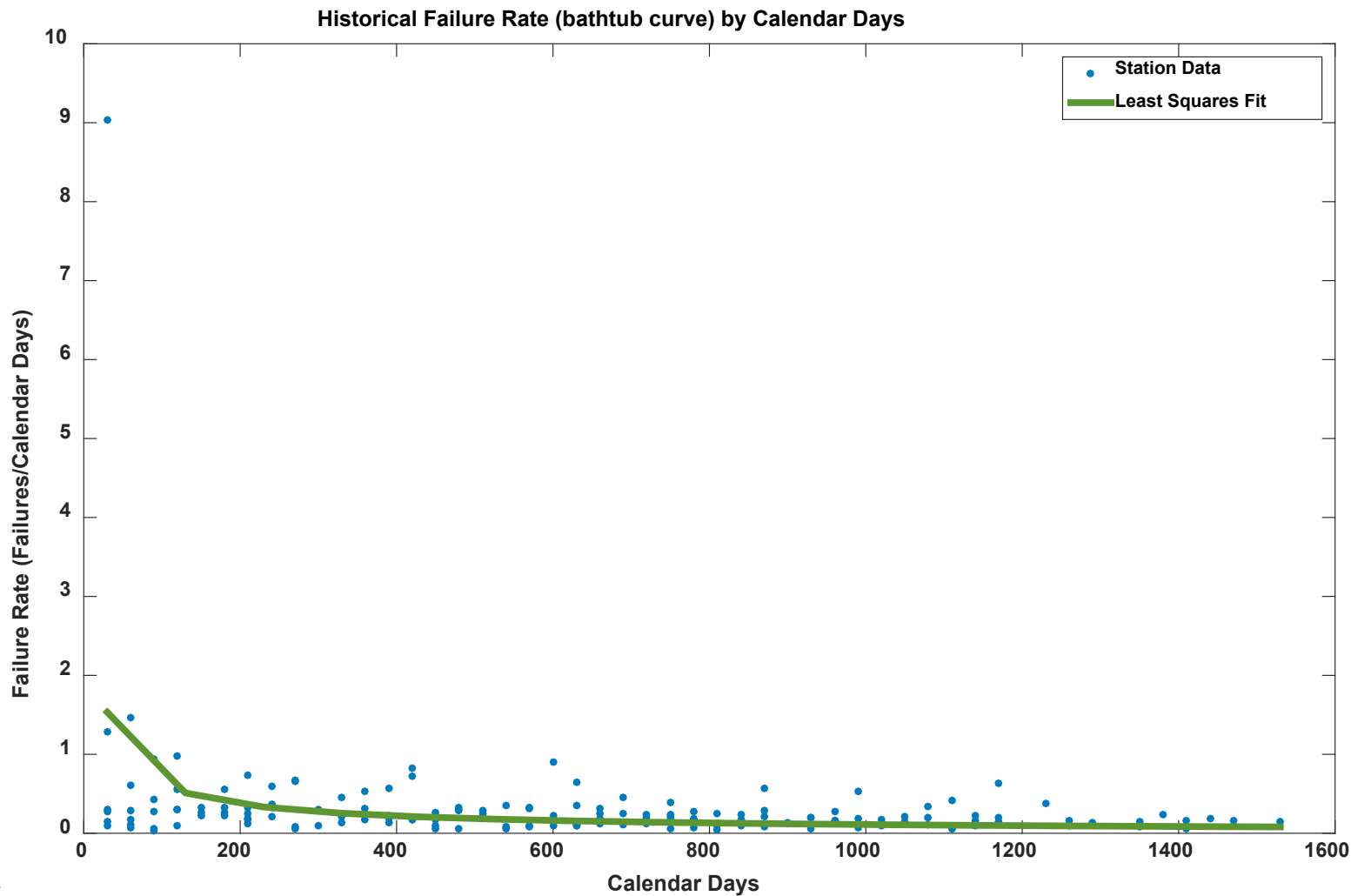


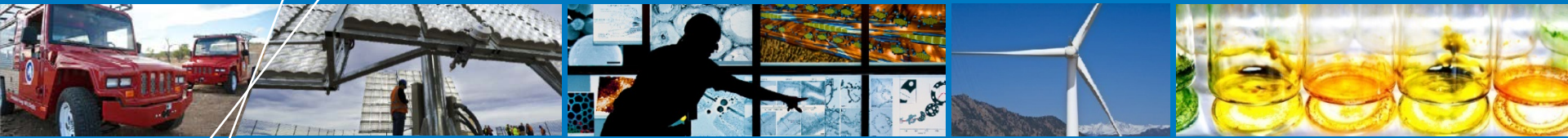
Historical Failure Rate by Amount Dispensed



CDP-INFR-61

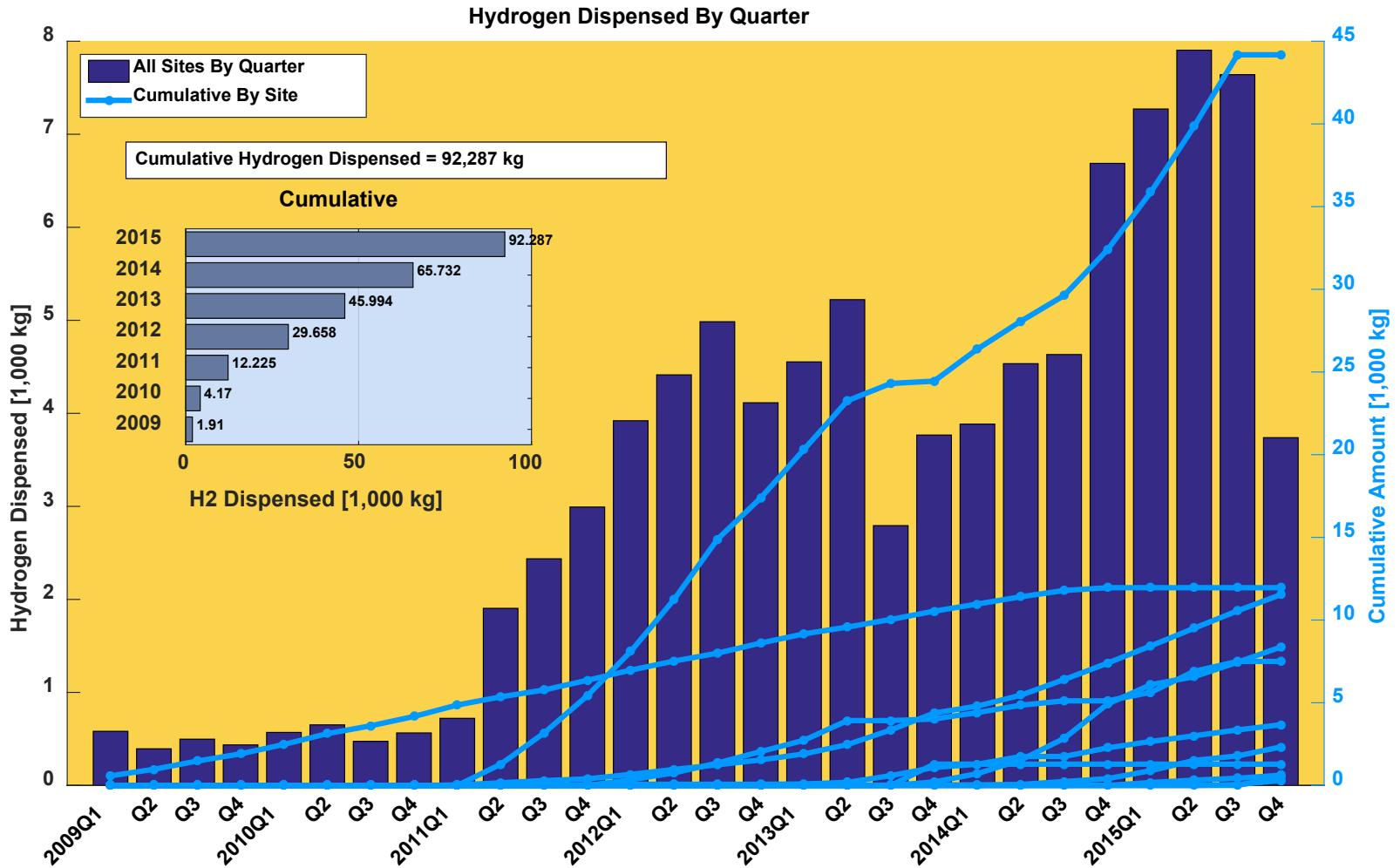
Historical Failure Rate by Calendar Days



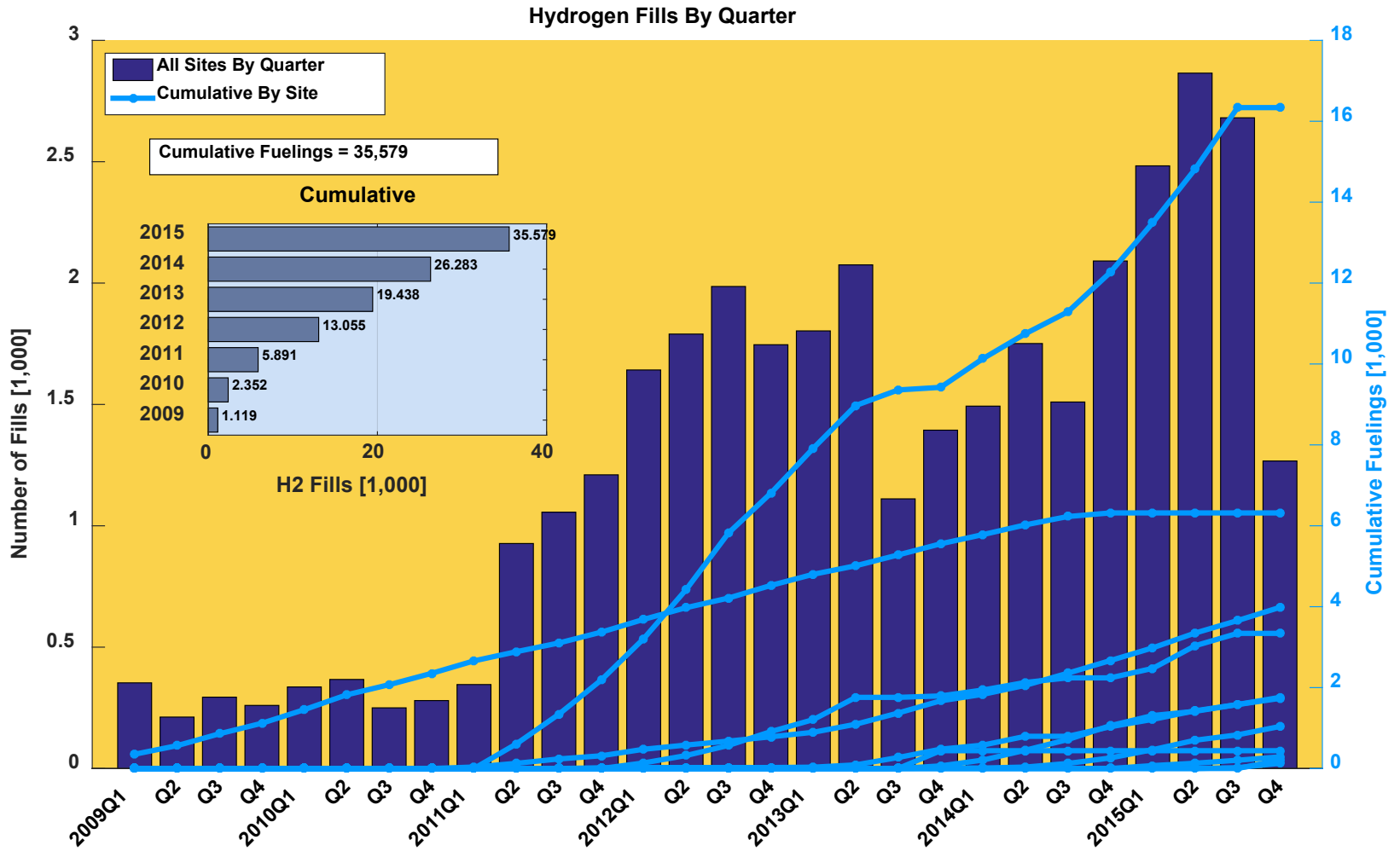


Performance

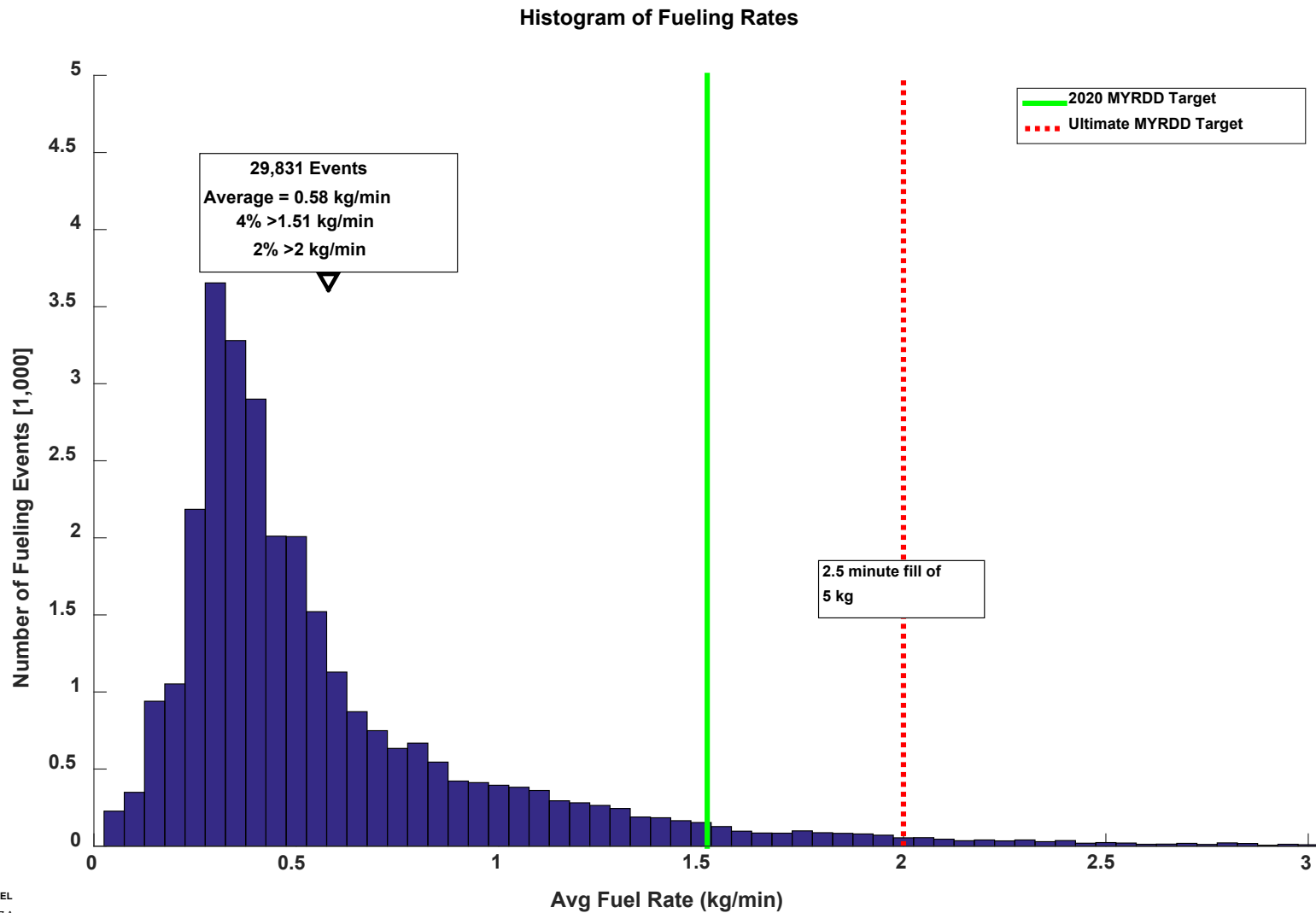
Hydrogen Dispensed by Quarter



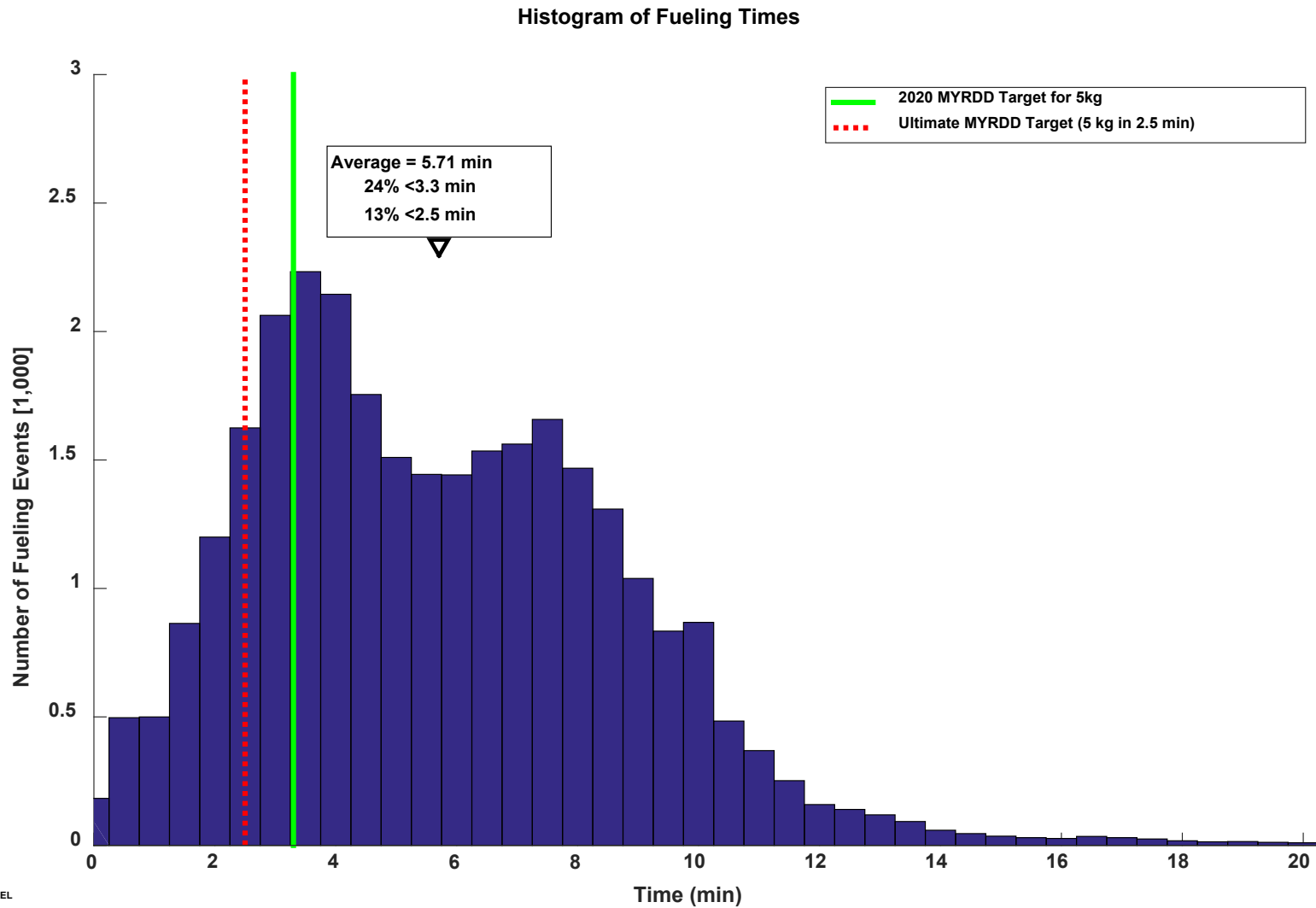
Hydrogen Fills by Quarter



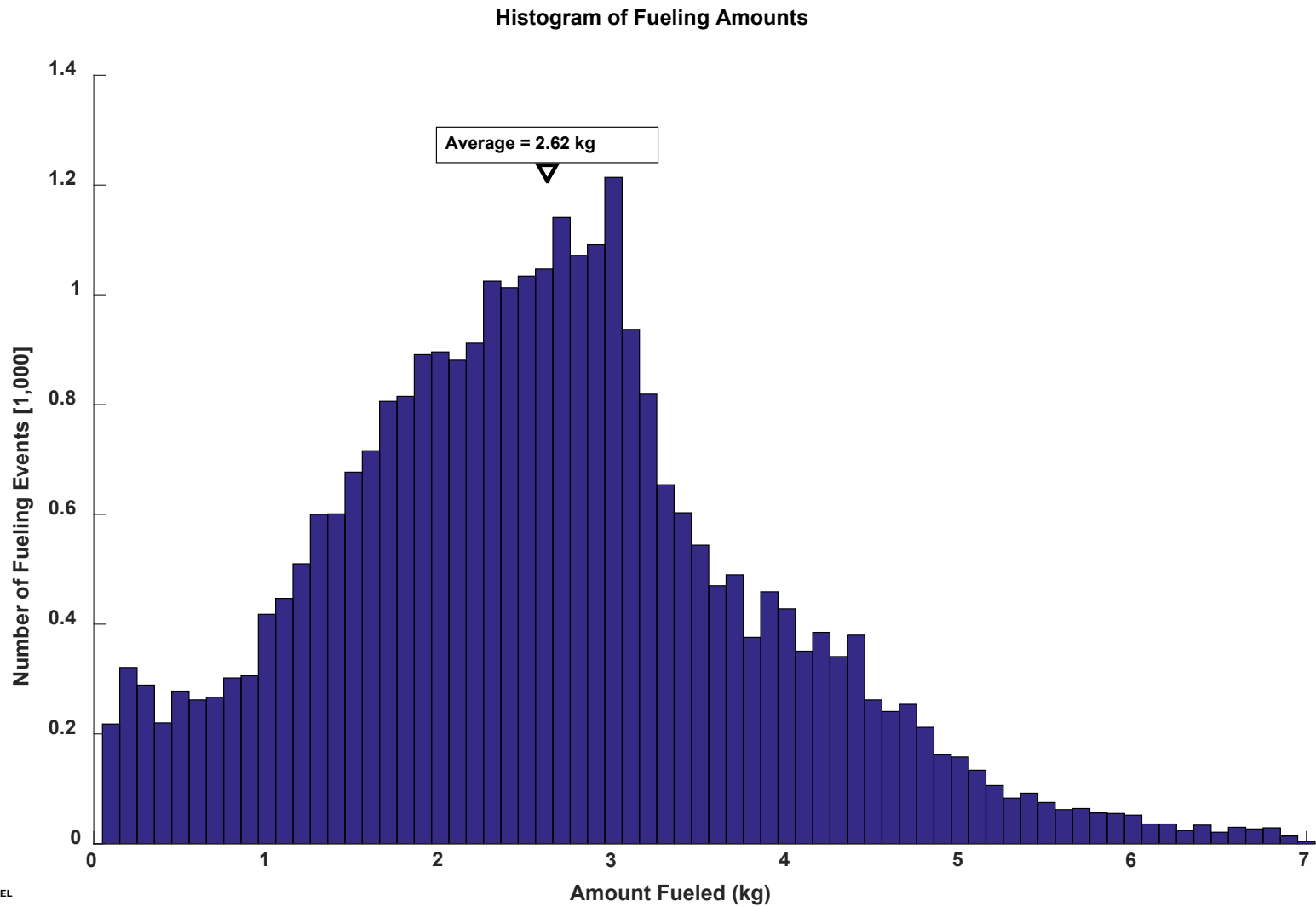
Histogram of Fueling Rates



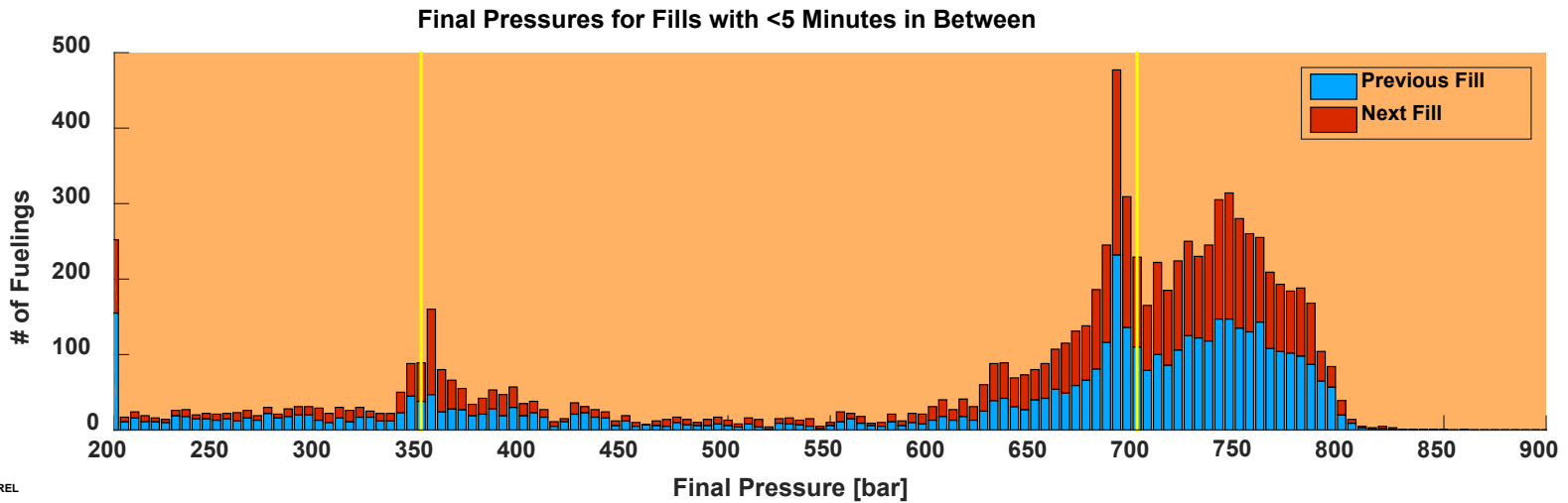
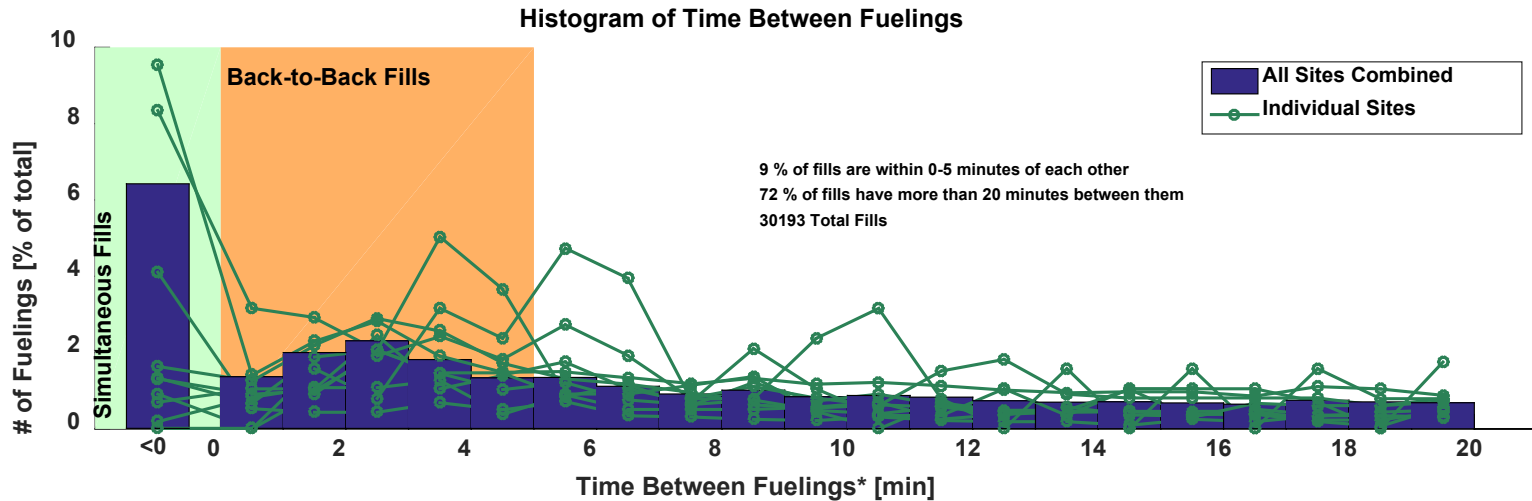
Histogram of Fueling Times



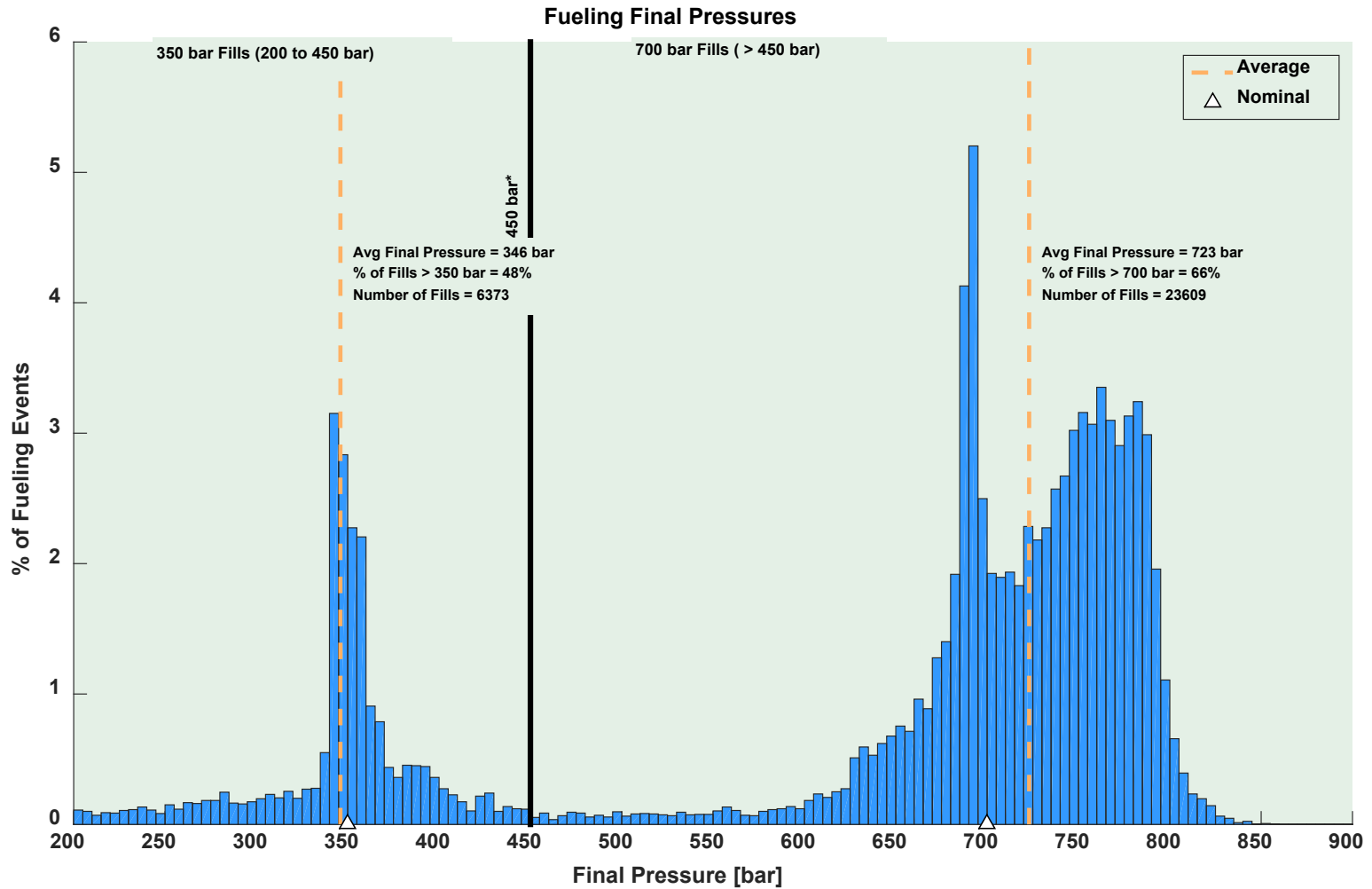
Histogram of Fueling Amounts



Time Between Fueling

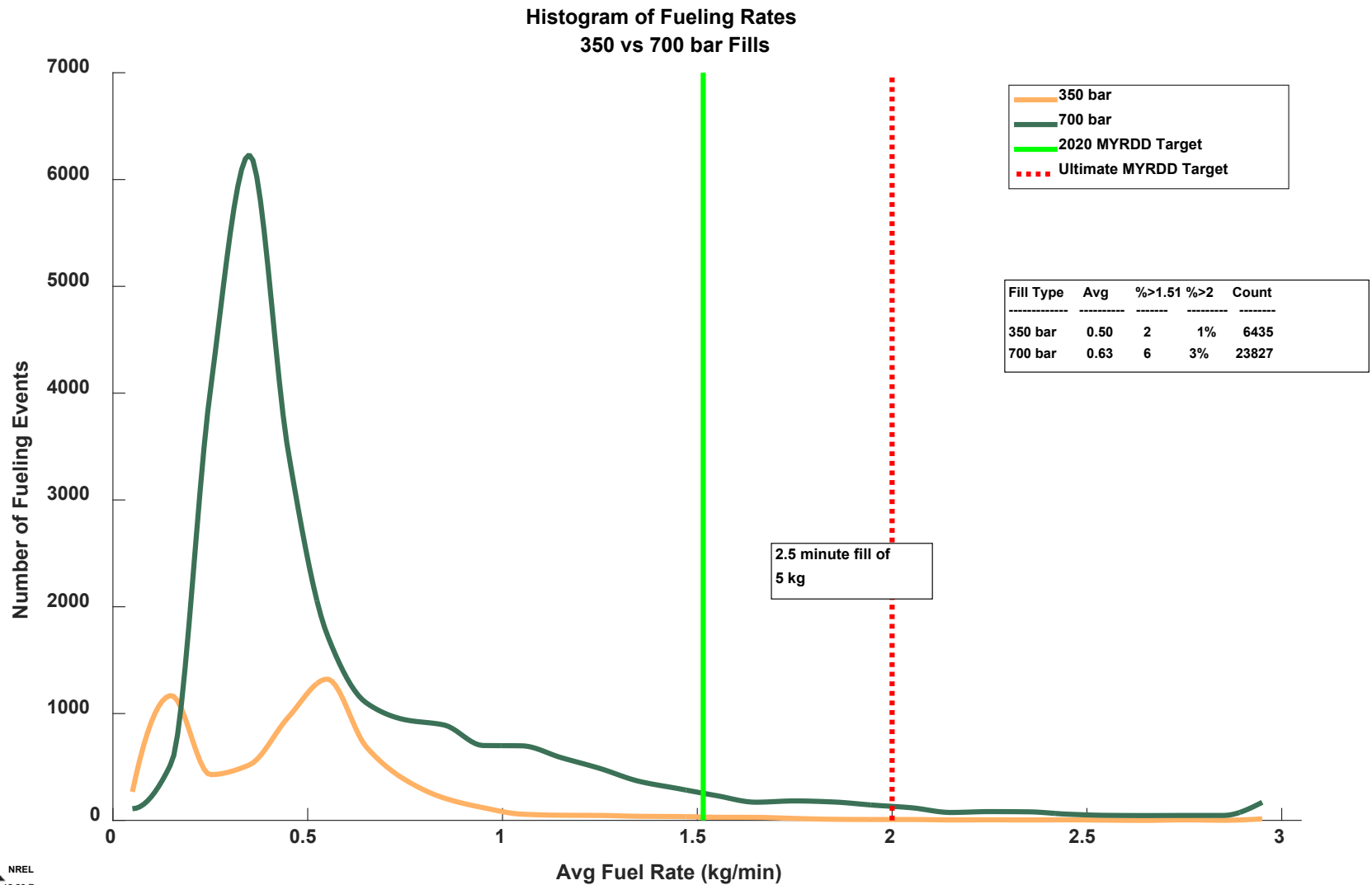


Fueling Final Pressures



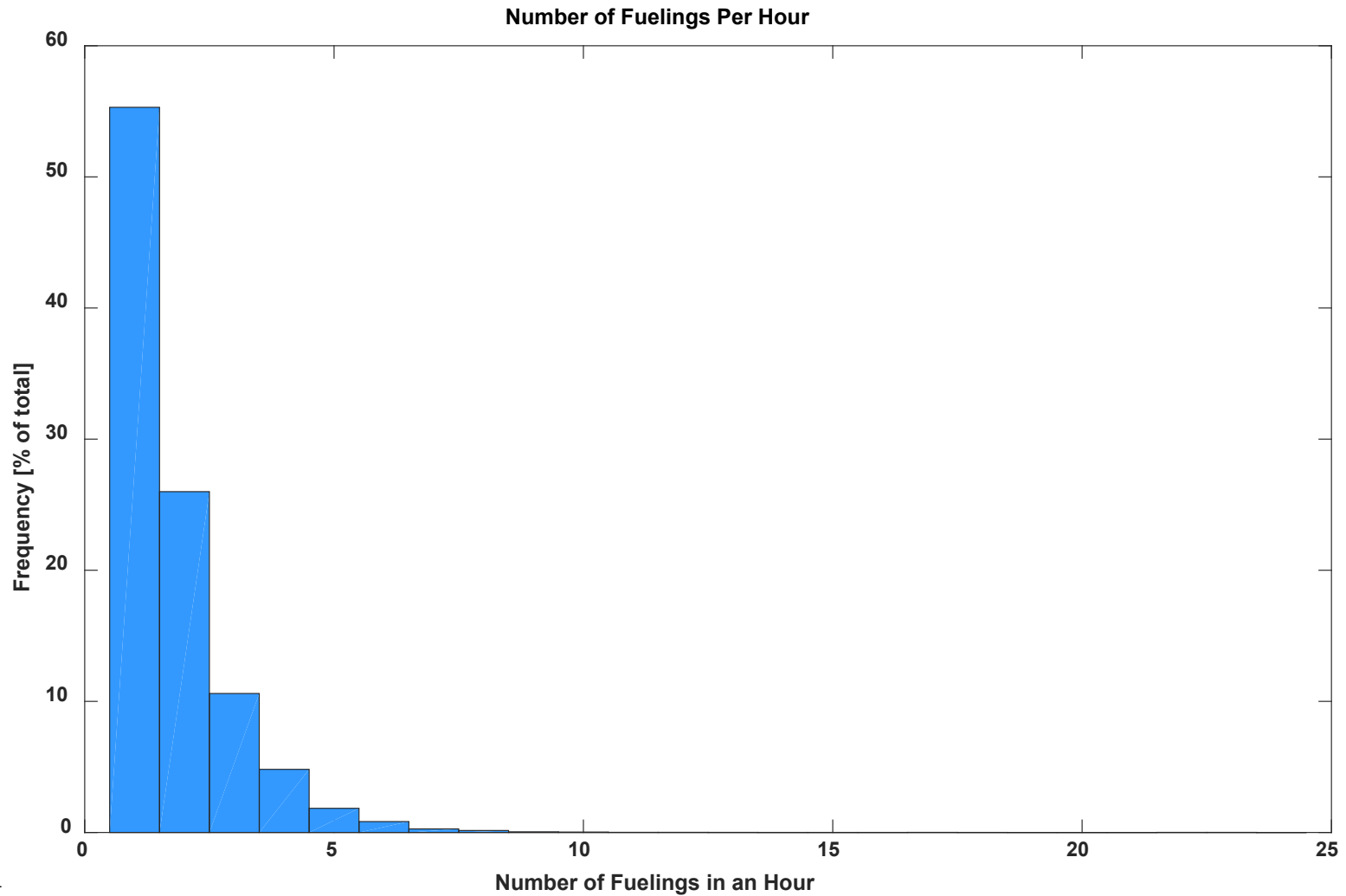
Created: Apr. 15, 16 12:20 P

Fueling Rates 350 vs. 700 bar

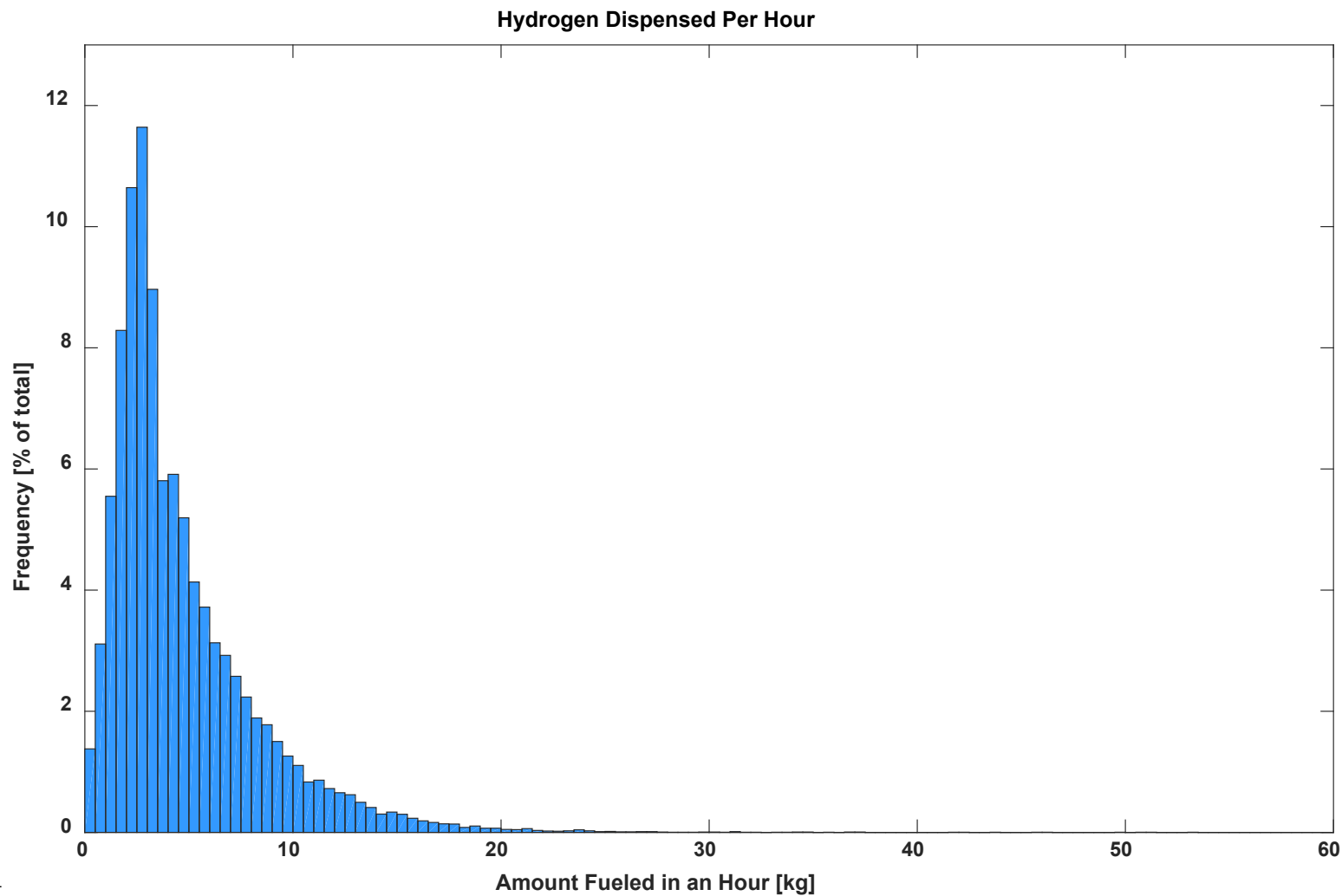


CDP-INFR-13

Number of Fueling Events per Hour

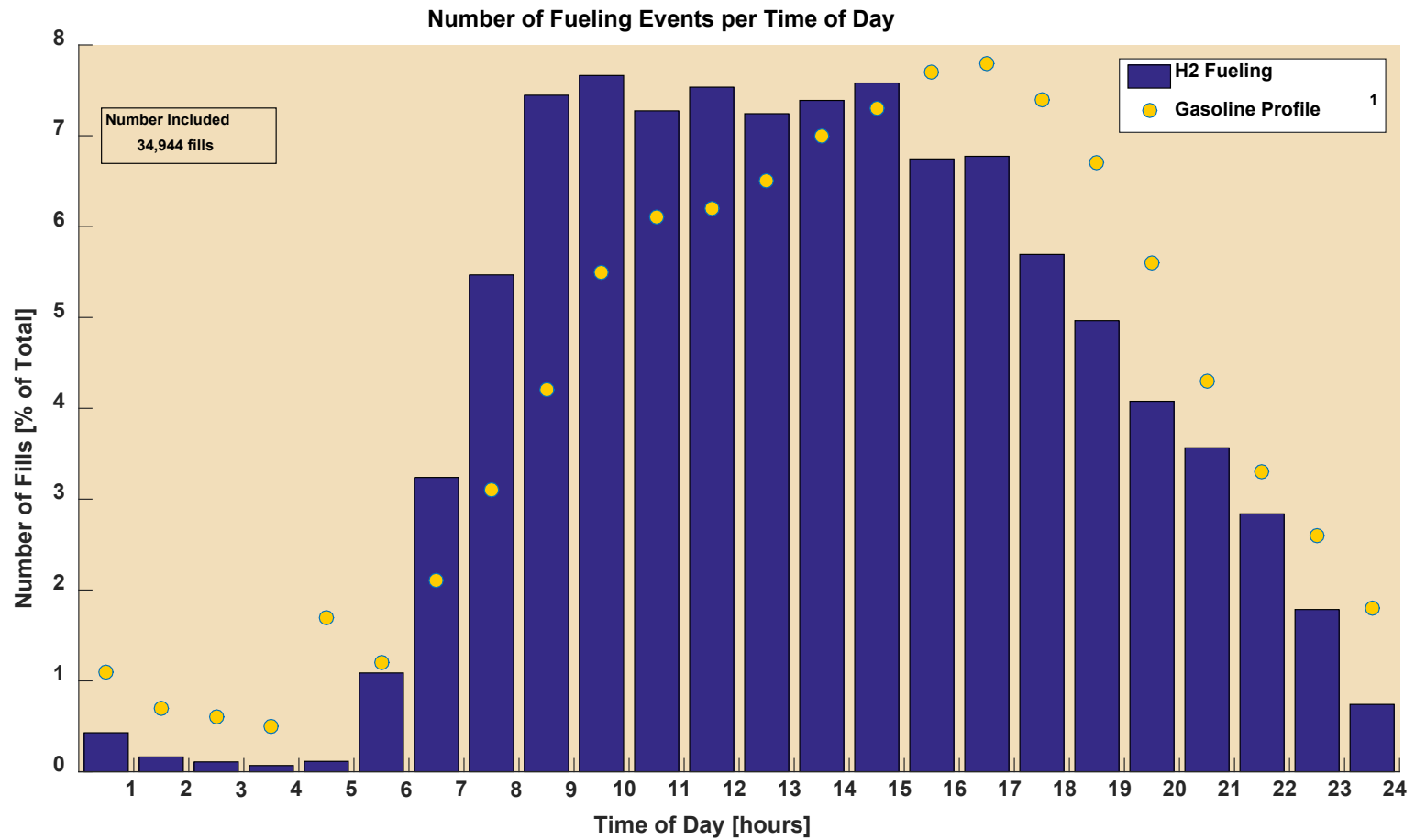


Hydrogen Dispensed per Hour

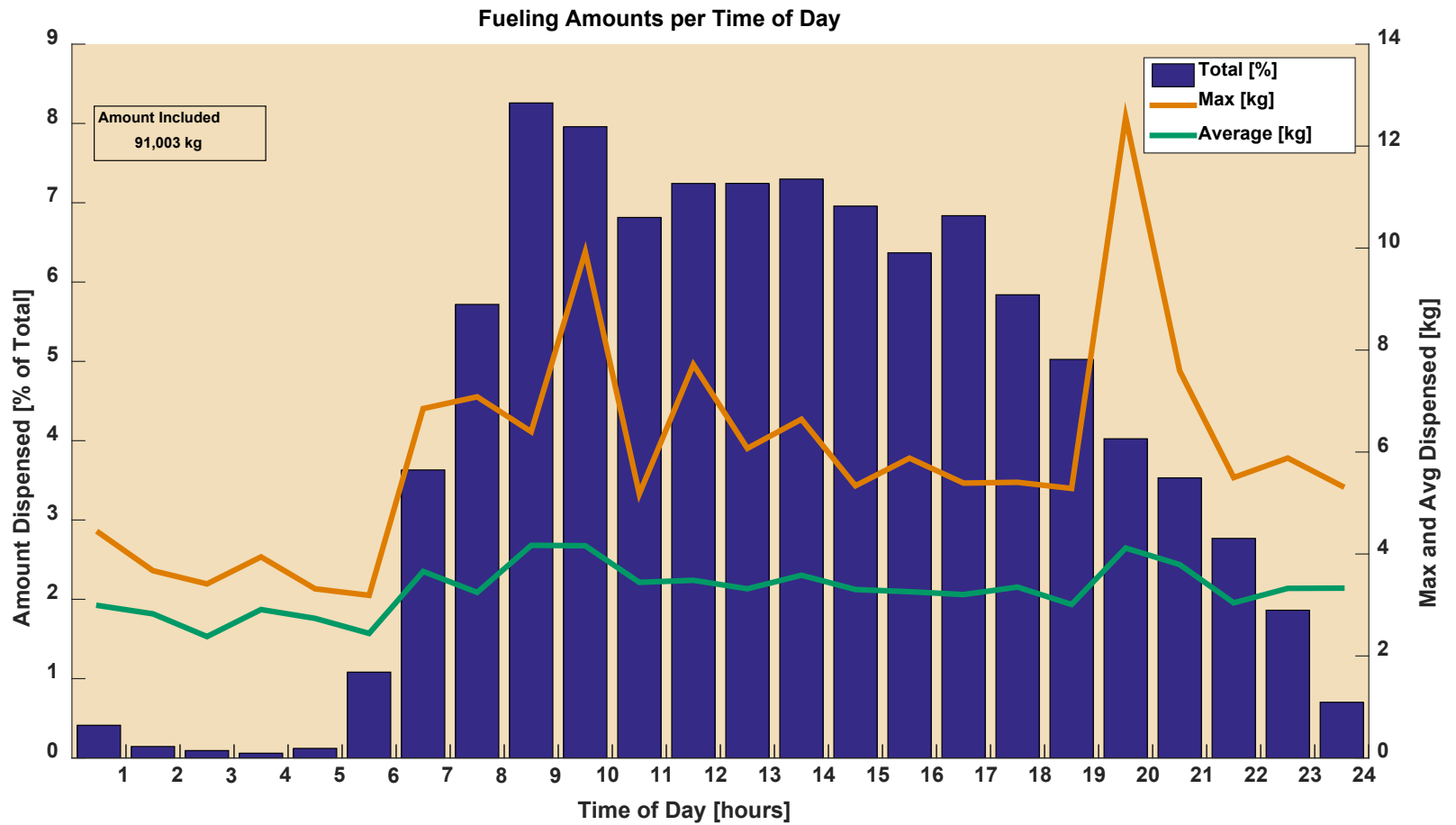


Created: Apr-15-18 12:20 P

Number of Fills by Time of Day

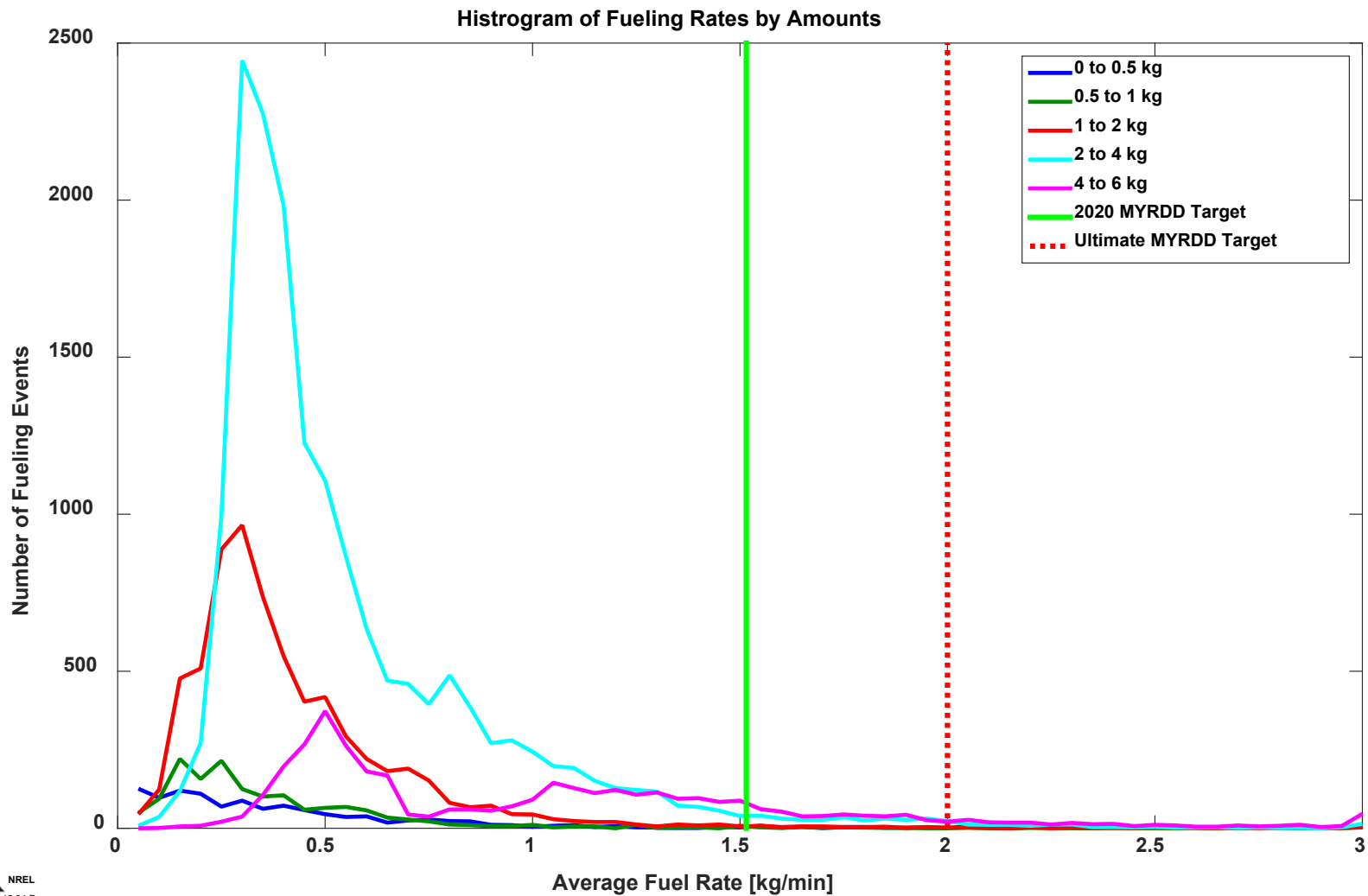


Fueling Amounts per Time of Day



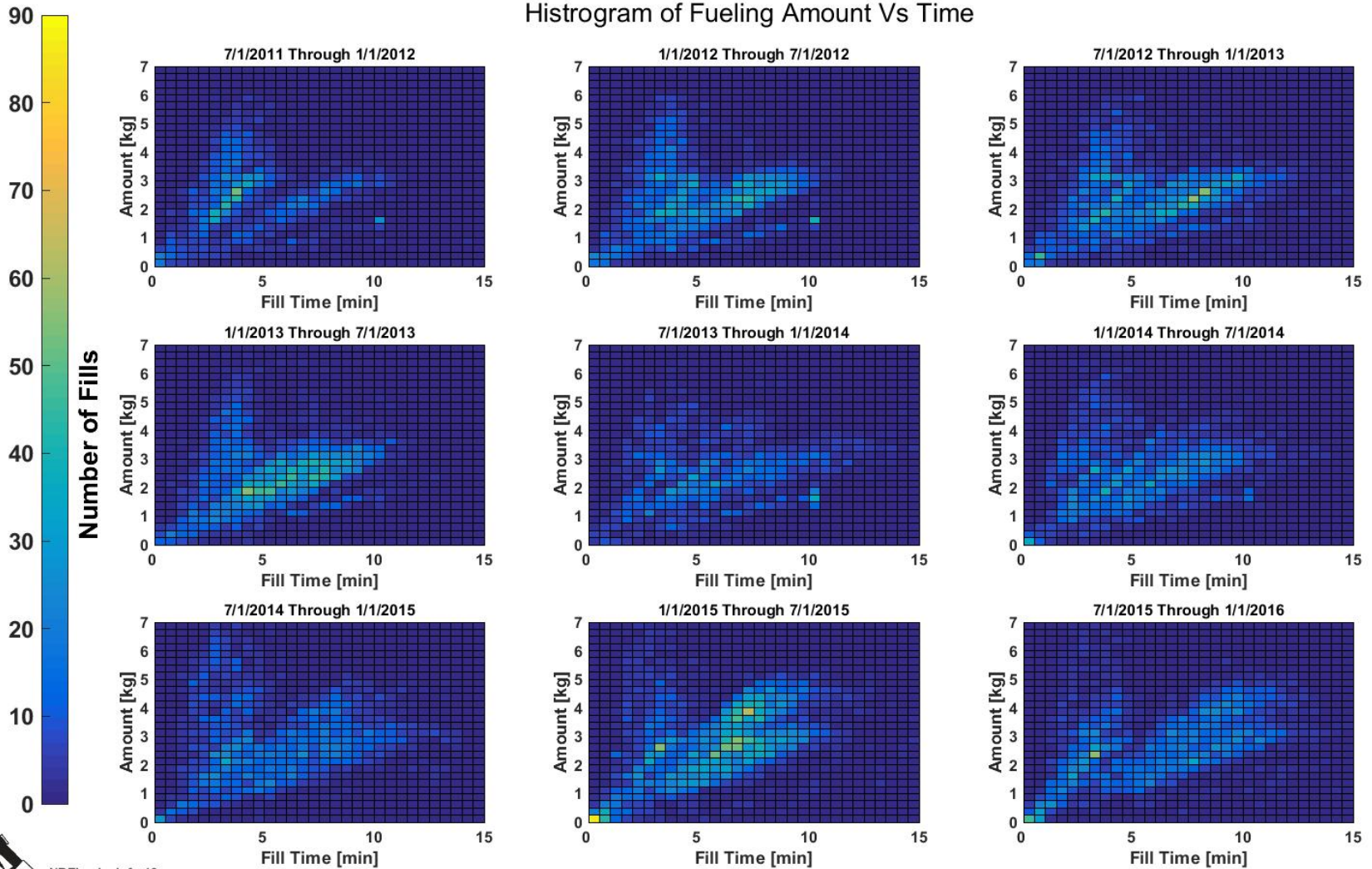
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Fueling Rates by Amount Filled



CDP-INFR-18

Fueling Amount vs. Time to Fill



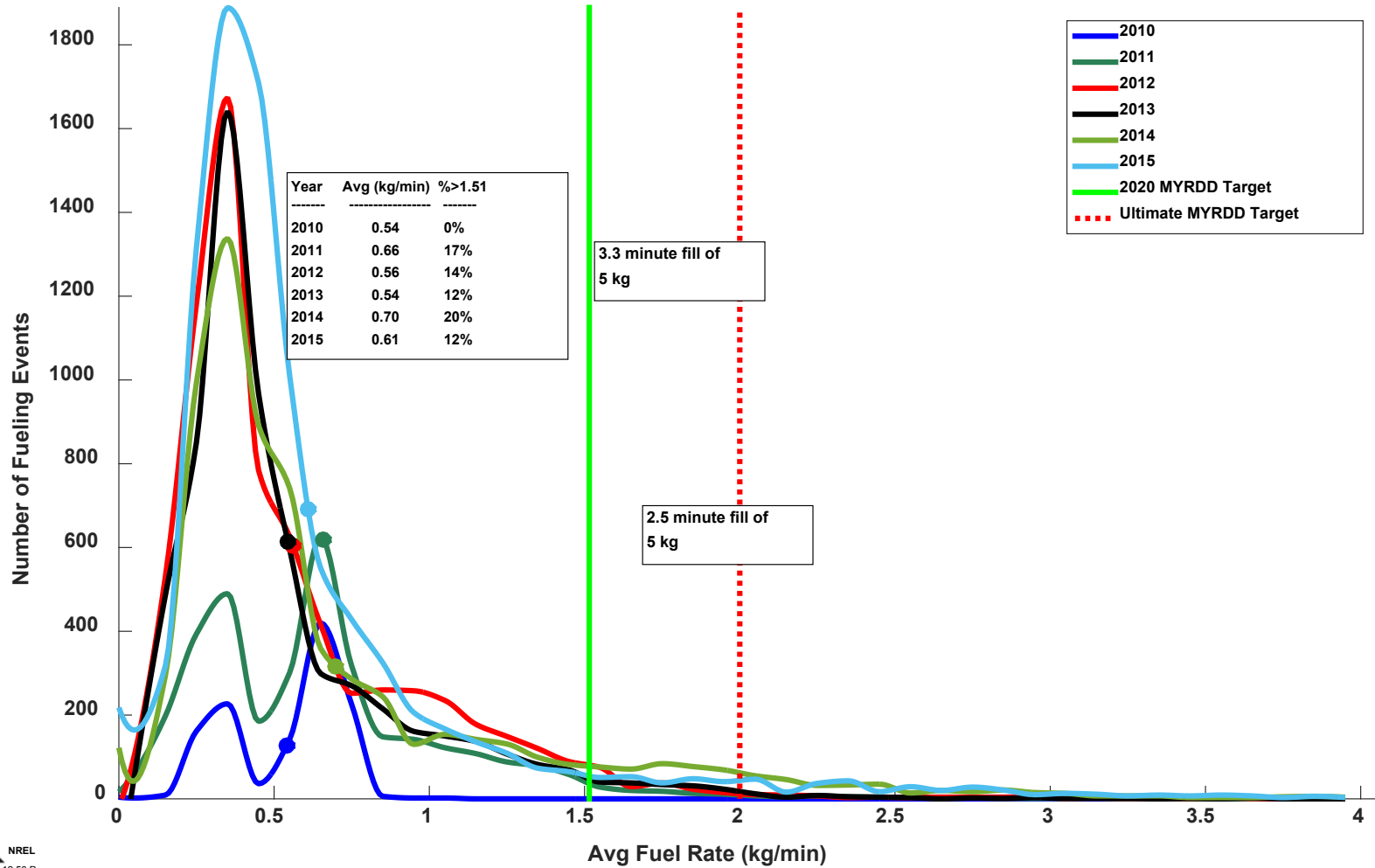
NREL cdp_infr_18

Created: Apr-15-16 12:36 PM | Data Range: 2008Q3-2015Q4

CDP-INFR-56

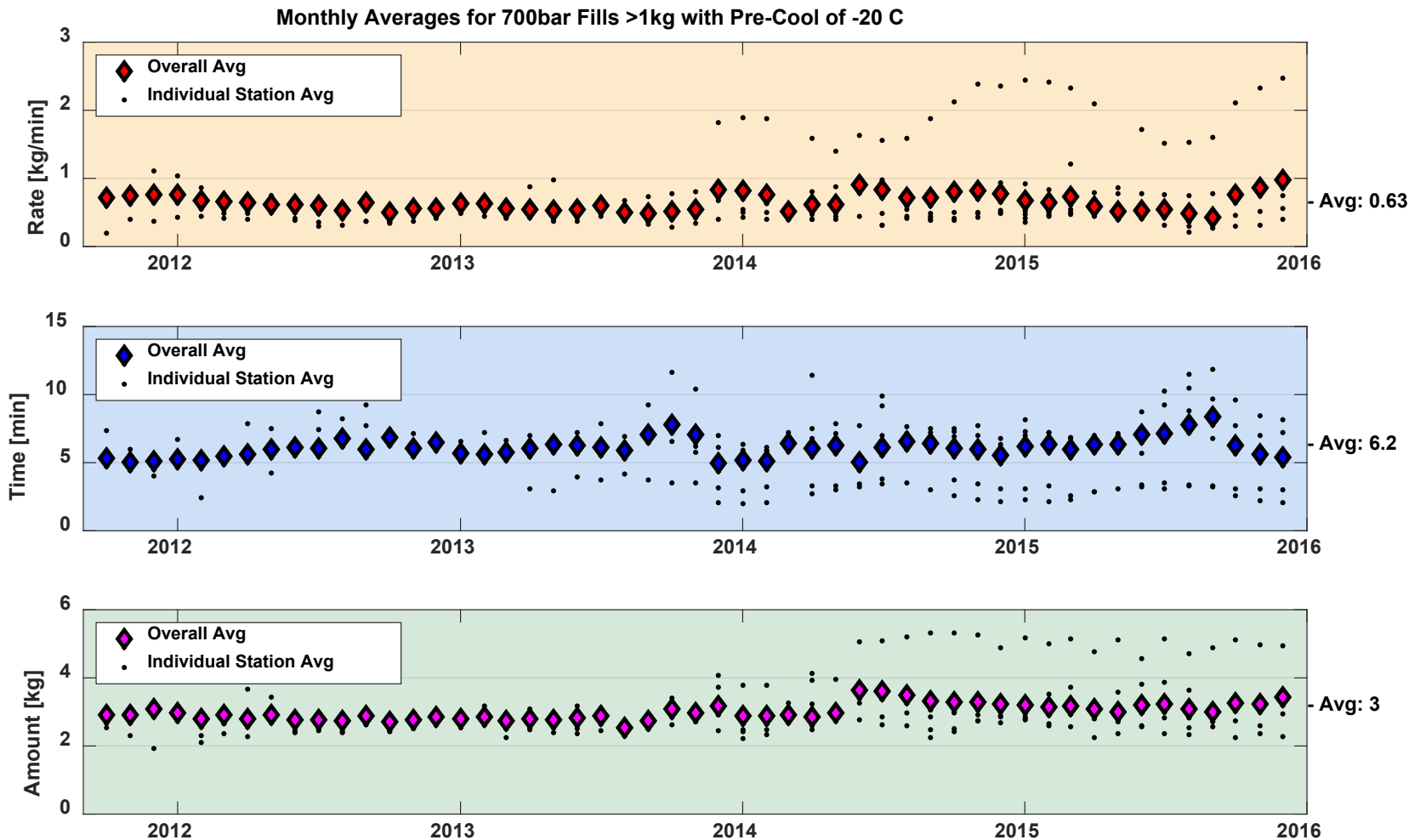
Fueling Rates by Year

Histogram of Fueling Rates
By Year



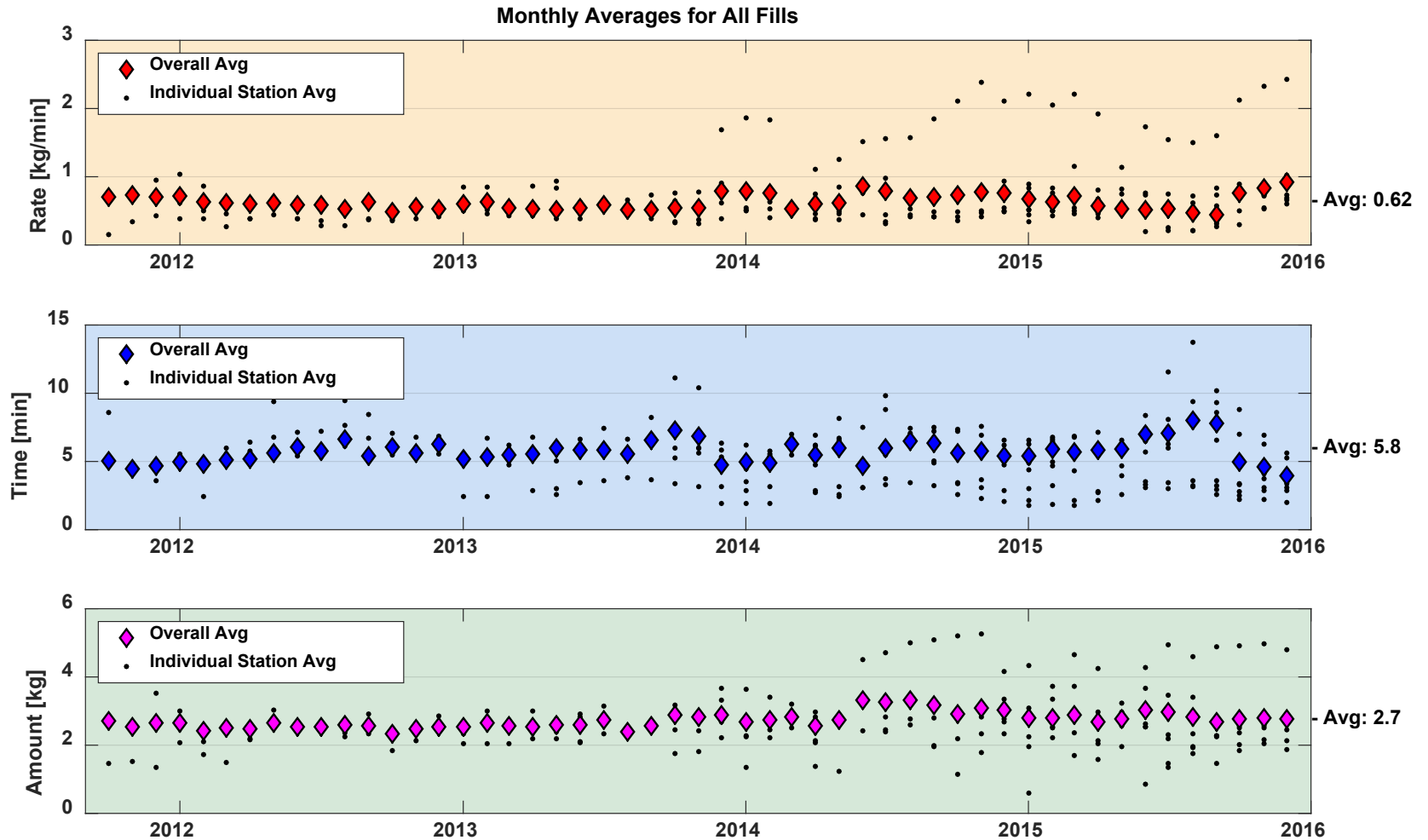
CDP-INFR-29

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



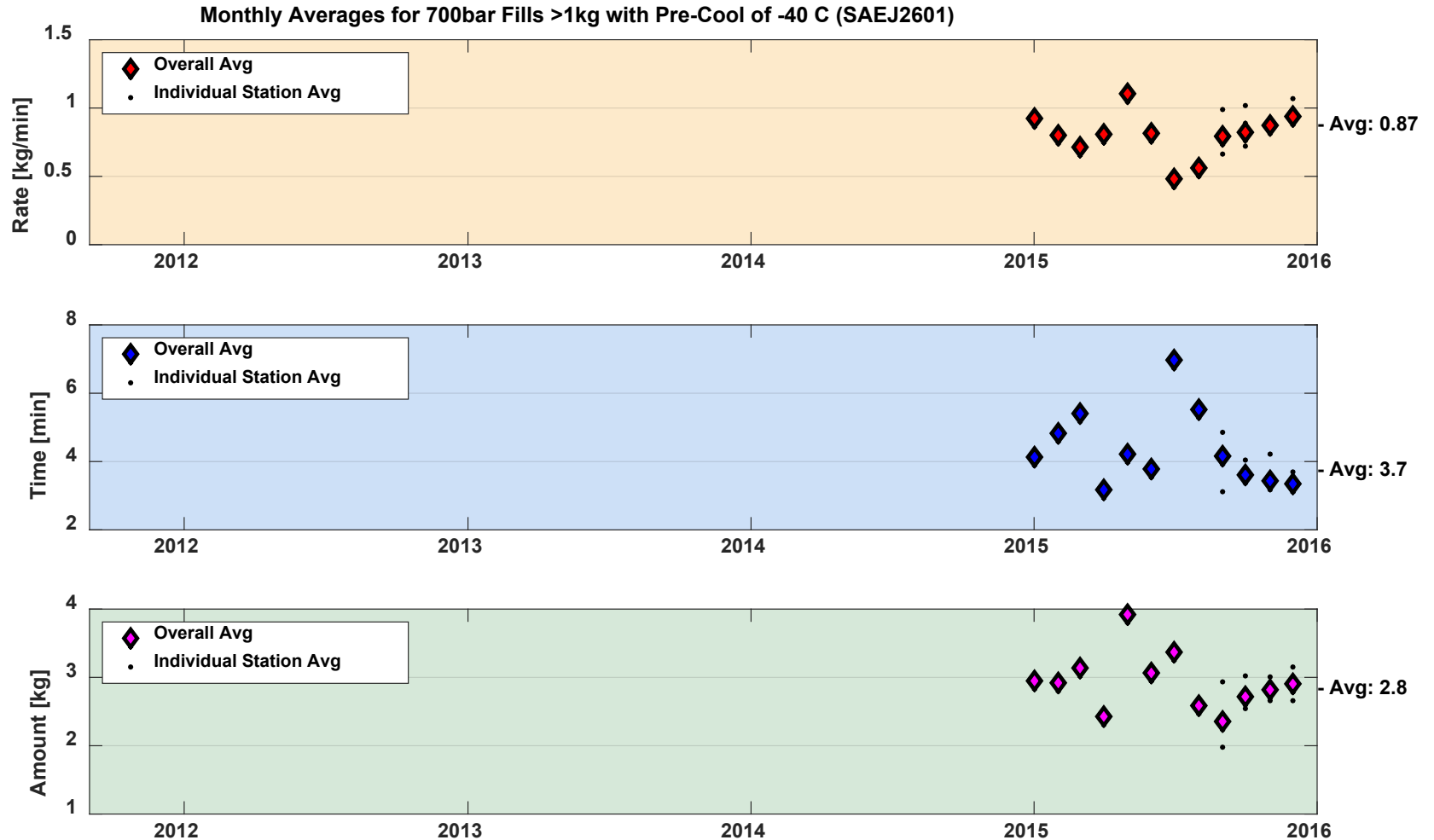
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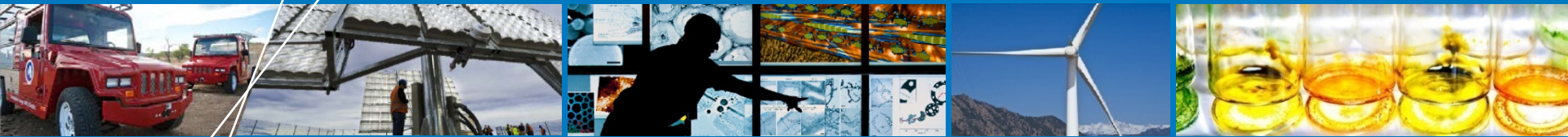
Monthly Averages for All Fills



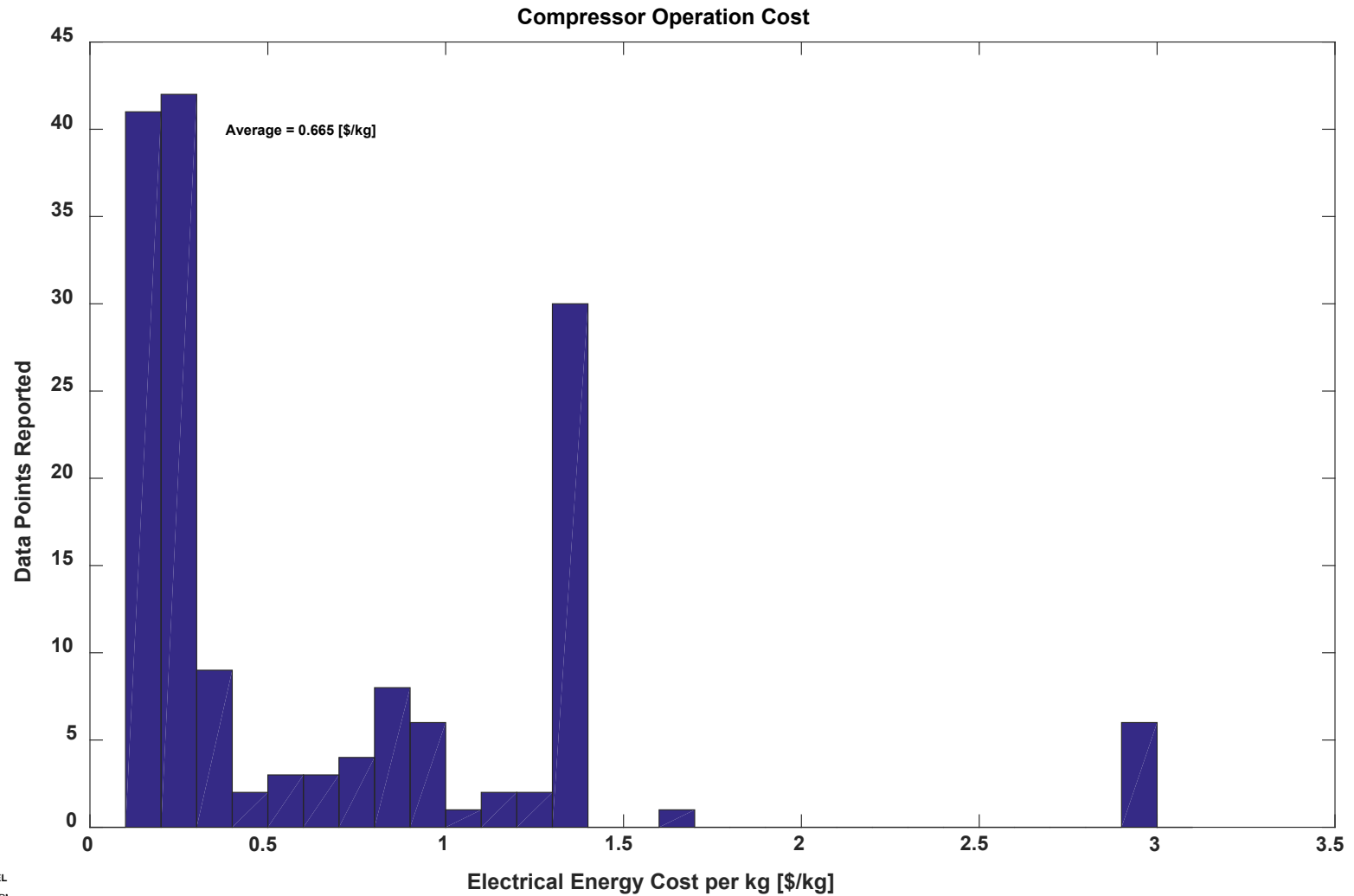
CDP-INFR-57

Monthly Averages for 700 bar Fills >1 kg with Pre-Cool of -40°C

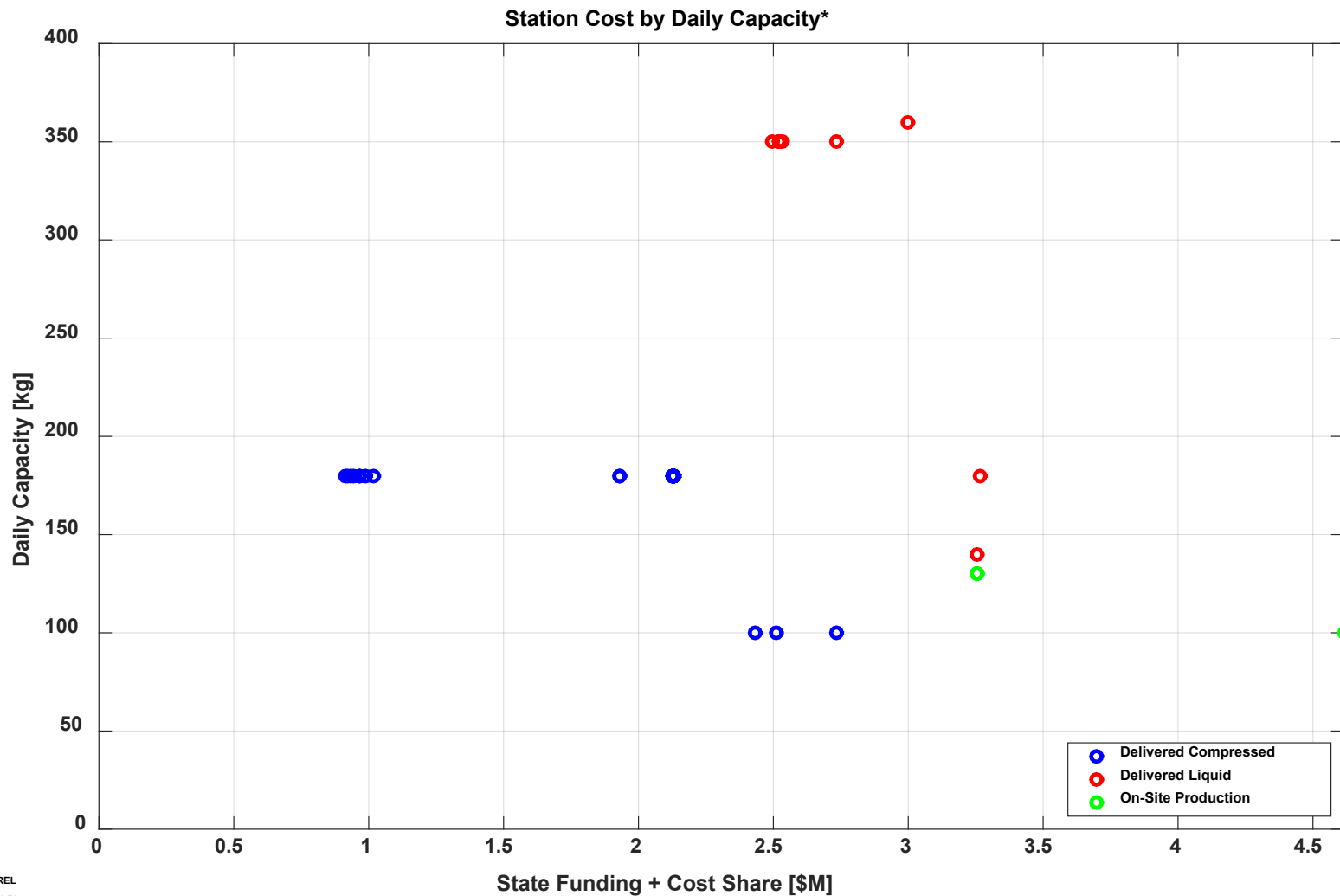




Cost



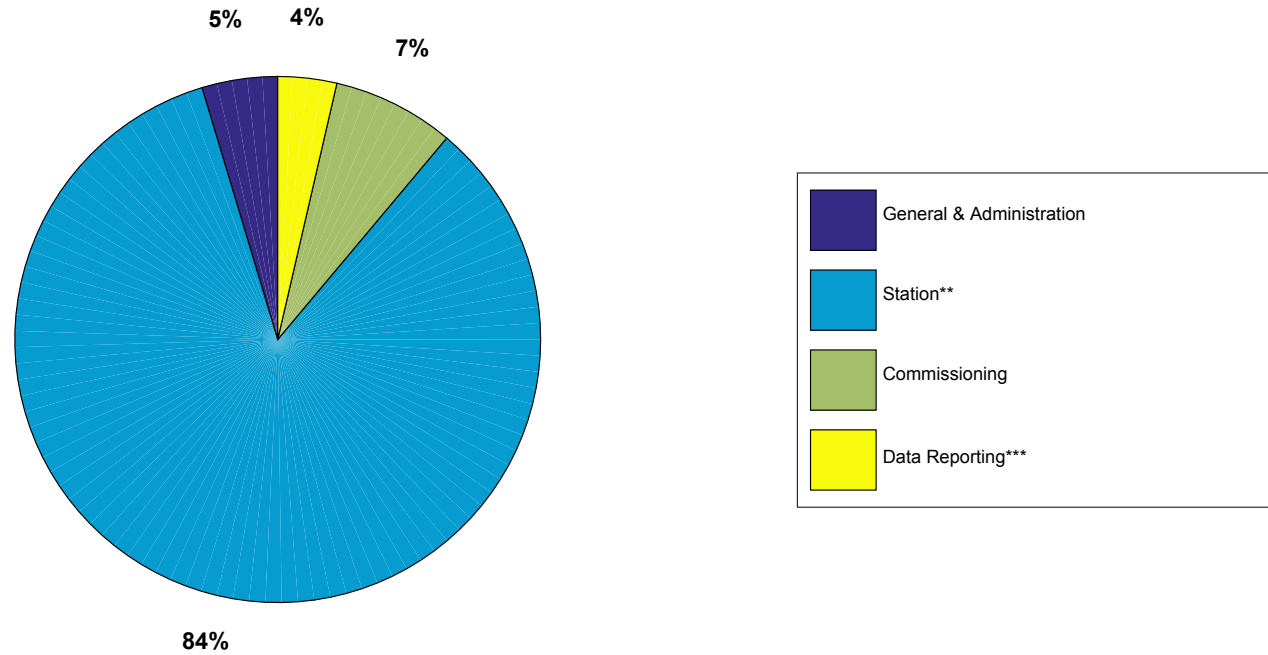
Station Costs by Daily Capacity



CDP-INFR-41

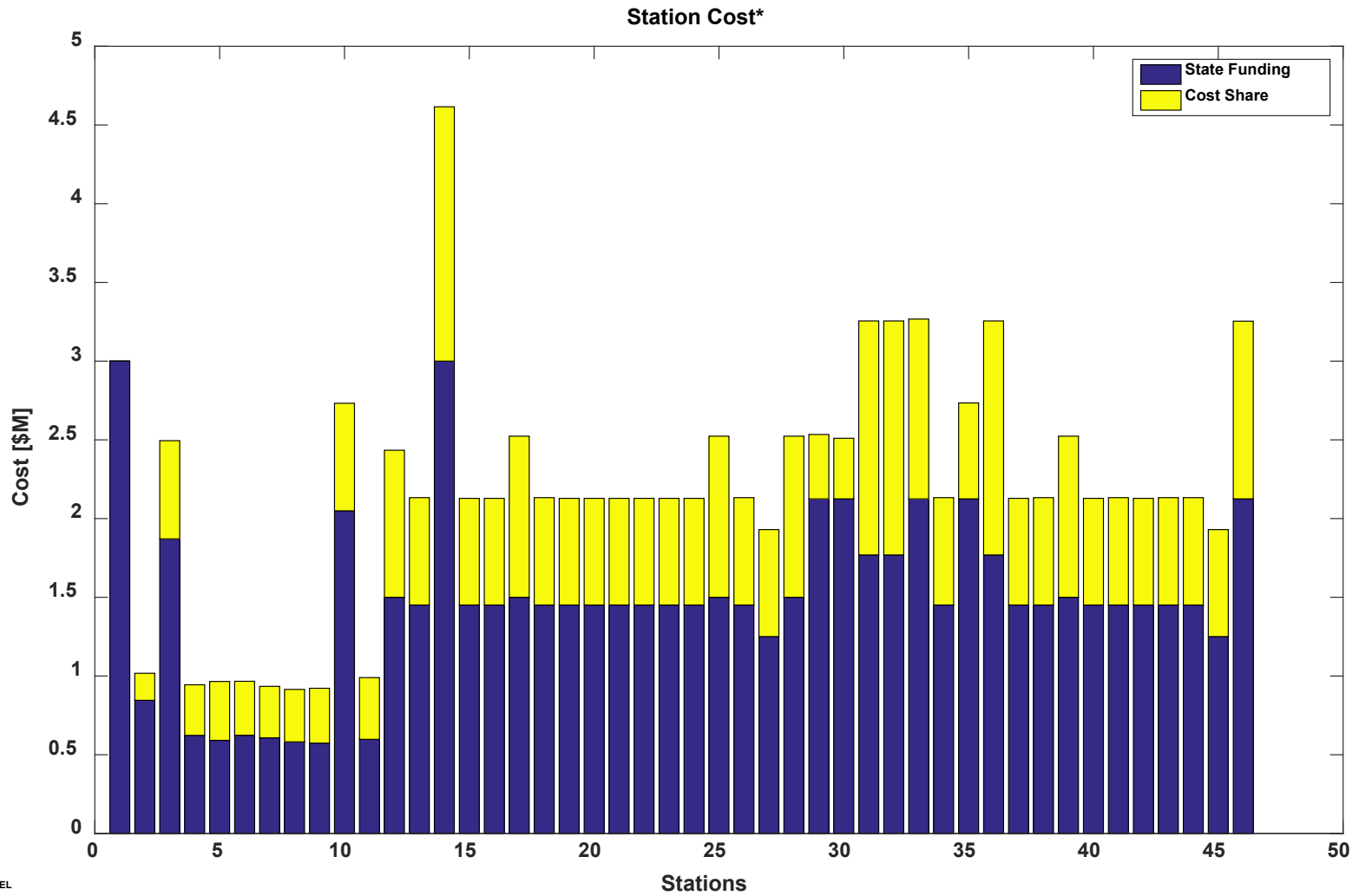
Station Cost by Category

Budget Amounts* (Avg Total = \$2.2M), 46 Stations



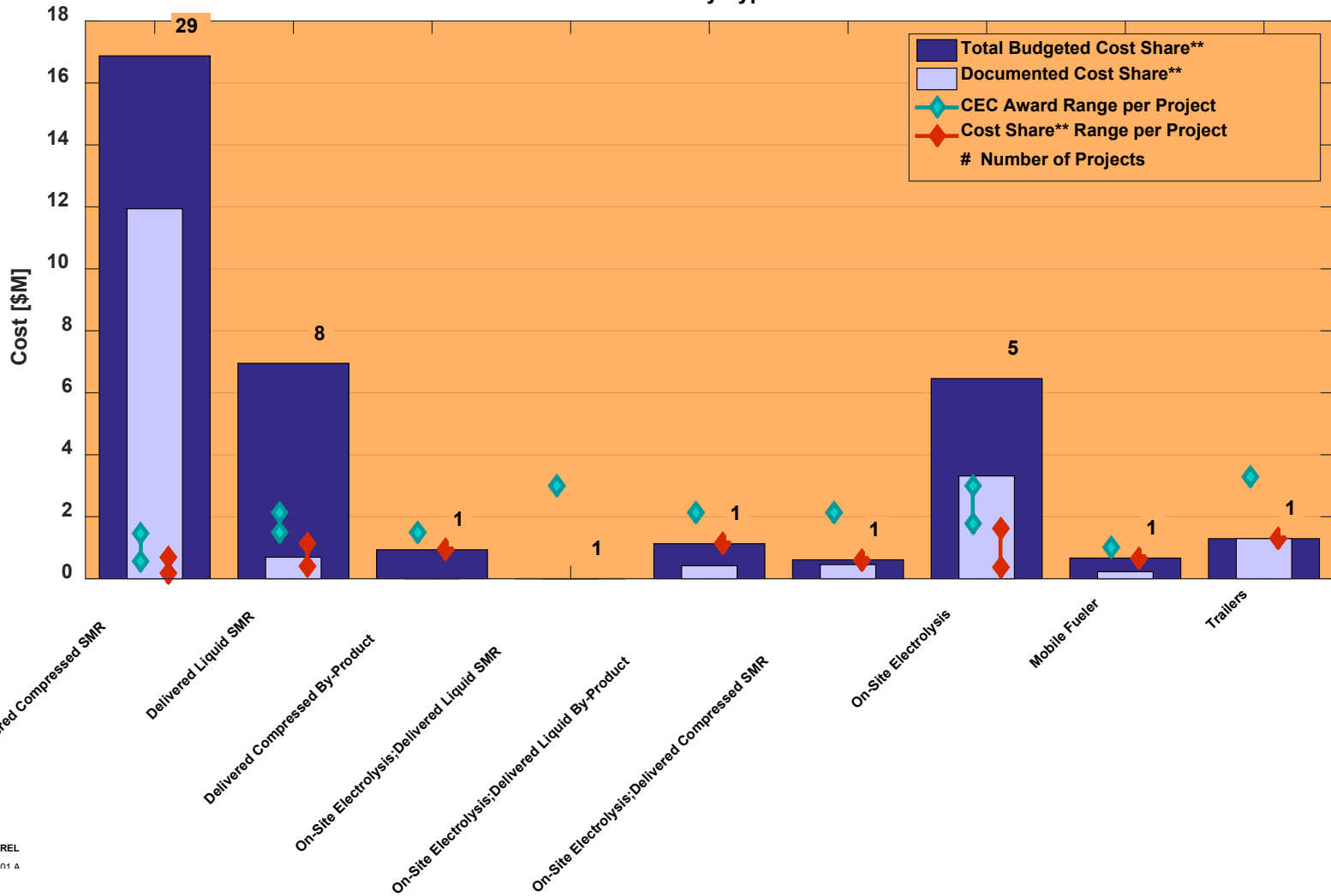
CDP-INFR-42

Station Costs

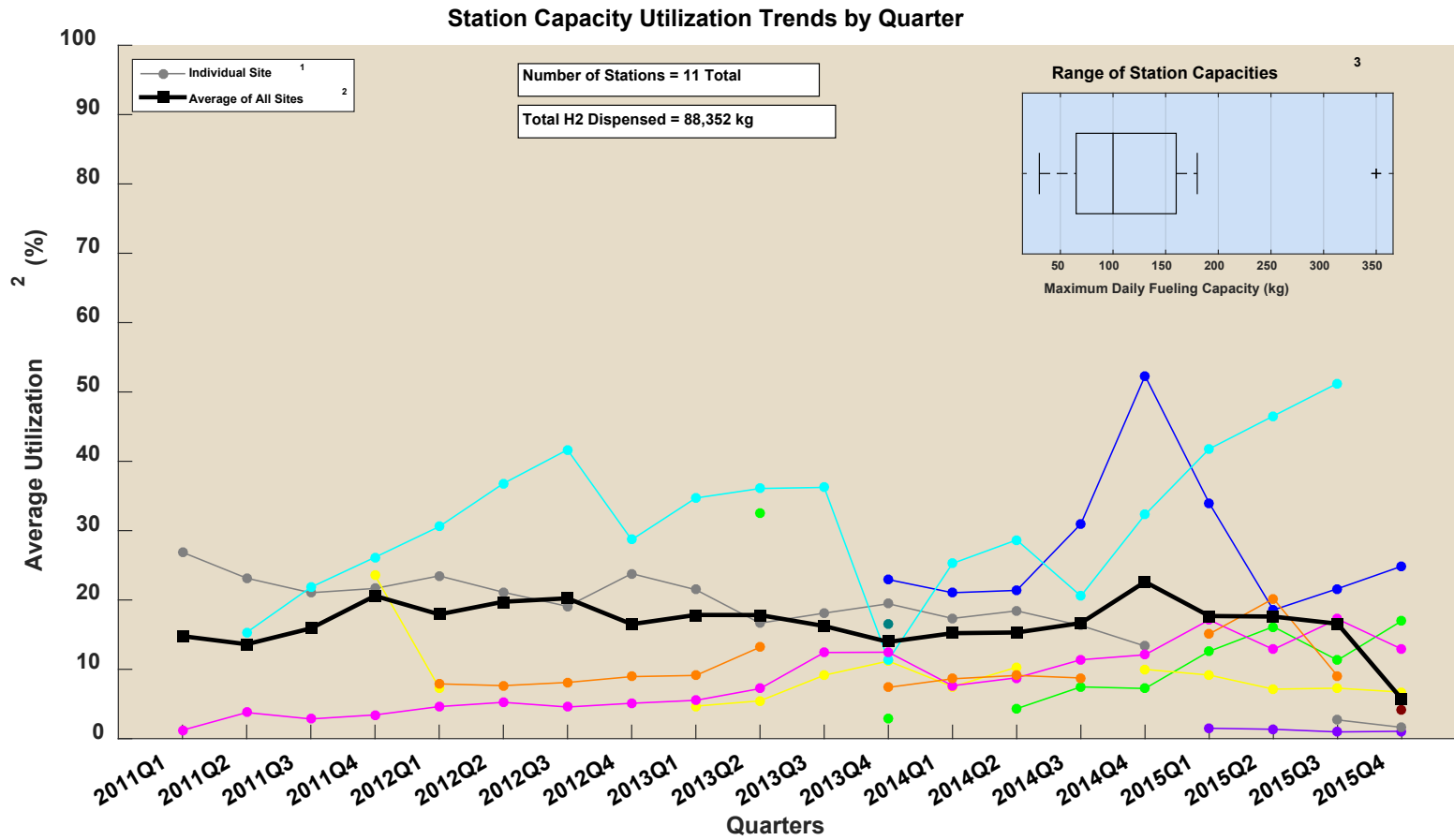


Station Cost by Type

Station Cost by Type*

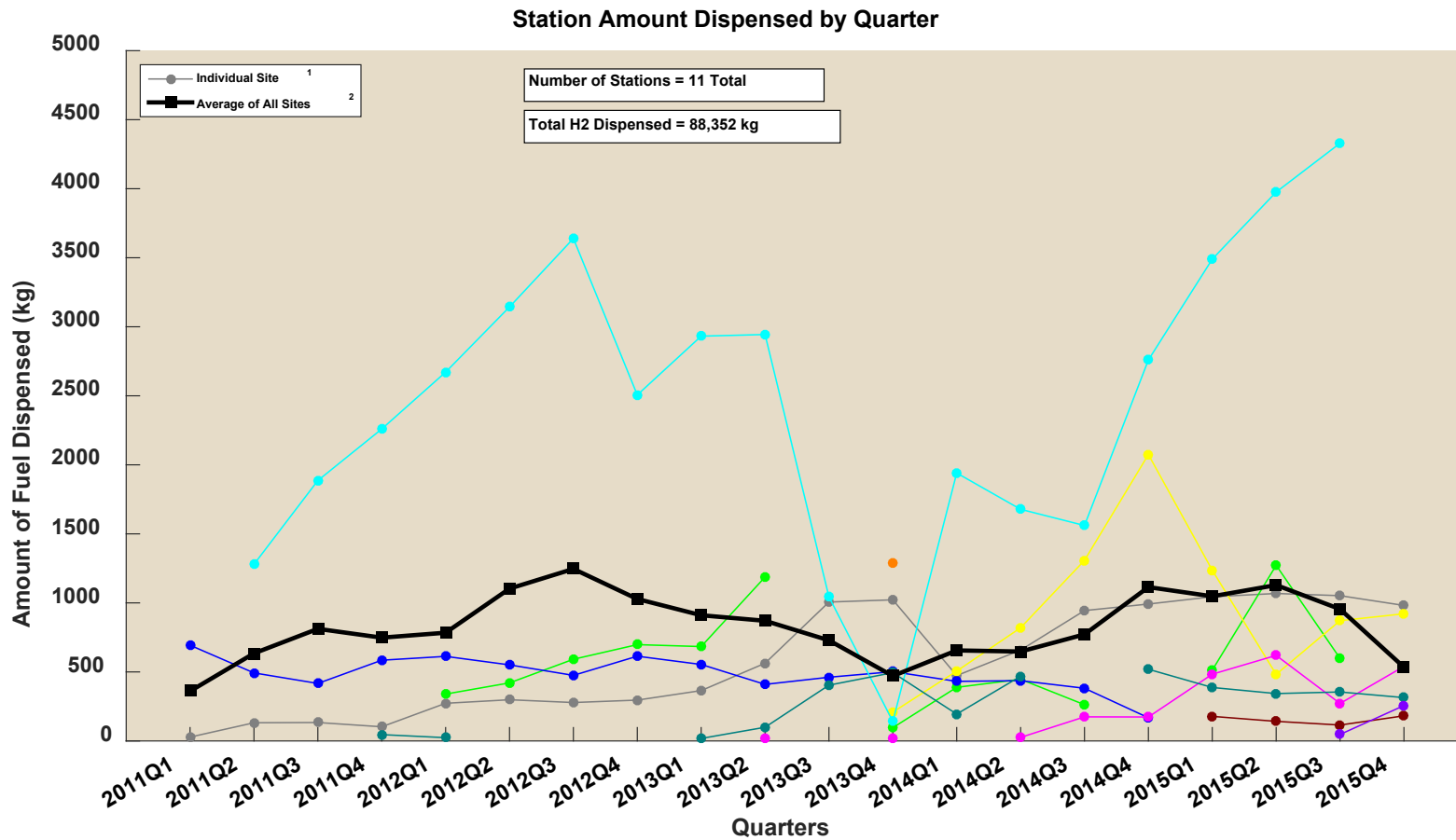


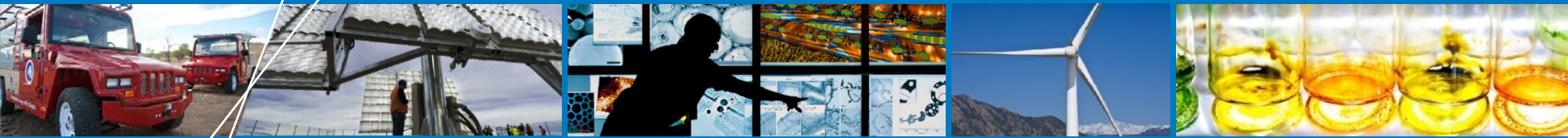
Station Capacity Utilization Trends by Quarter



CDP-INFR-45

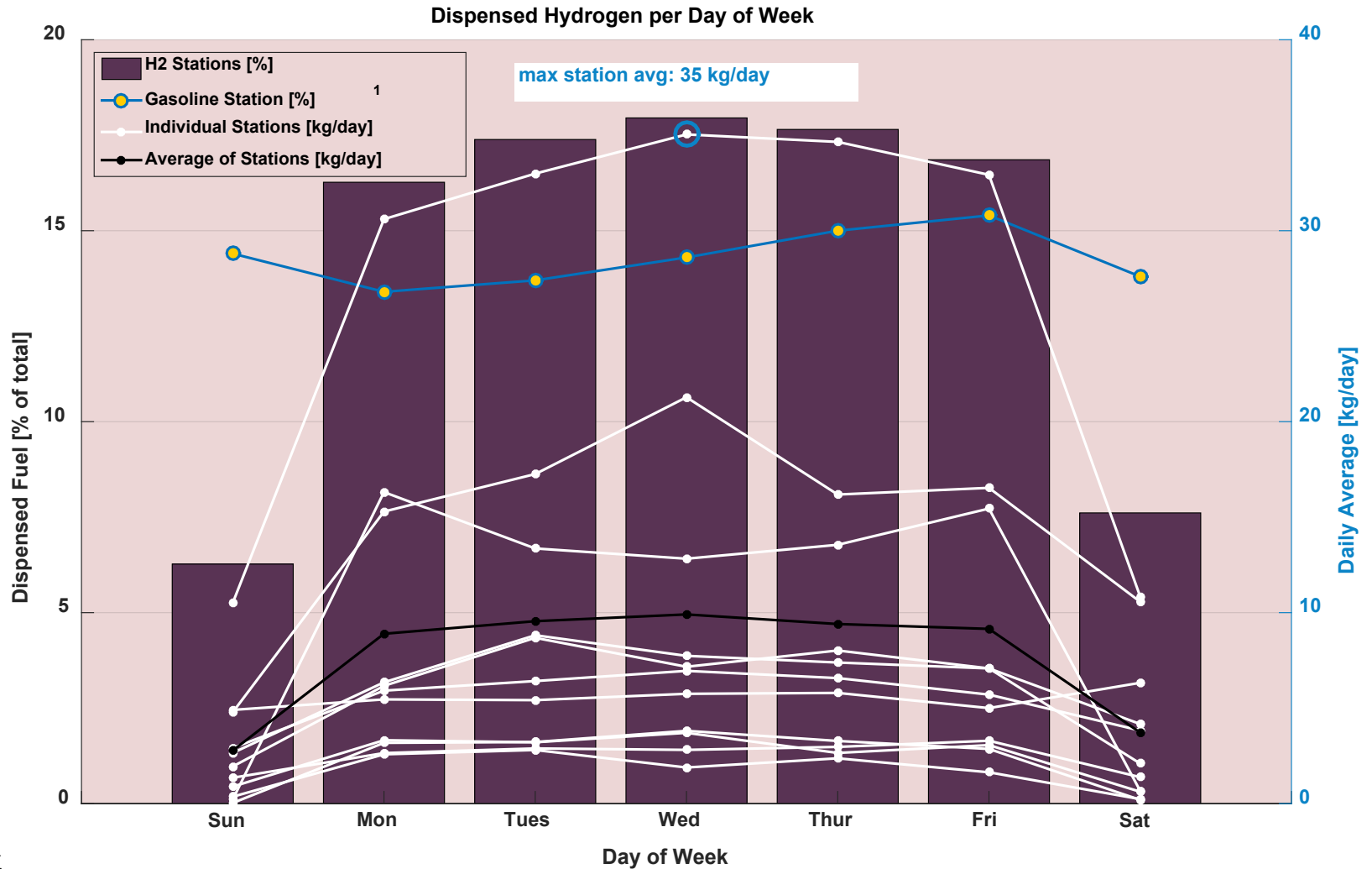
Station Amount Dispensed by Quarter



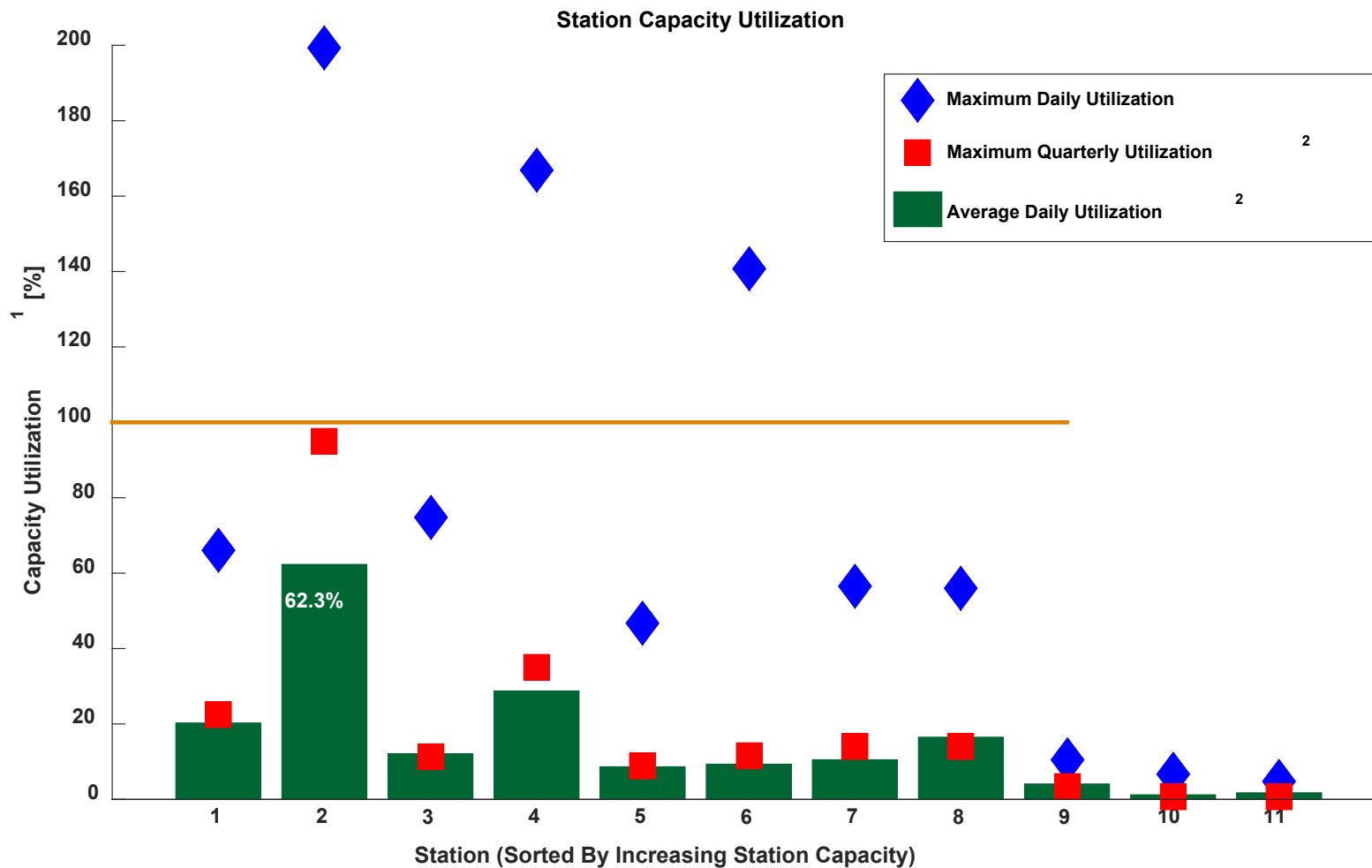


Utilization

Dispensed Hydrogen per Day of Week



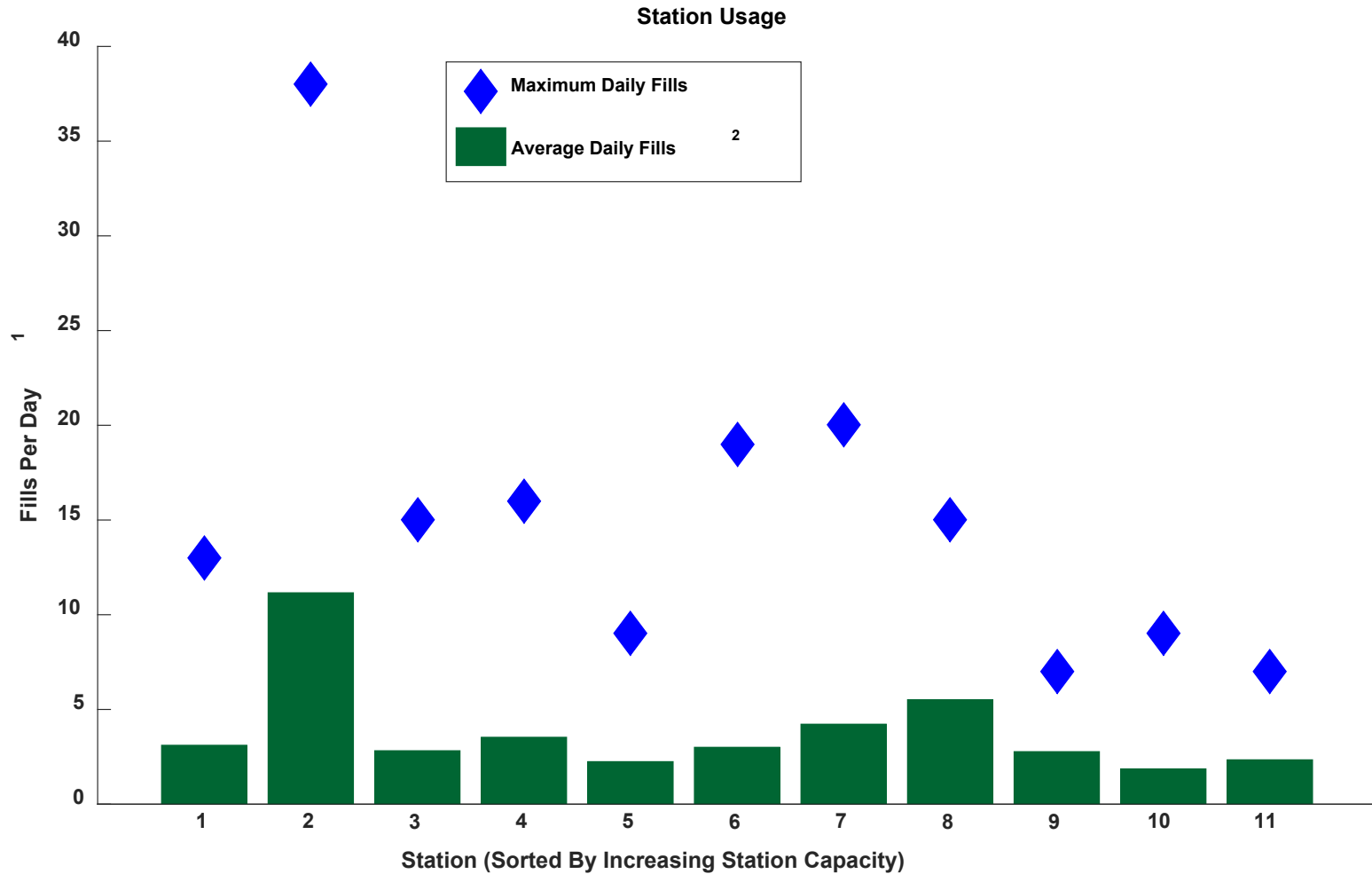
Station Capacity Utilization



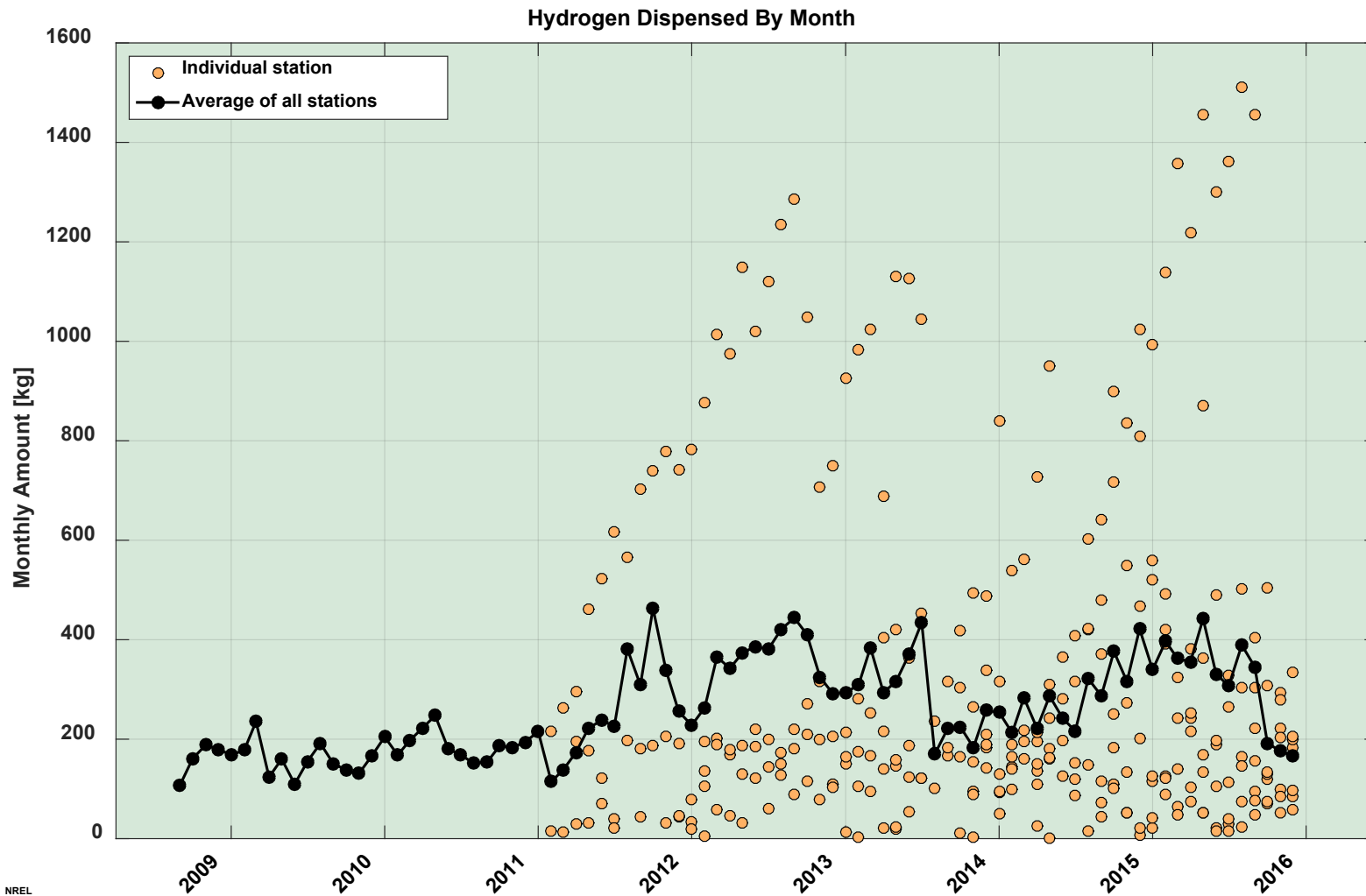
Created: Apr.27.16 5:12 PM

CDP-INFR-07

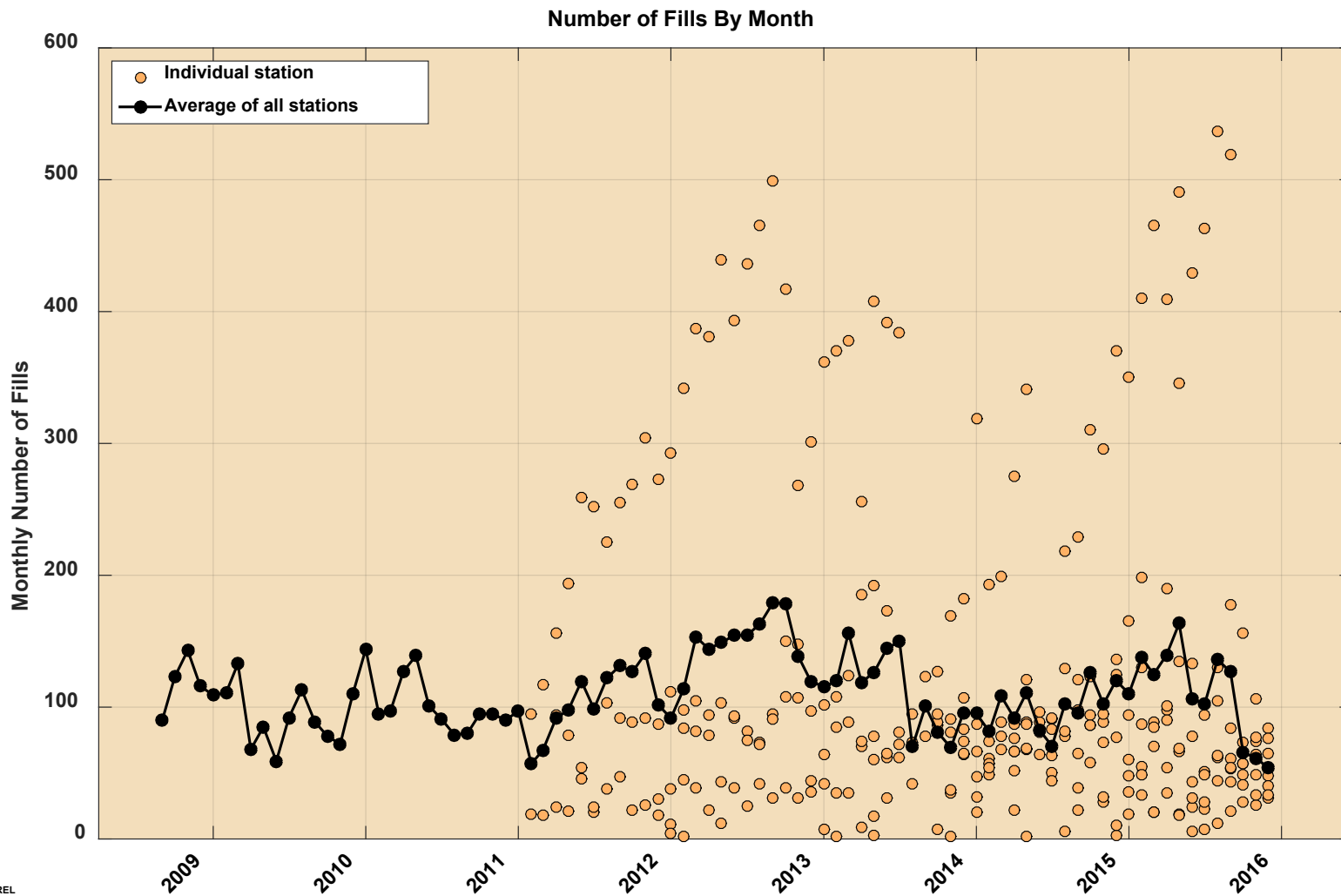
Station Usage



Hydrogen Dispensed by Month

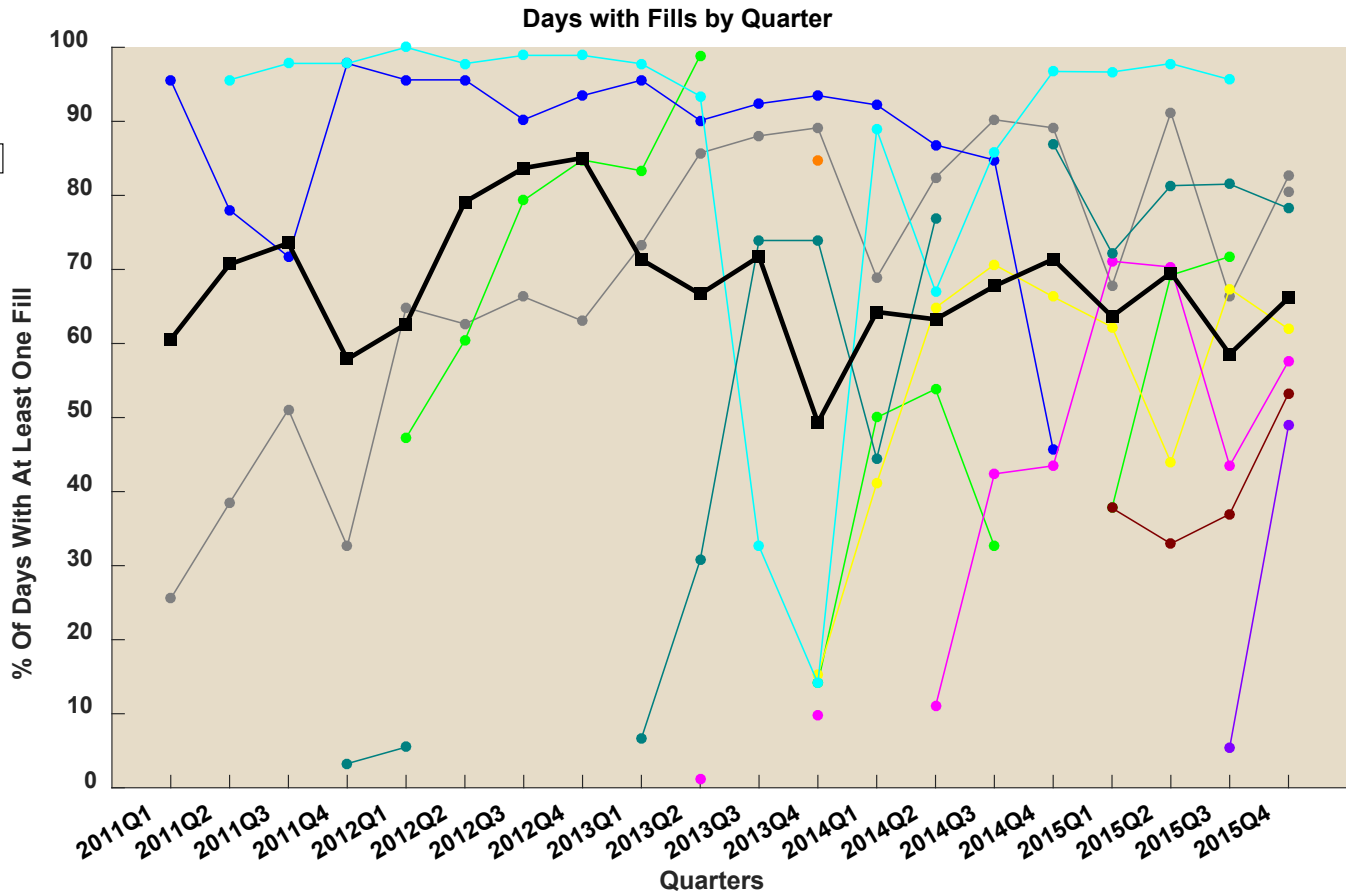


Number of Fills by Month



CDP-INFR-46

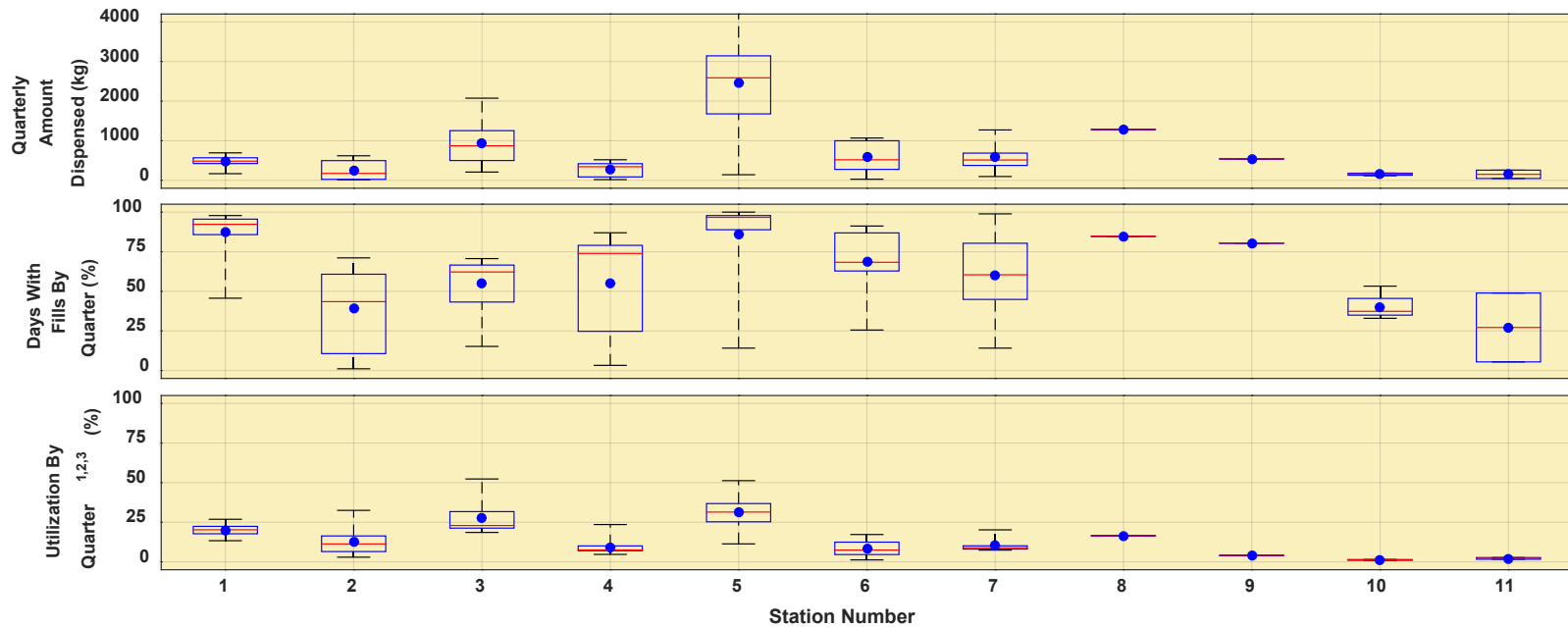
Days with Fills by Quarter

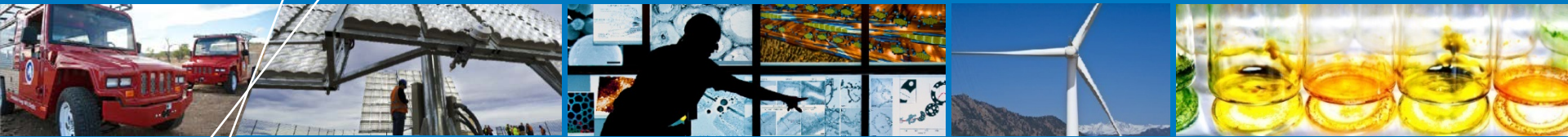


Summary of Station Usage Statistics

Summary of Station Usage Statistics

4

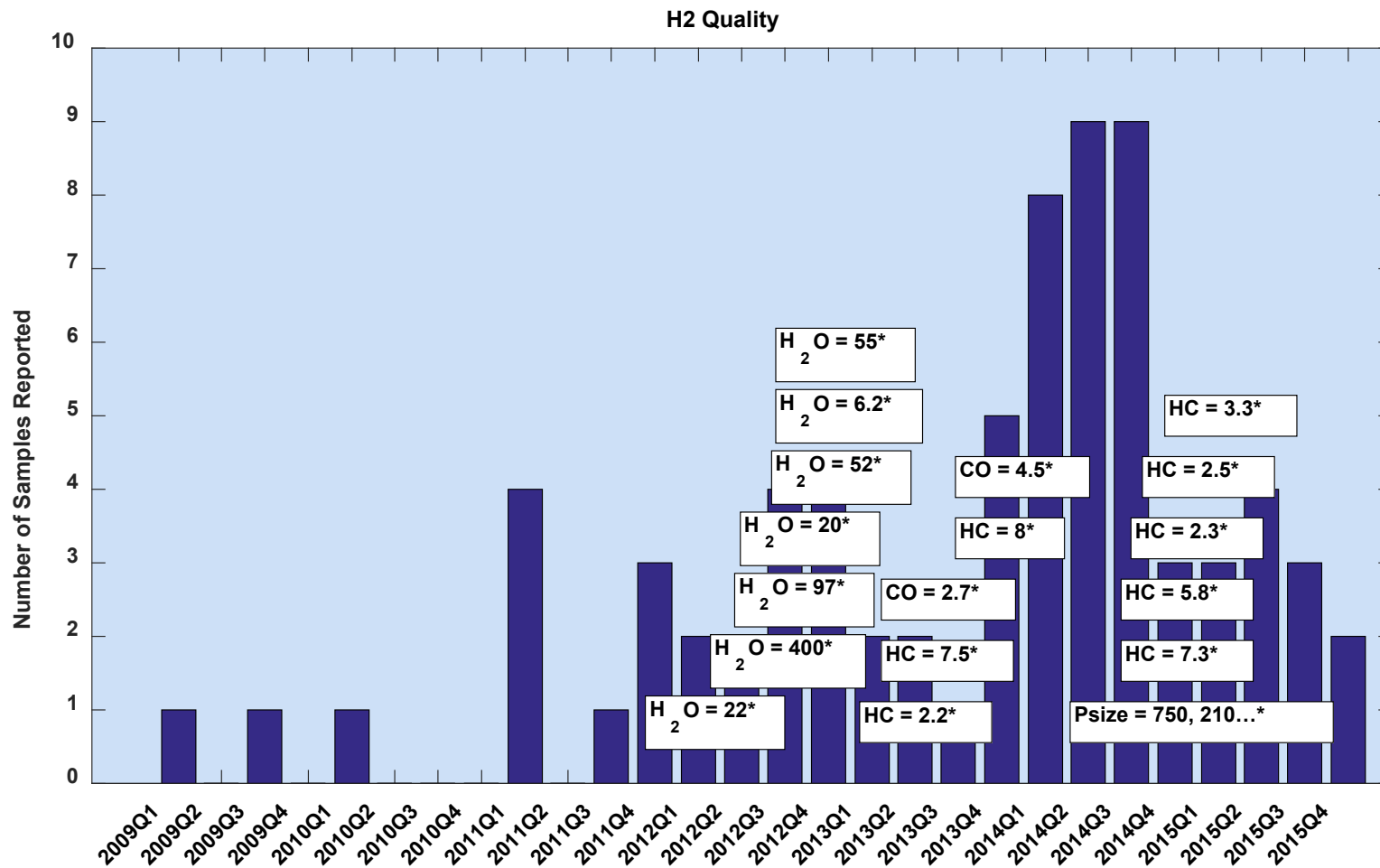




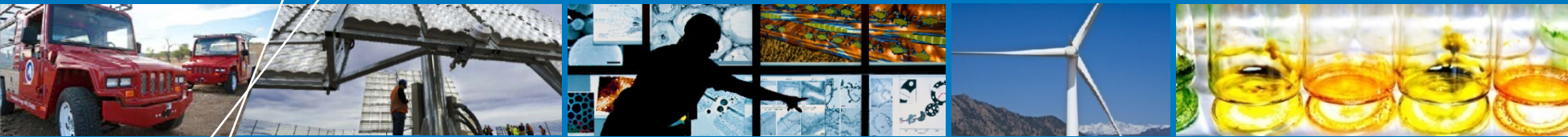
Hydrogen Quality

CDP-INFR-25

Hydrogen Quality



NREL
Created: Apr-18-16 5:00 PM



Component Energy

CDP-INFR-36

Electrolyzer Energy

