Next Generation Hydrogen Station Composite Data Products: Retail Stations

Summer 2020: Data through Quarter 2 of 2020

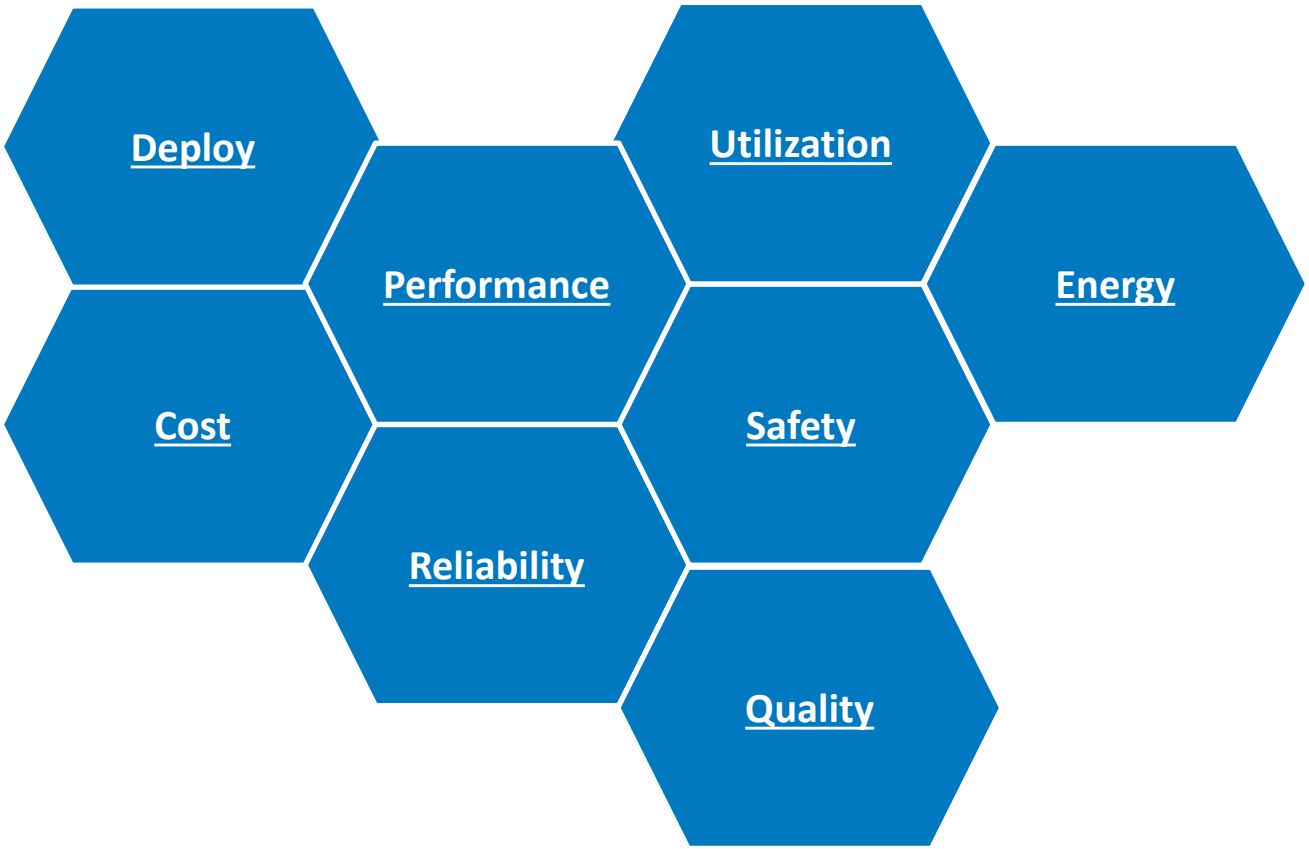
Genevieve Saur, Spencer Gilleon, and Sam Sprik

February 2021

Hydrogen Station Project Partners

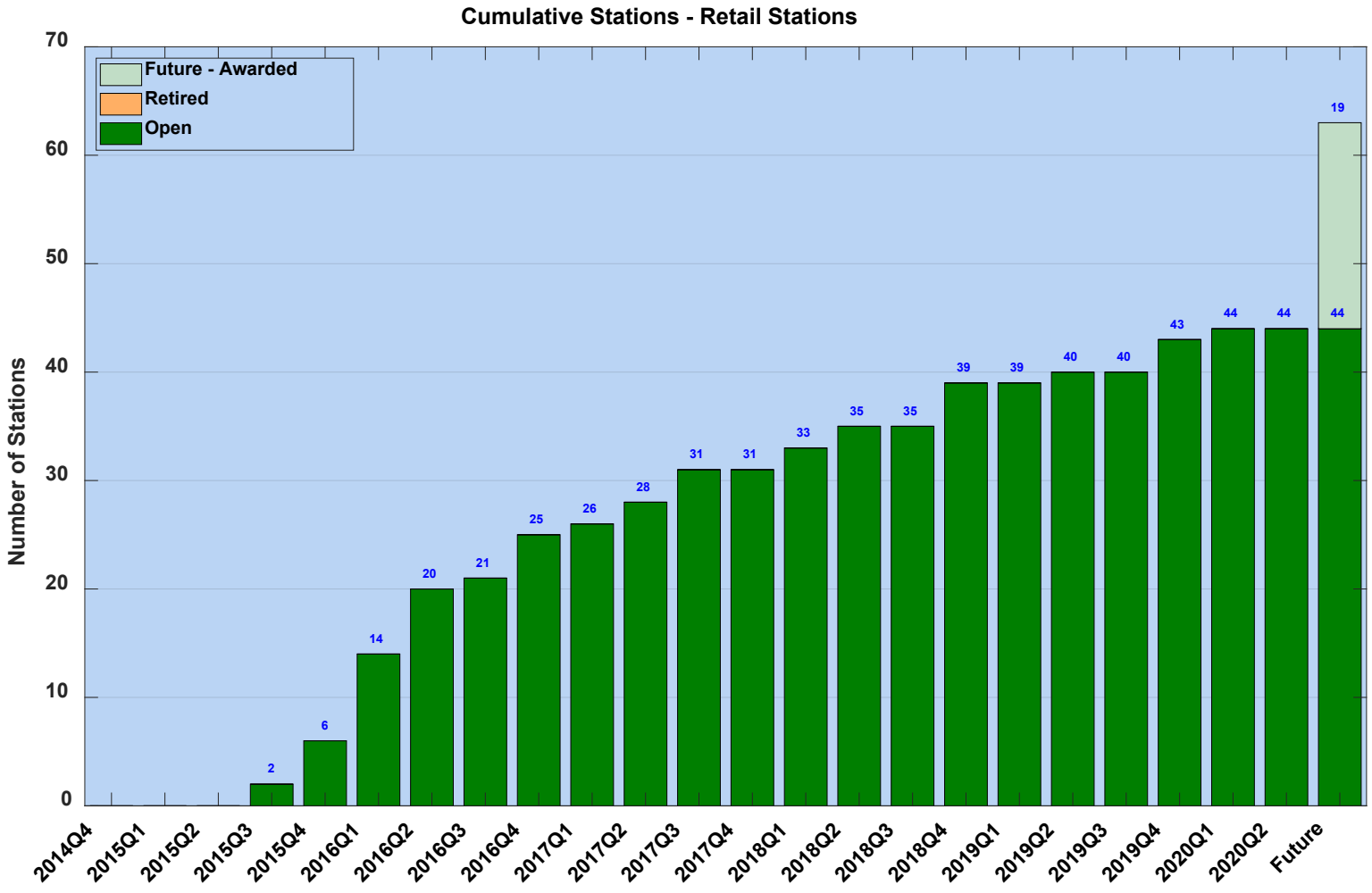
- Air Liquide
- Air Products
- California Air Resources Board
- California Energy Commission
- California State University Los Angeles
- Equilon
- FirstElement Fuel
- Gas Technology Institute
- ITM Power
- Iwatani
- Linde
- H2 Frontier
- Messer
- Proton OnSite
- Shell
- IPHE and HySUT

Analysis Categories



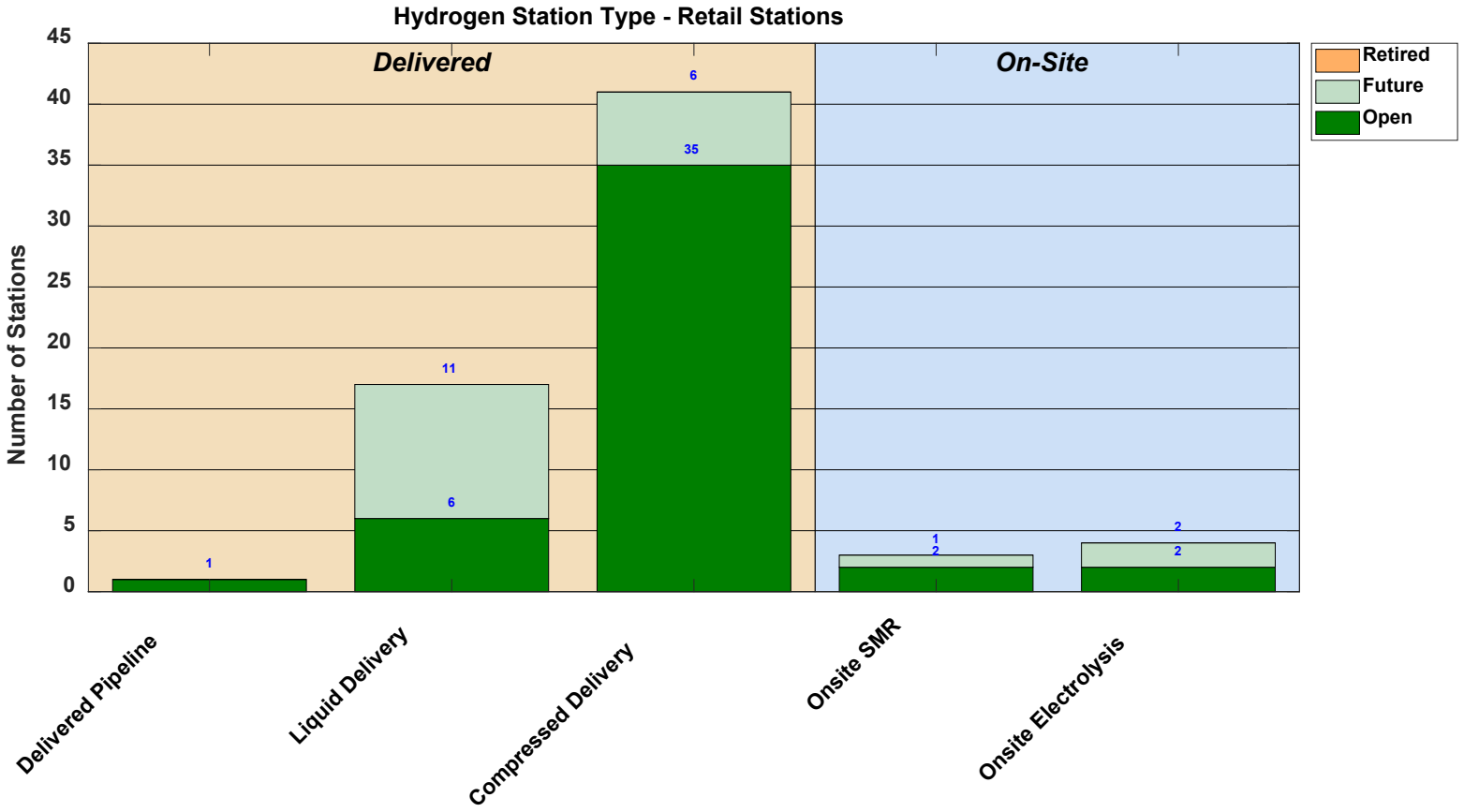
Deployment

CDP-INFR-10
Cumulative Number of Stations



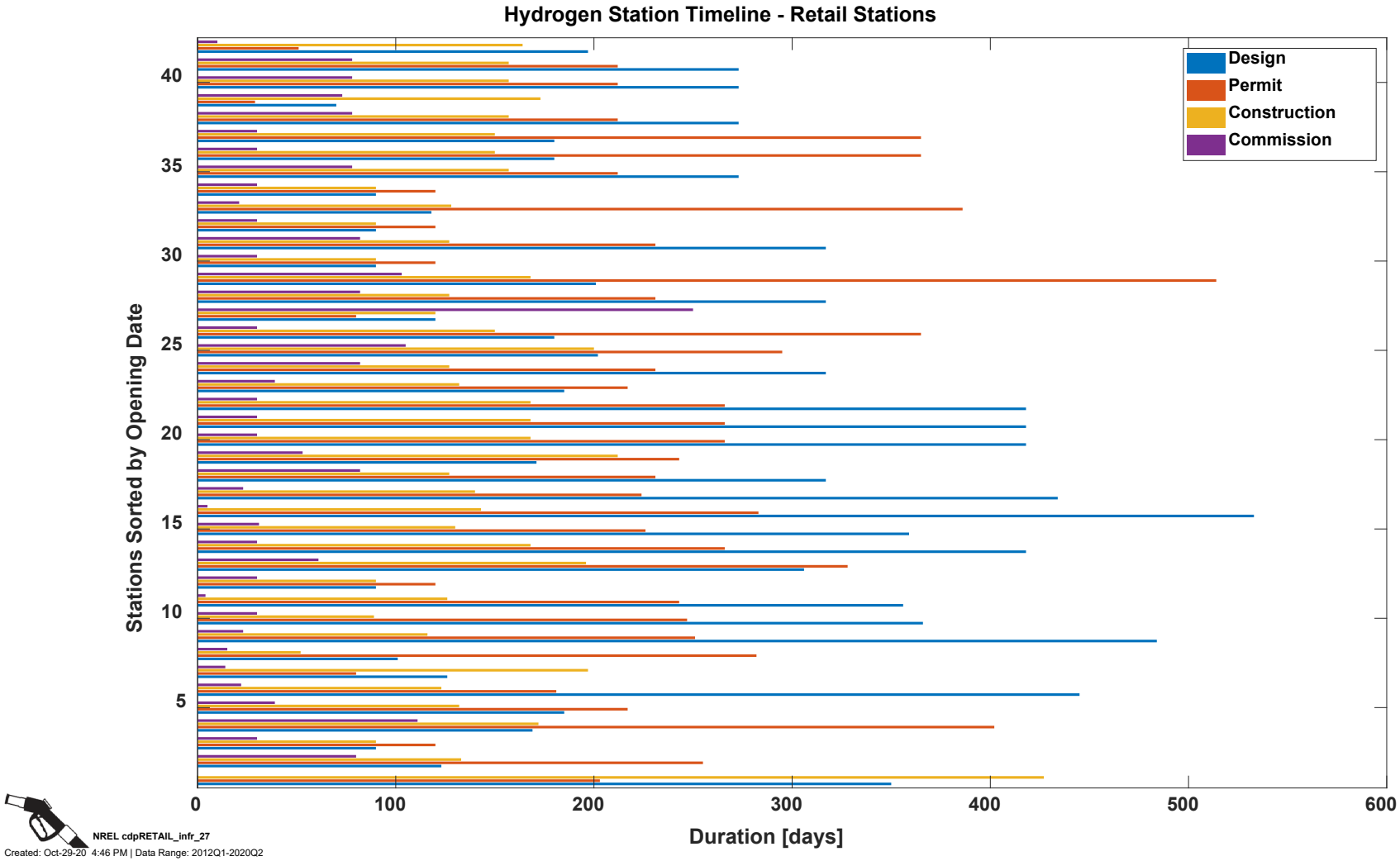
NREL cdpRETAIL_infr_10
Created: Jan-21-21 1:06 PM | Data Range: 2011Q1-2020Q2

CDP-INFR-11
Hydrogen Stations by Type

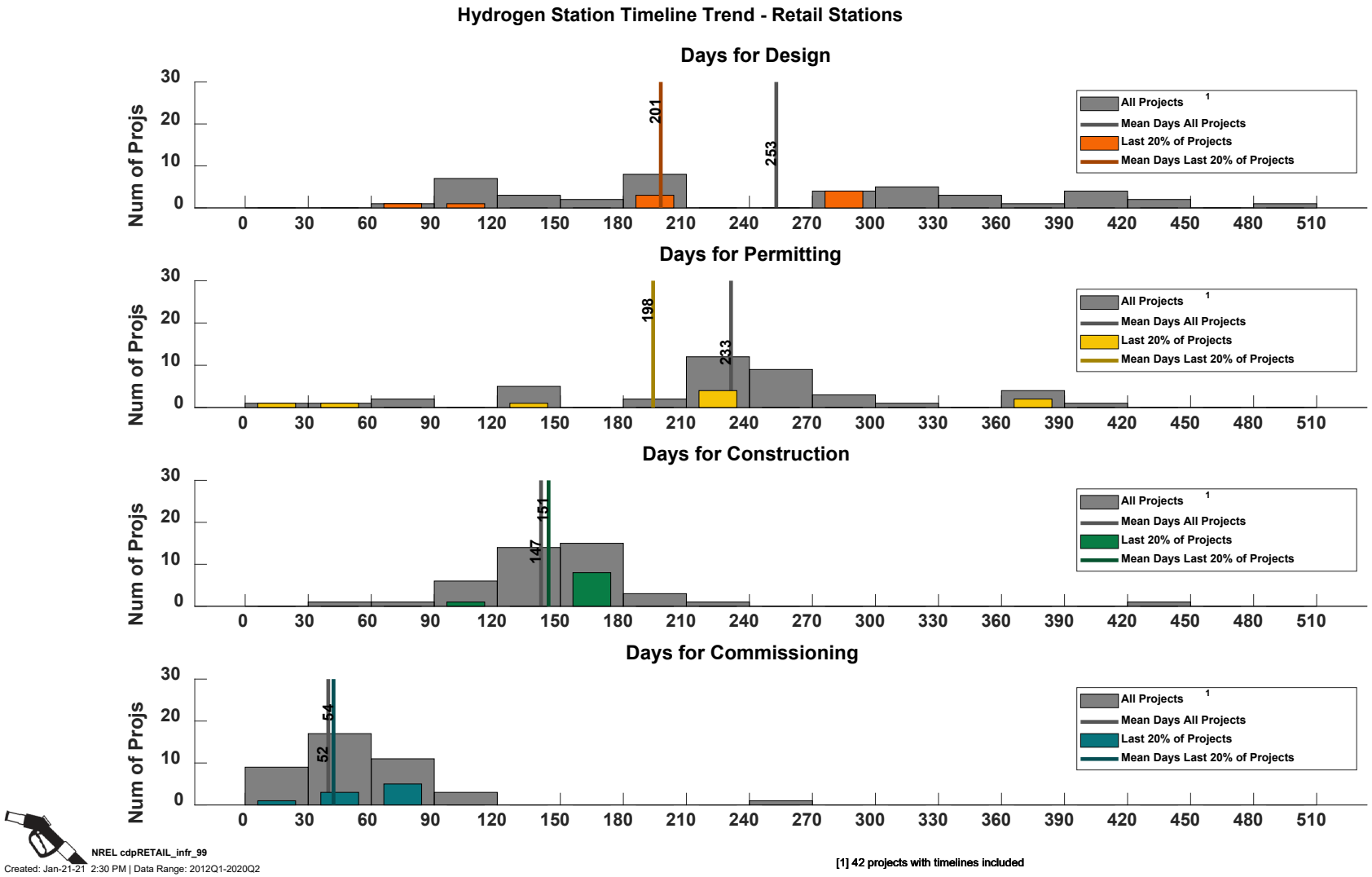


NREL cdpRETAIL_infr_11
Created: Jan-21-21 1:07 PM | Data Range: 2011Q1-2020Q2

CDP-INFR-27
Hydrogen Station Timeline



CDP-INFR-99
Hydrogen Station Timeline Trend - Retail Stations

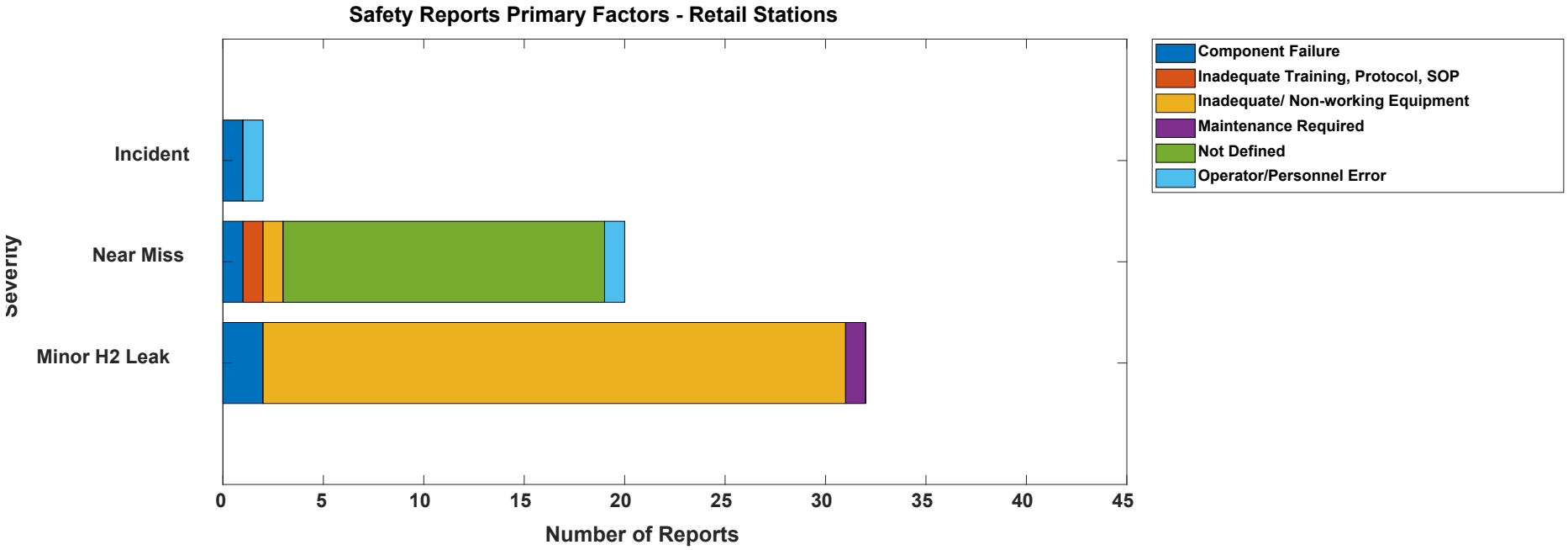


NREL cdpRETAIL_infr_99
Created: Jan-21-21 2:30 PM | Data Range: 2012Q1-2020Q2

[1] 42 projects with timelines included

Safety

CDP-INFR-31
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

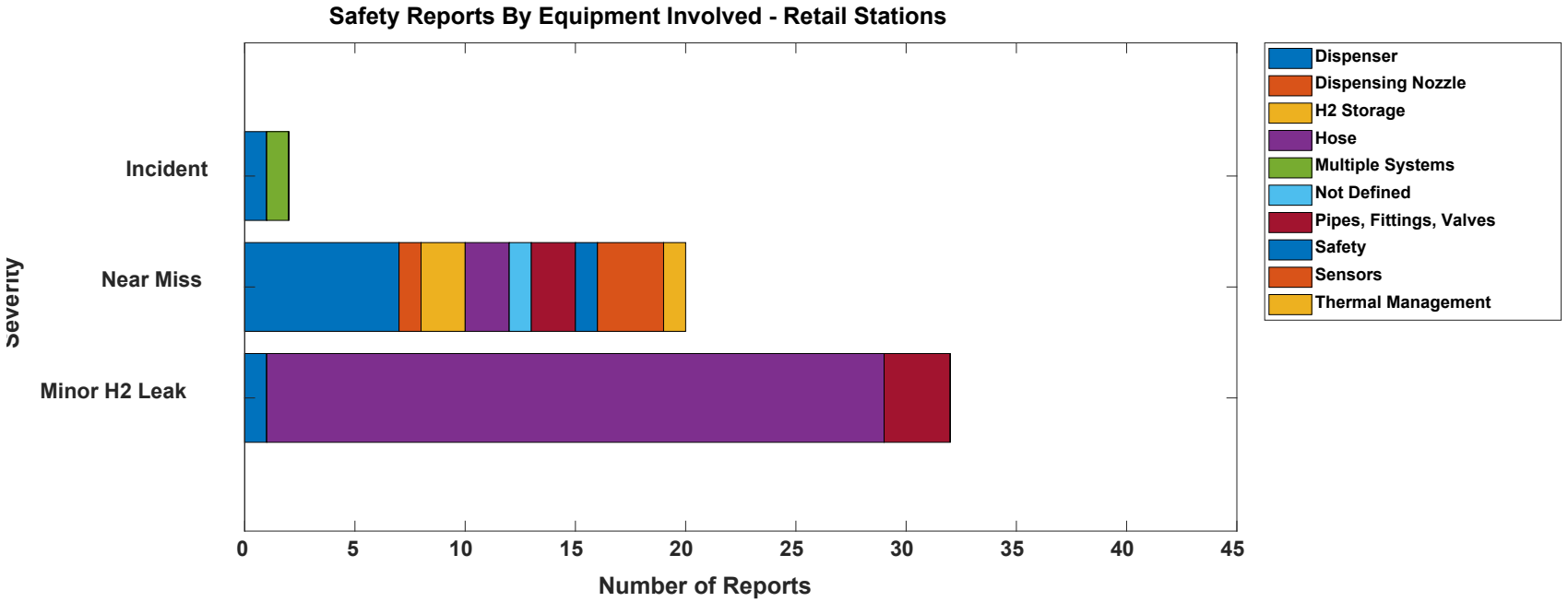
A Minor H2 Leak is:

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

NREL cdpRETAIL_infr_31

Created: Nov-13-20 9:20 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-32
Safety Reports by Equipment Involved



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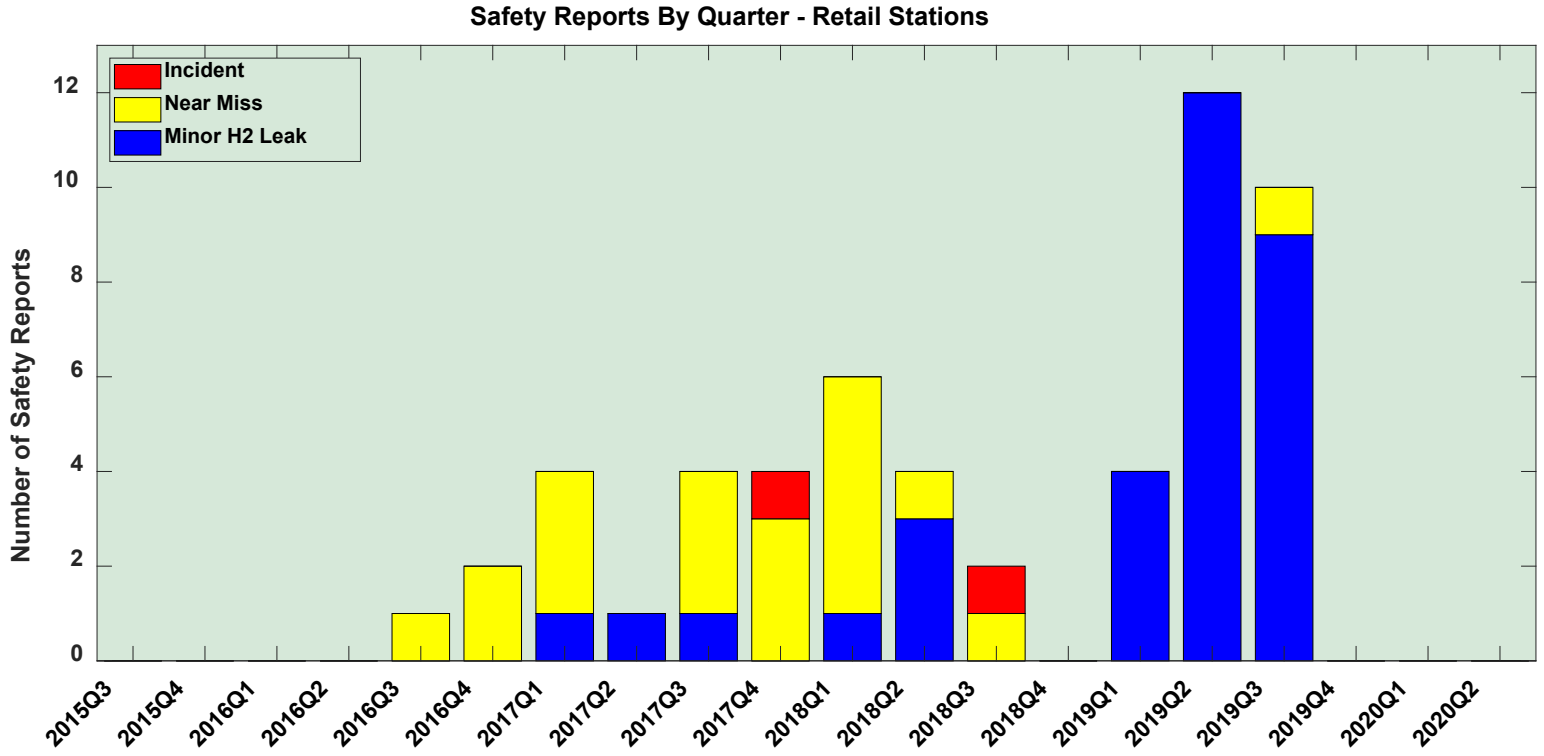
NREL cdpRETAIL_infr_32

Created: Nov-13-20 9:14 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-33
Safety Reports by Quarter



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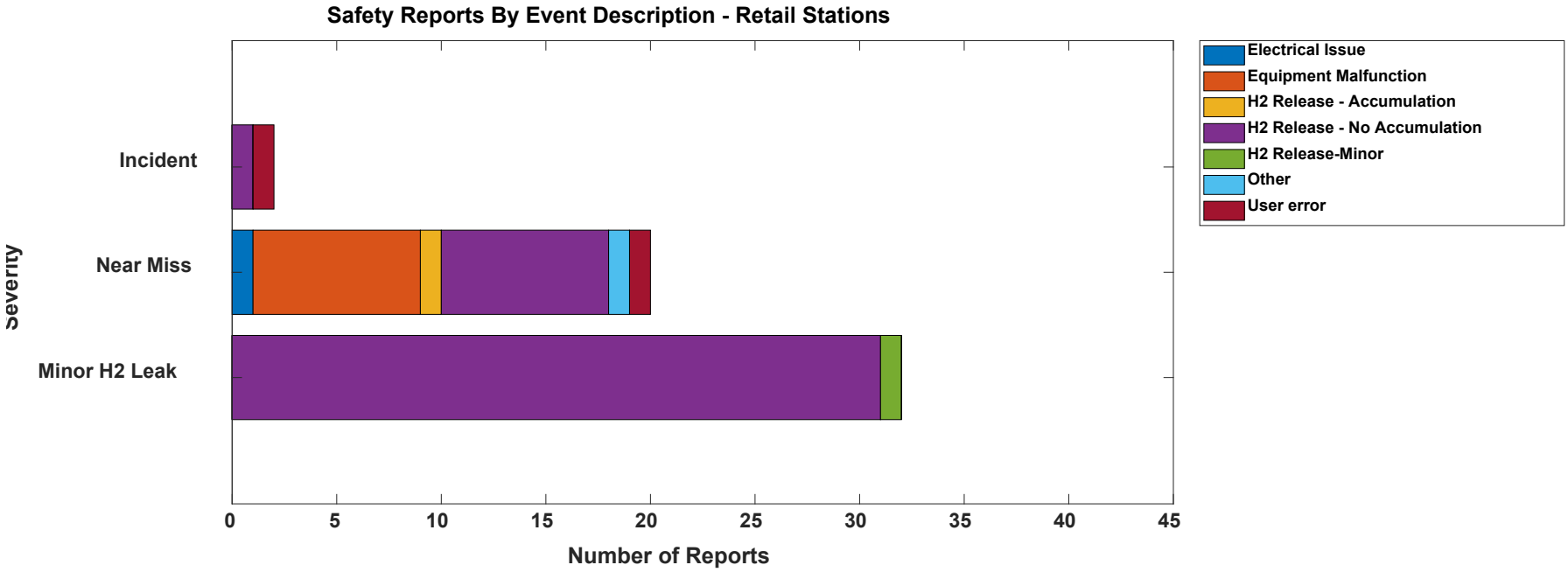
NREL cdpRETAIL_infr_33
Created: Nov-13-20 9:09 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-34
Safety Reports by Event Description



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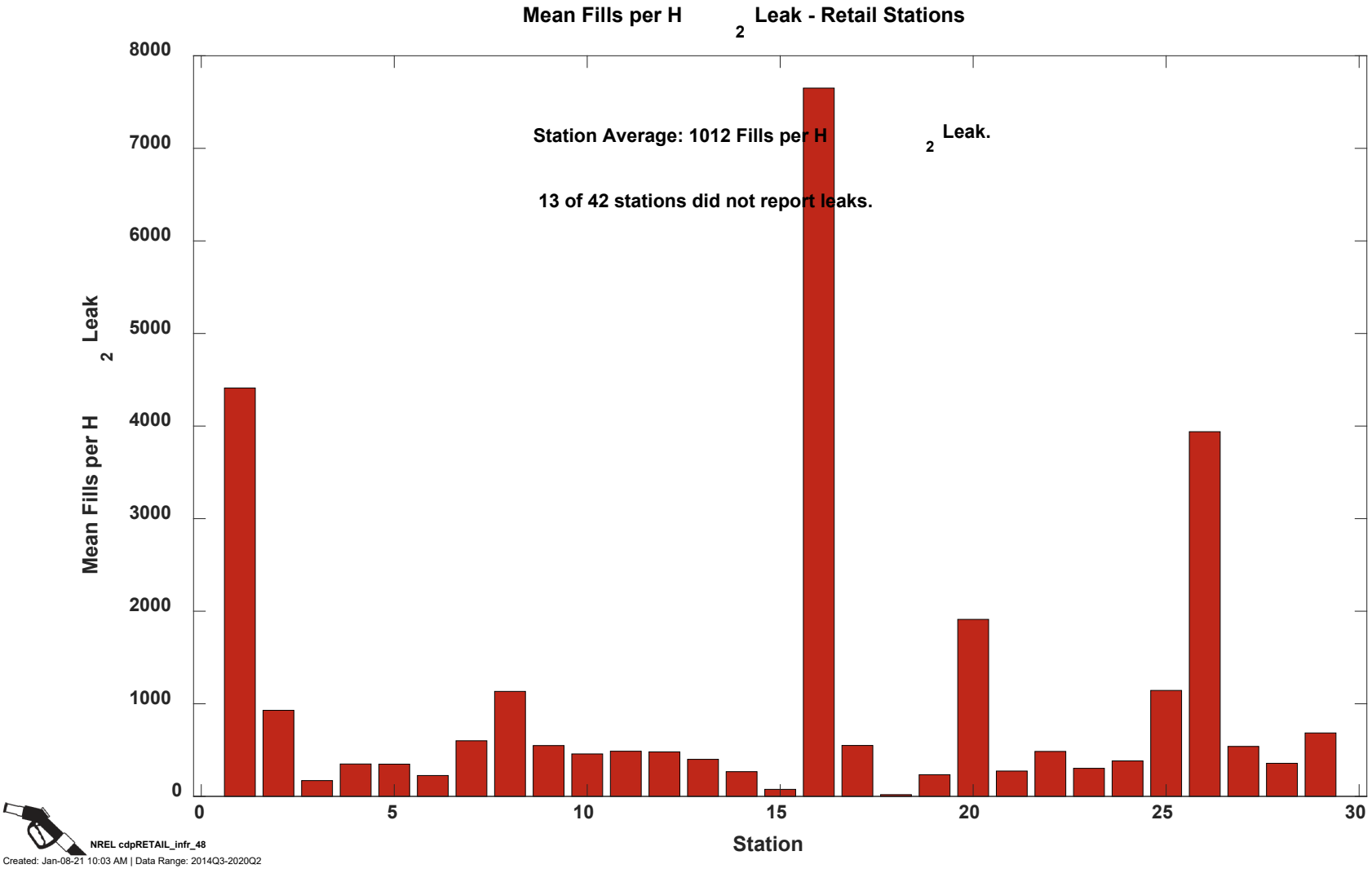
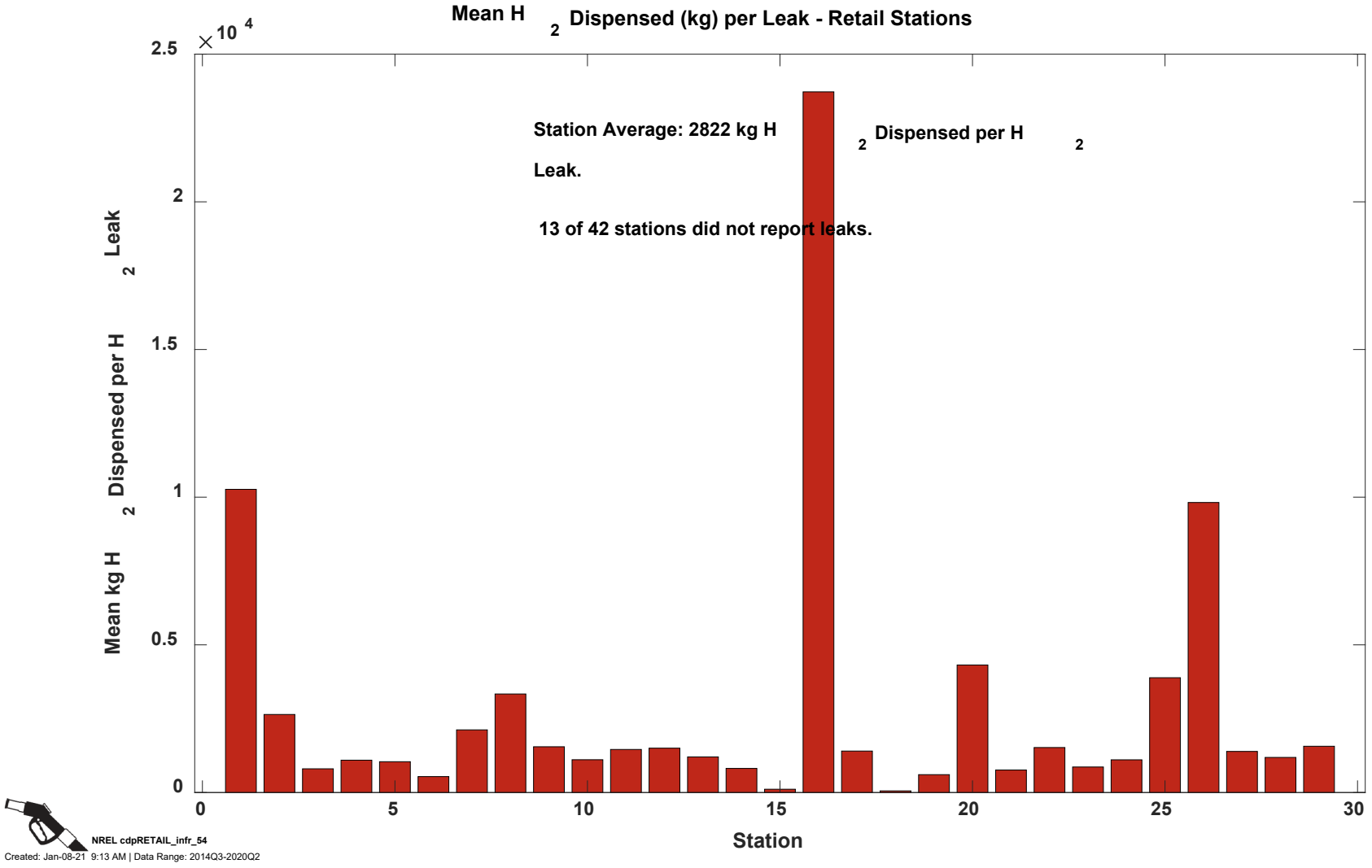
NREL cdpRETAIL_infr_34

Created: Nov-13-20 9:03 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-48
Mean Fills per Hydrogen Leak

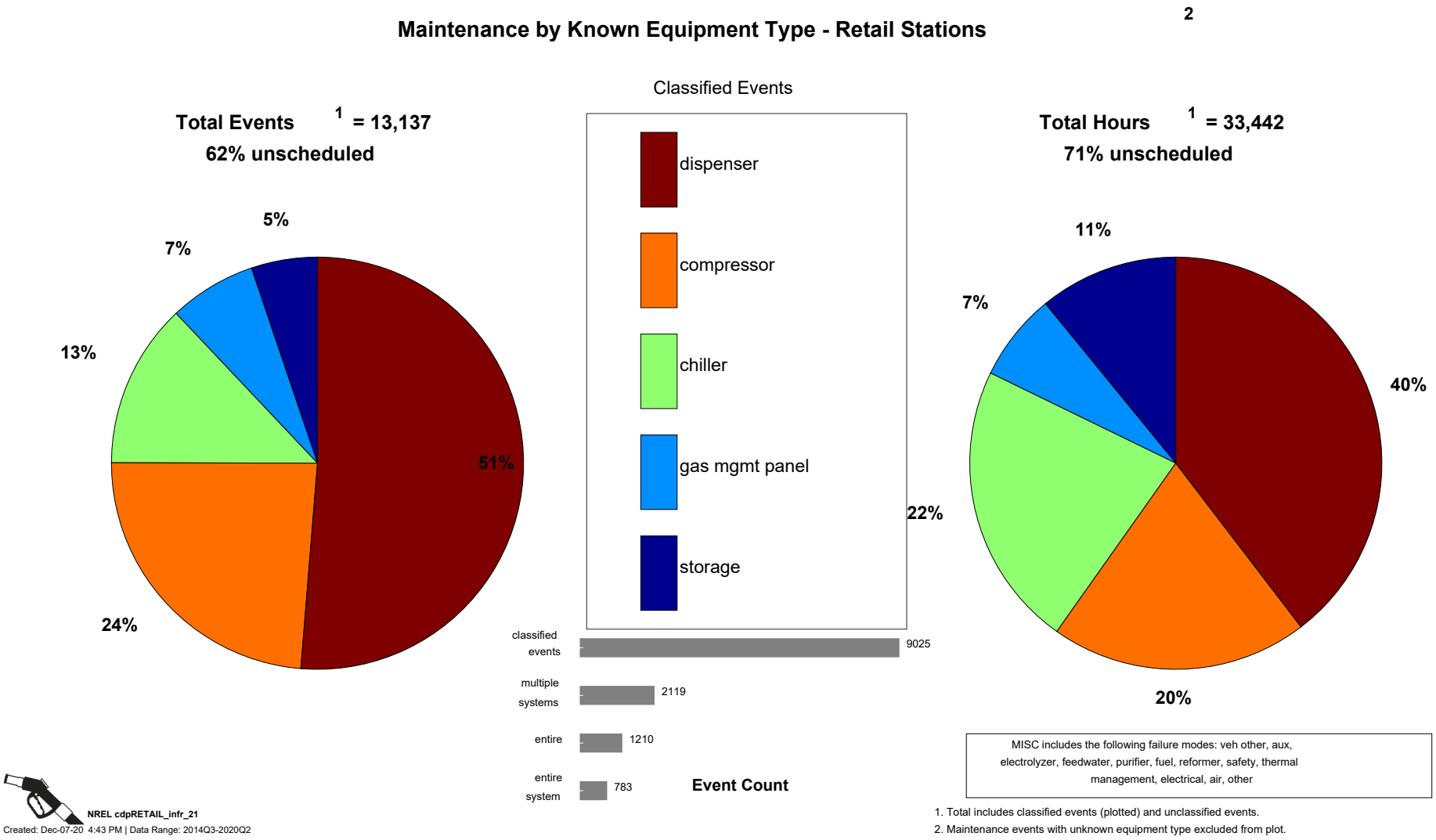


CDP-INFR-54
Mean Hydrogen Dispensed per Hydrogen Leak

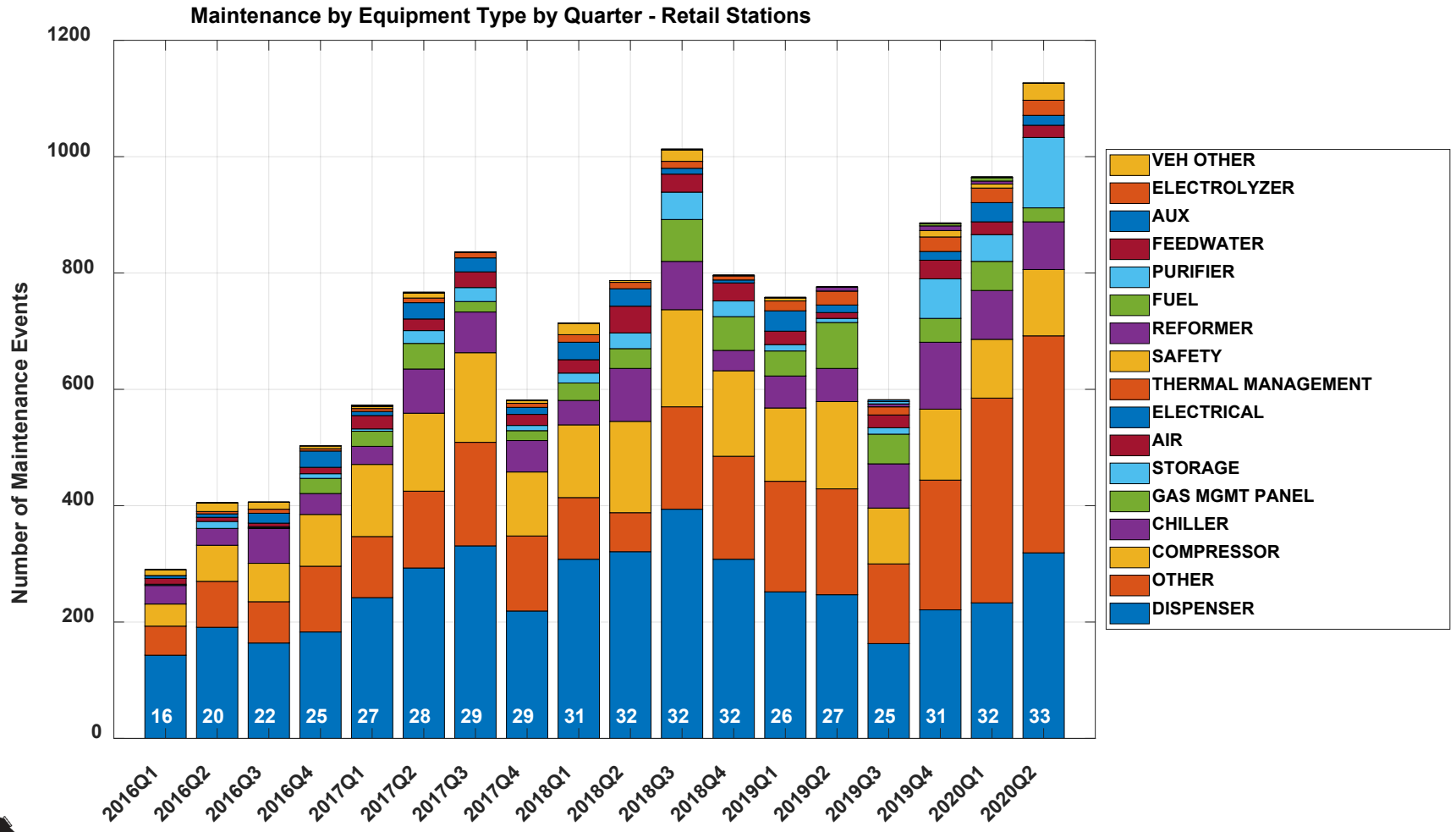


Maintenance and Reliability

CDP-INFR-21
Maintenance by Known Equipment Type



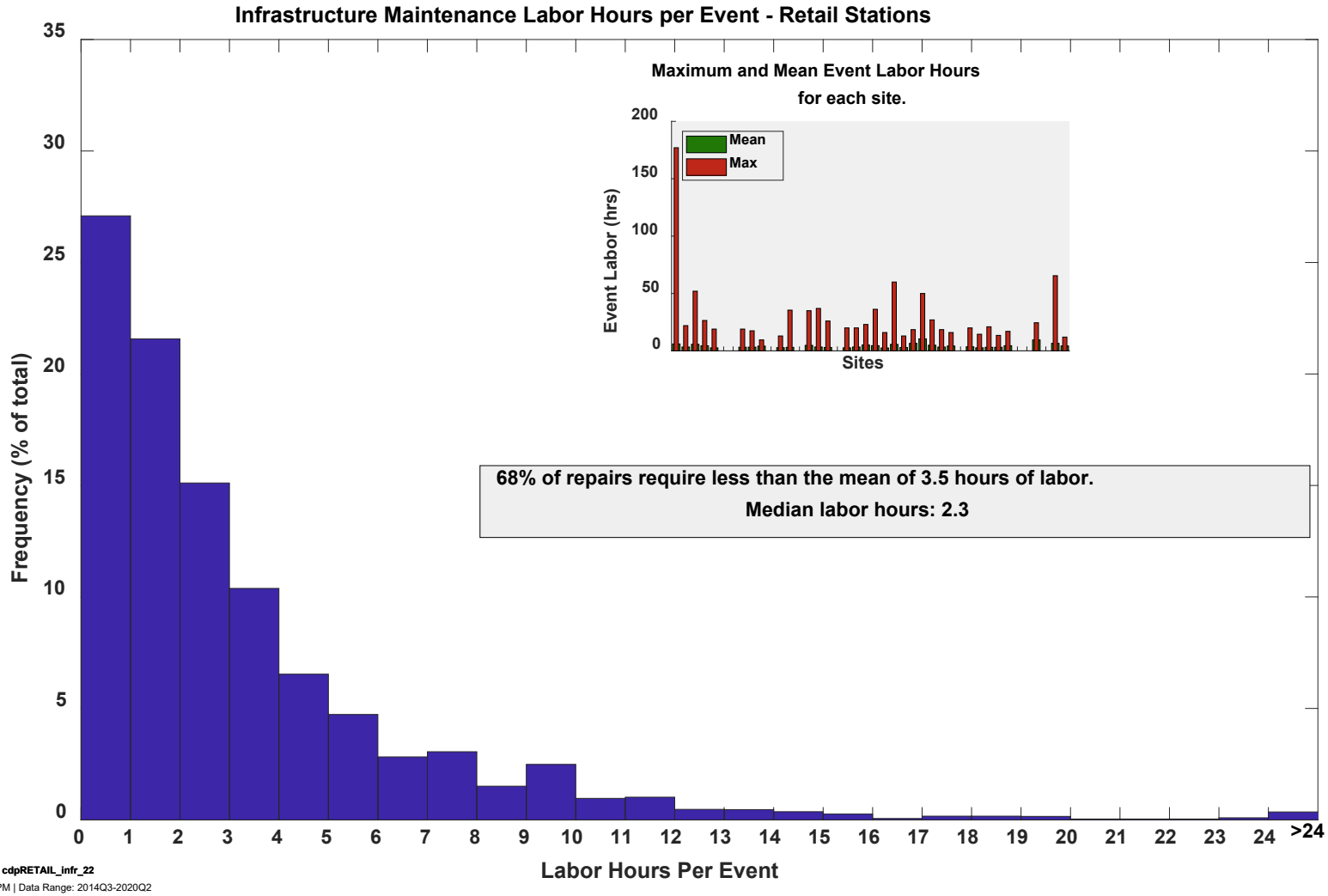
CDP-INFR-94
Maintenance by Equipment Type by Quarter



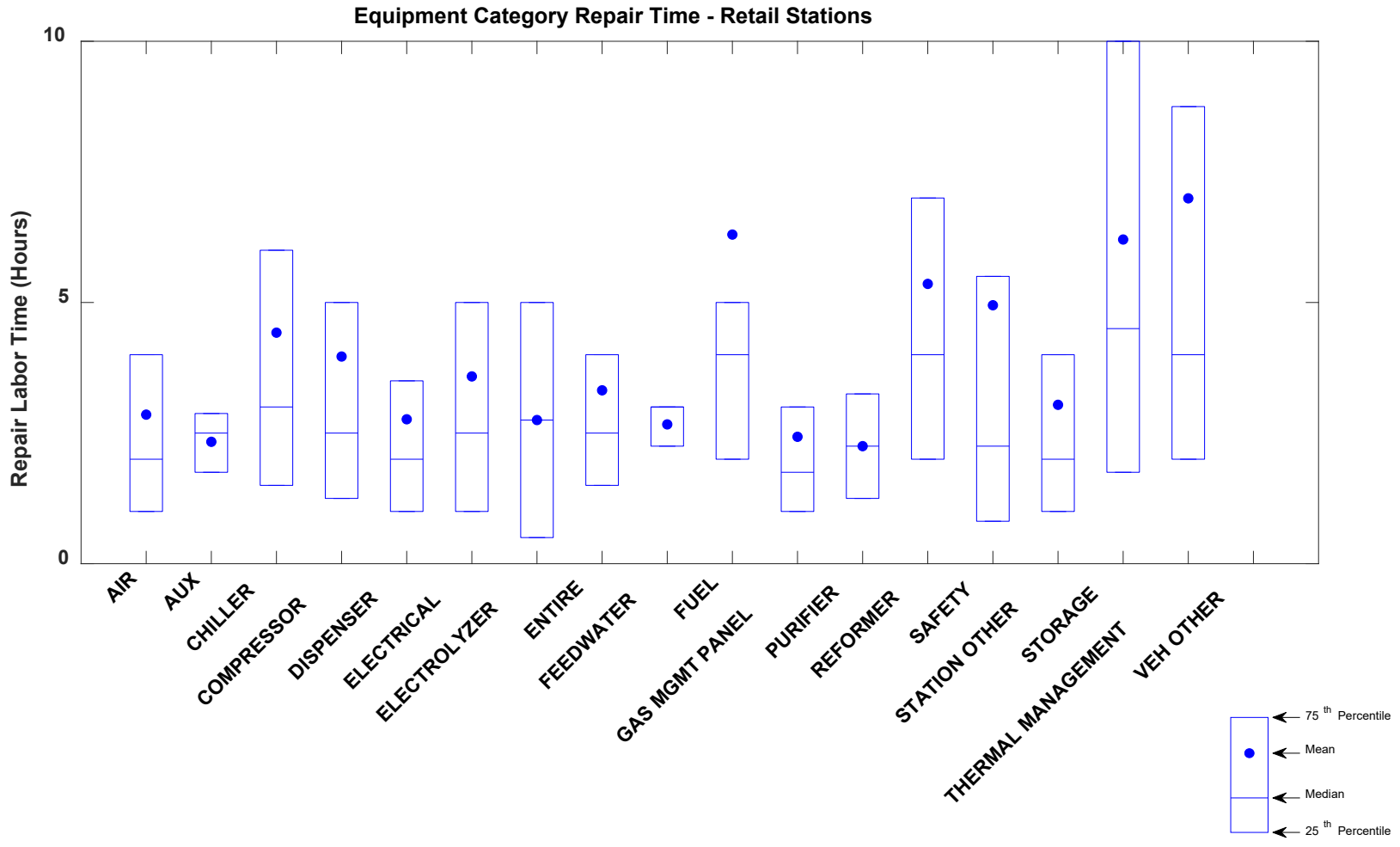
NREL cdpRETAIL_infr_94
Created: Dec-10-20 2:45 PM | Data Range: 2014Q3-2020Q2

Number at bottom of bars is number of stations reporting for that quarter.
"OTHER" includes items for which equipment type could not be determined from the data.

CDP-INFR-22
Maintenance Labor Hours per Event

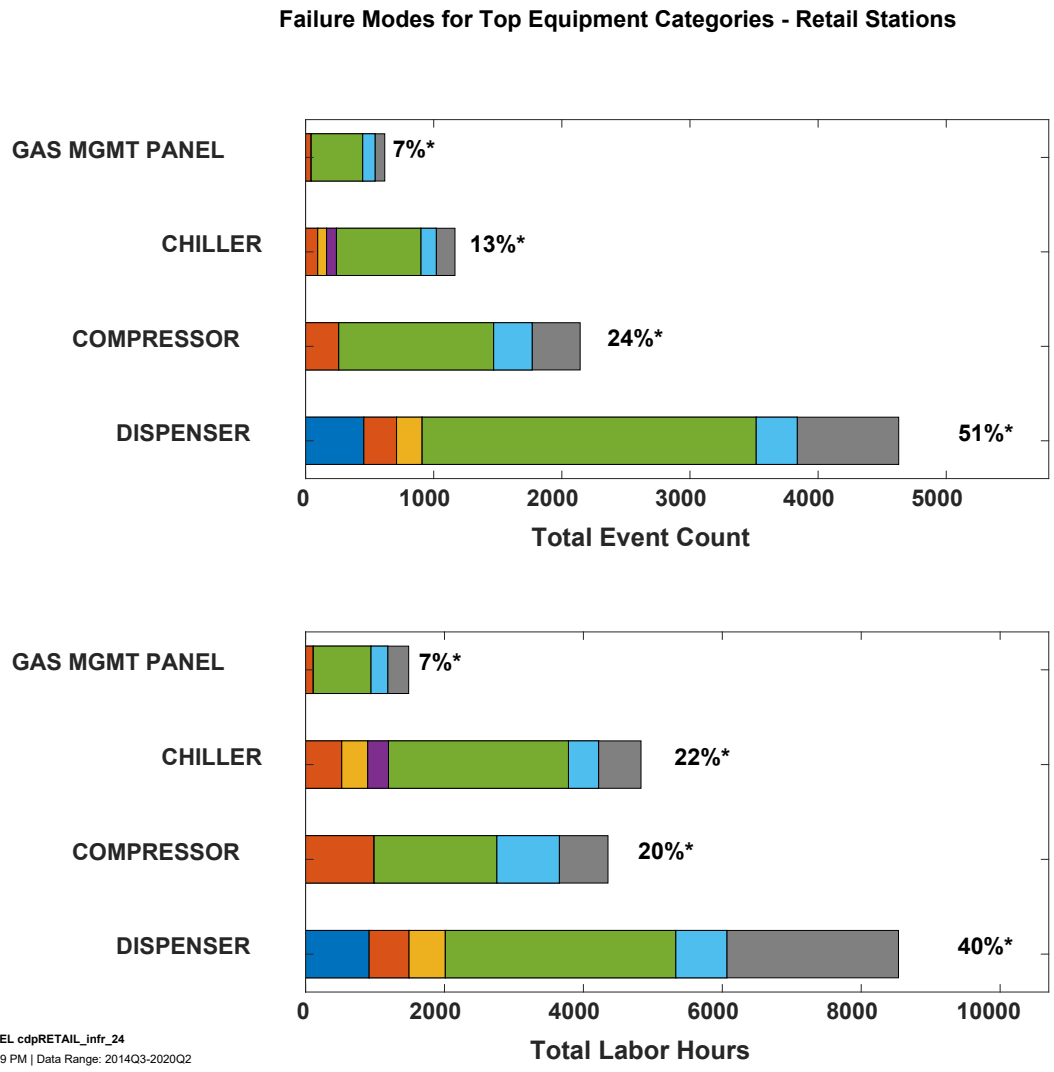


CDP-INFR-23
Equipment Category Repair Time



NREL cdpRETAIL_infr_23
Created: Dec-07-20 4:27 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-24
Failure Modes for Top Equipment Categories

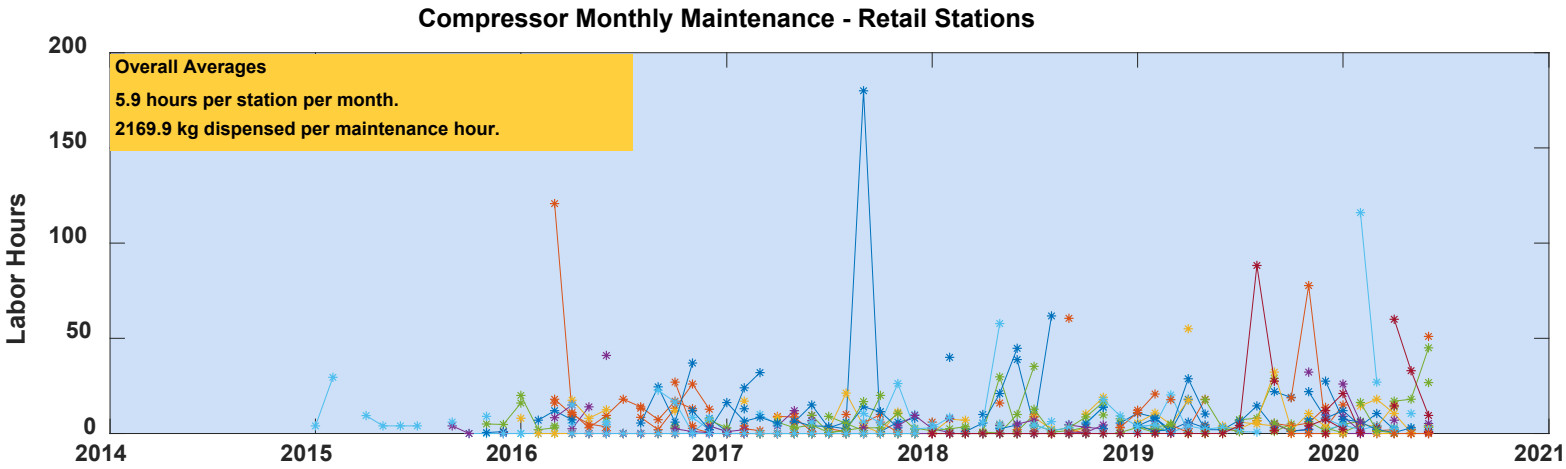


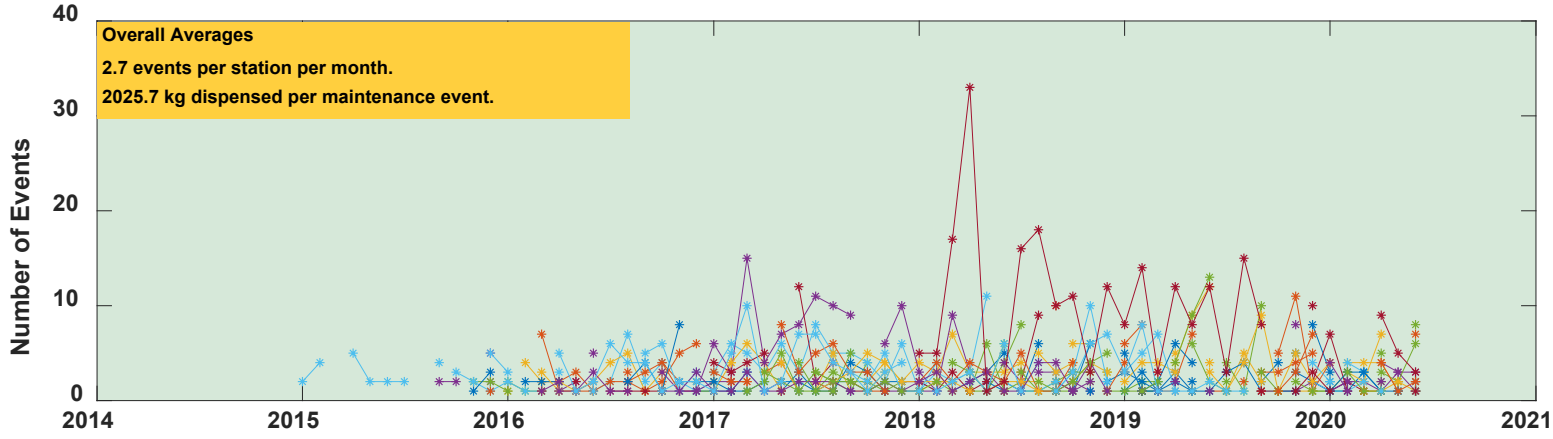
MISC includes the following failure modes: collision, communication error, contamination, debris, design flaw, electrical breaker, end of life, environmental factors, fluid temp, freezing, installation error, level low, loose electrical, loose mechanical, lost signal, maintenance error, manufacturing defect, material deform/degrade/fatigue, metal fatigue, moisture, na, operator error, out of calibration, overtemperature, power outage/quality, pressure loss, software bug, stress outside design limit, tight, vandalism, vibration, other

*** Percentage of total events or hours.**

NREL cdpRETAIL_infr_24
Created: Dec-07-20 4:19 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-26
Compressor Monthly Maintenance

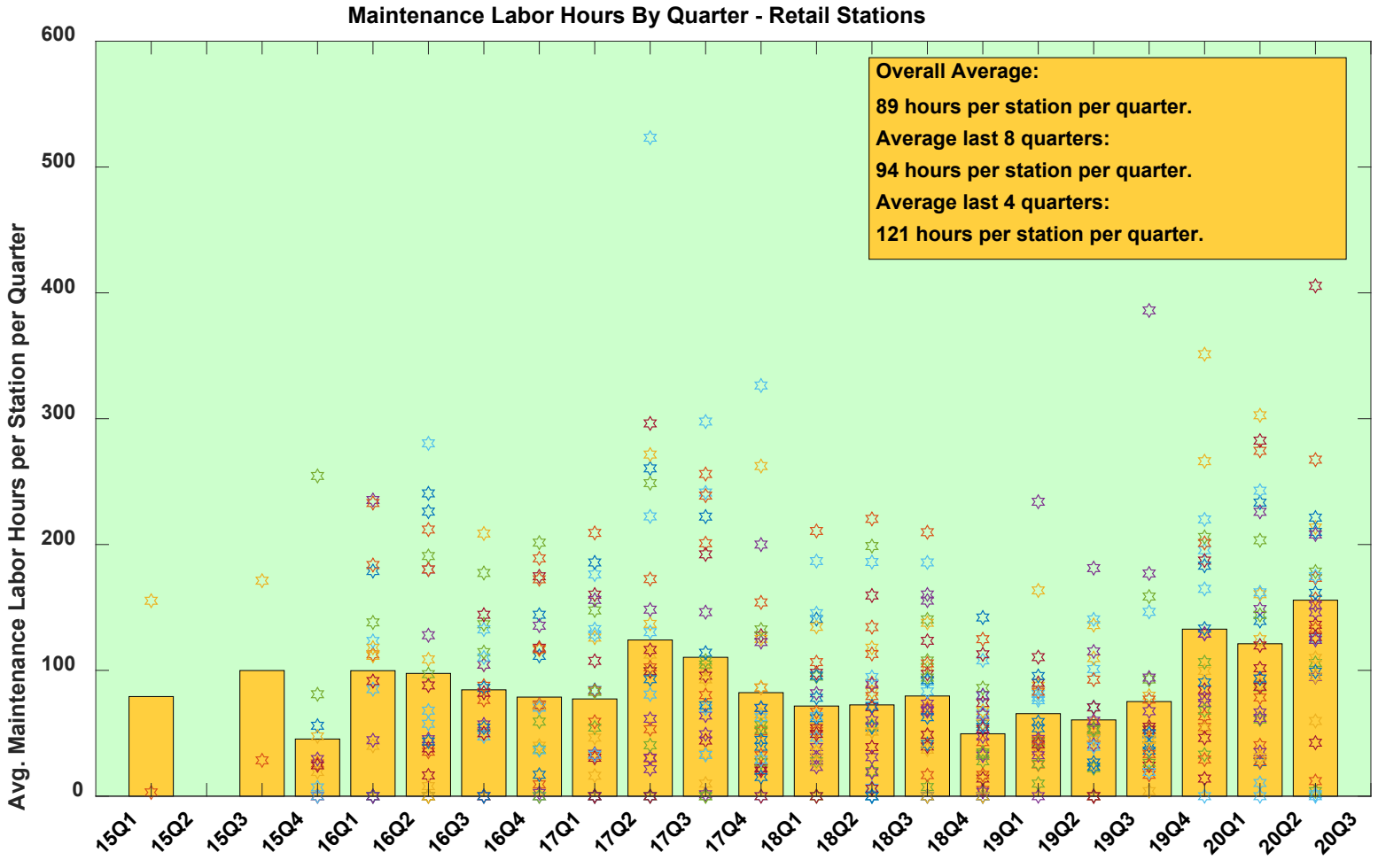




NREL cdpRETAIL_infr_26
Created: Dec-07-20 4:11 PM | Data Range: 2014Q3-2020Q2

* Trendlines connect continuous months of operation for a single station. Gaps in trendlines represent quarters in which a station was offline or missing data. Each station is represented by a unique color.

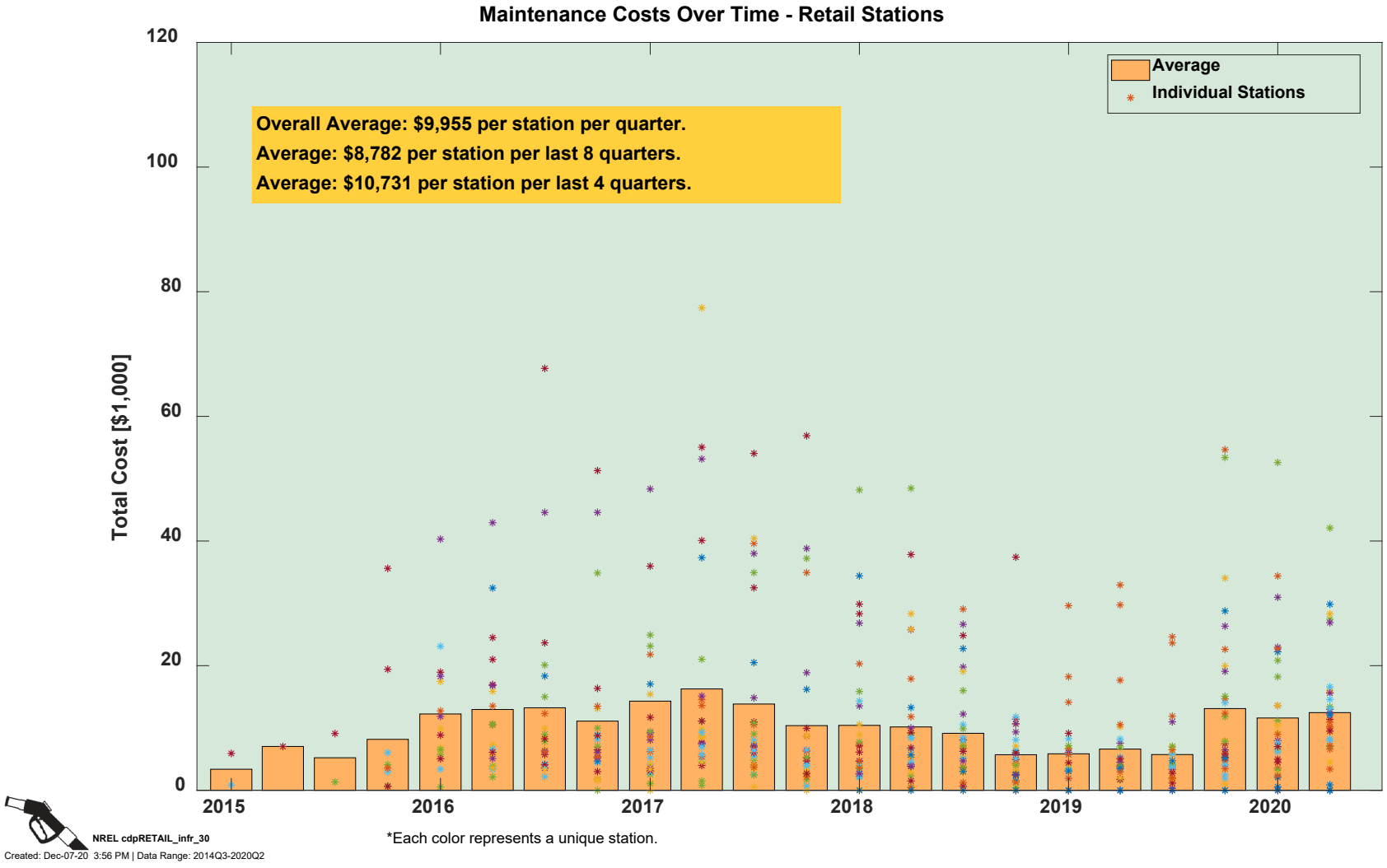
CDP-INFR-28
Maintenance Labor Hours by Quarter



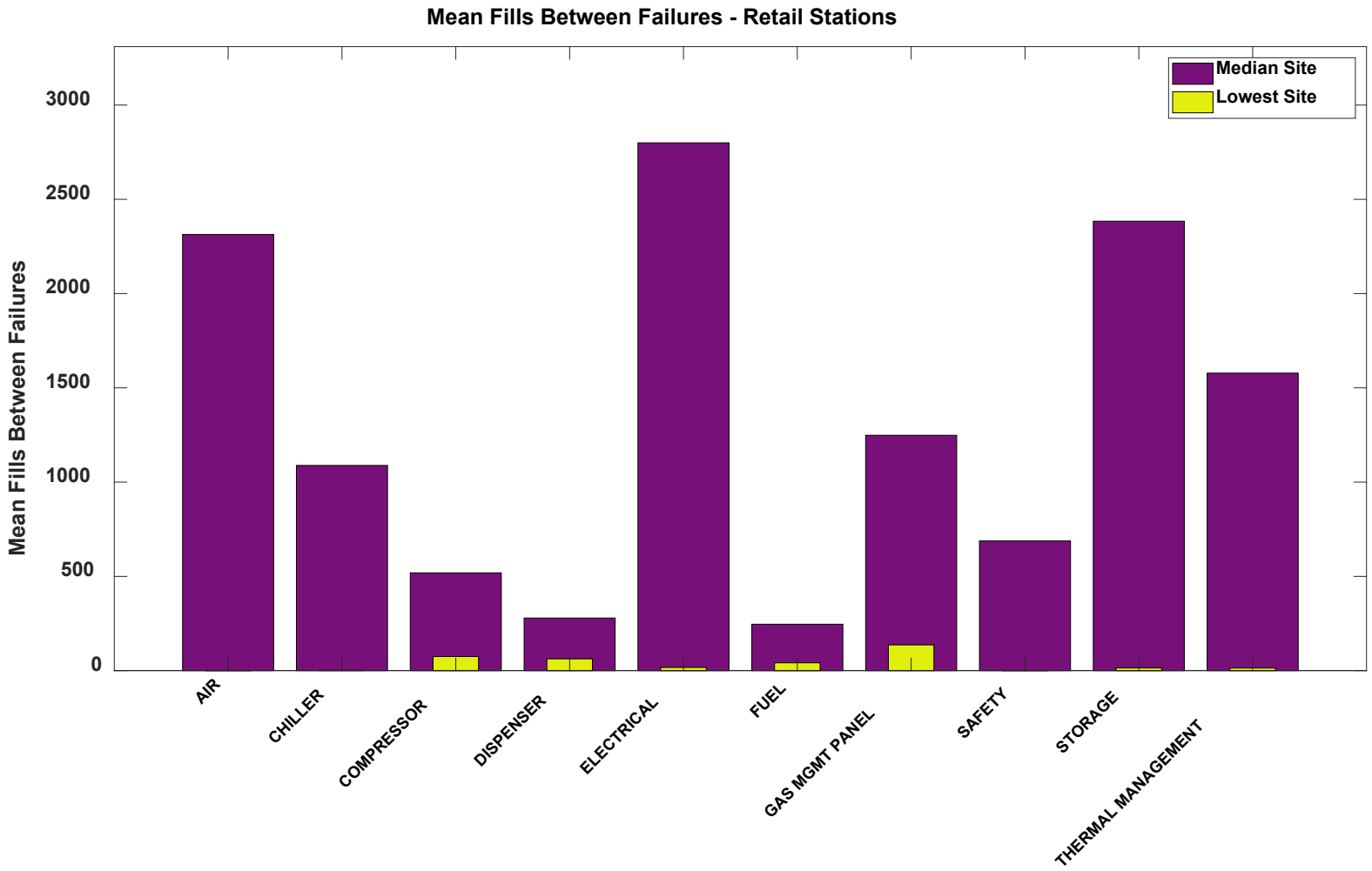
NREL cdpRETAIL_infr_28
Created: Dec-07-20 4:04 PM | Data Range: 2014Q3-2020Q2

Stars represent individual station maintenance hours in a given quarter.

CDP-INFR-30
Maintenance Costs Over Time



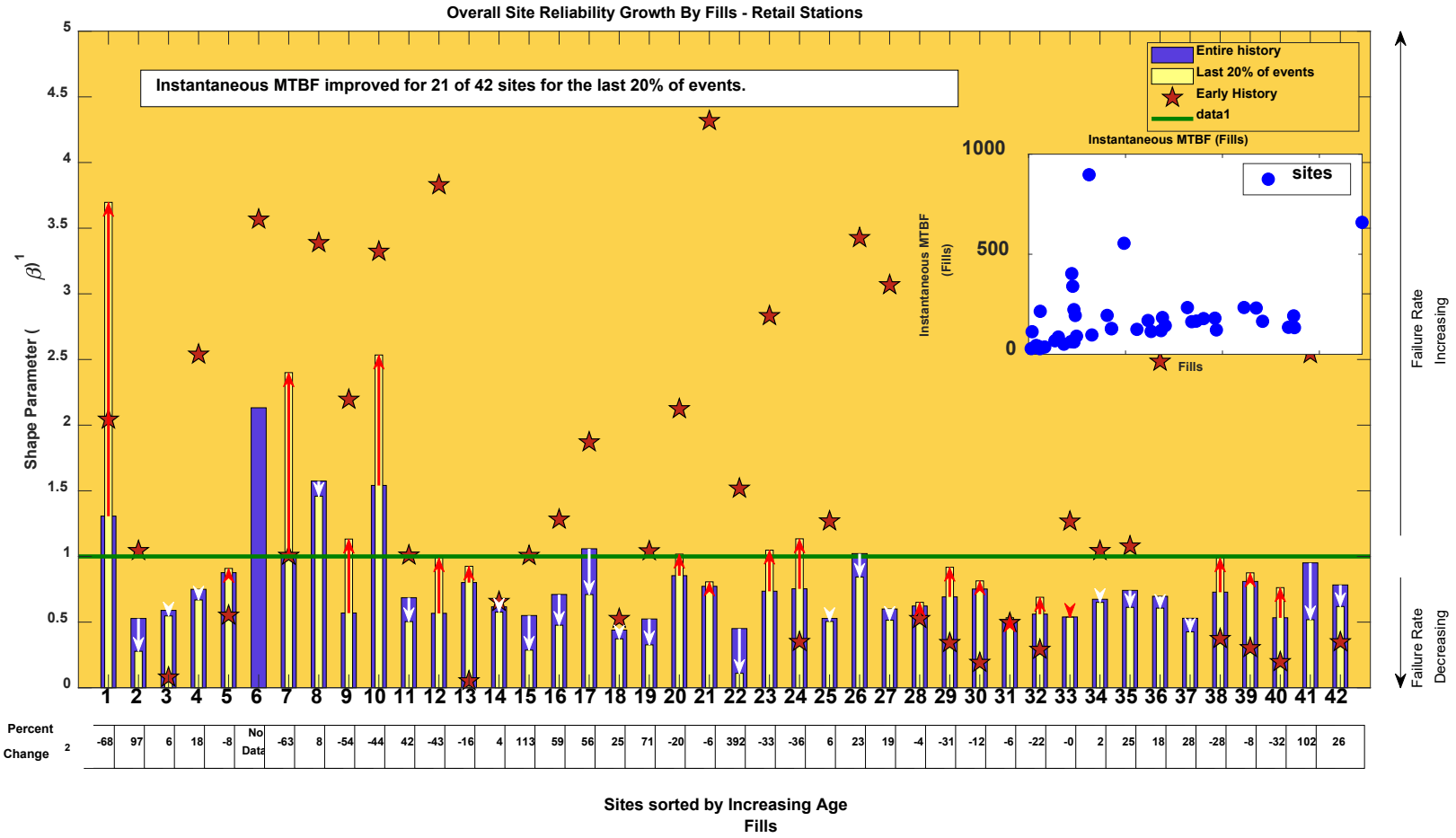
CDP-INFR-49
Mean Fills Between Failures



NREL cdpRETAIL_infr_49

Created: Jan-08-21 9:56 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-50
Reliability Growth by Fills

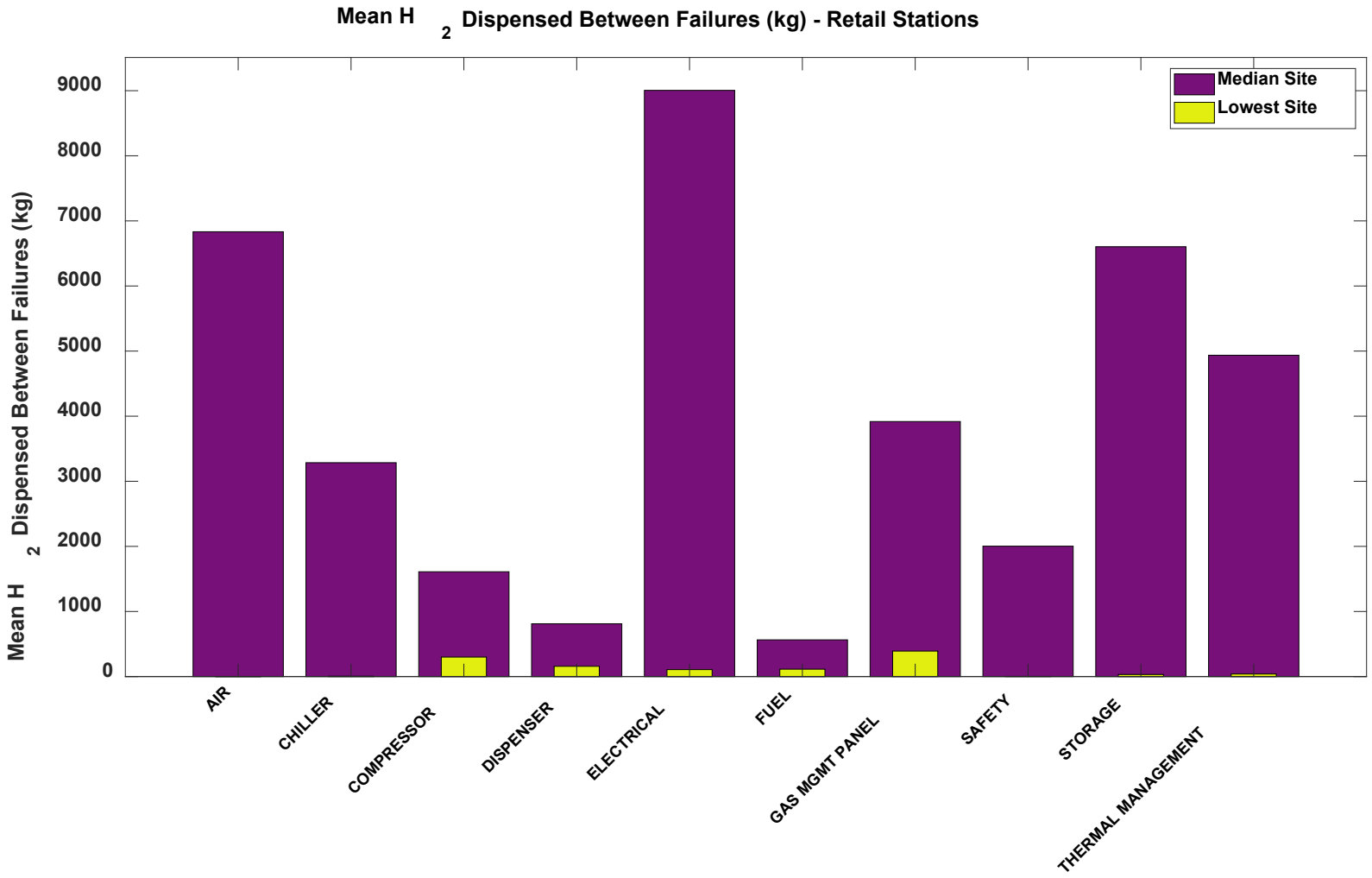


NREL cdpRETAIL_infr_50
Created: Jan-08-21 9:41 AM | Data Range: 2014Q3-2020Q2

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

2. % change in instantaneous mean Fills between failures

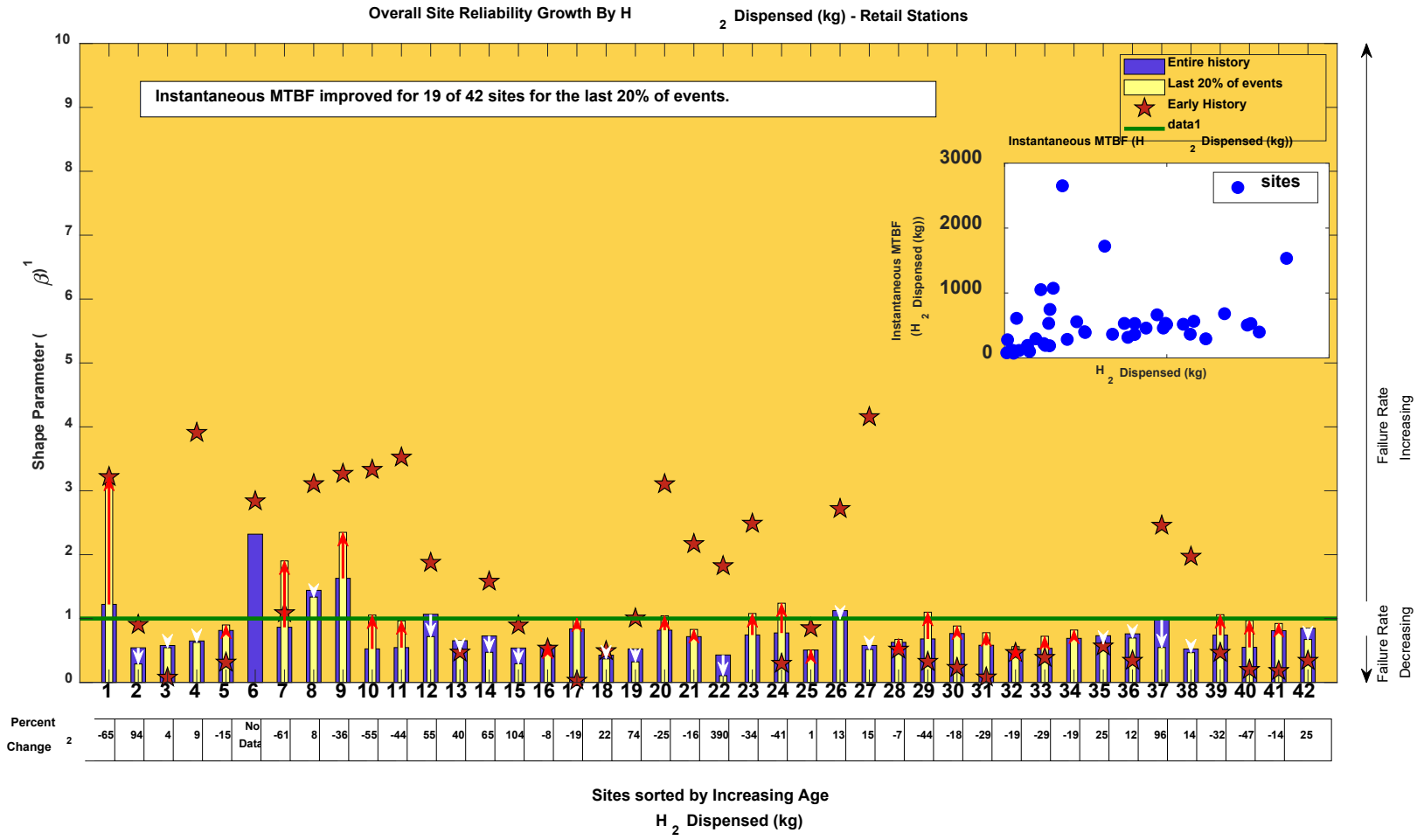
CDP-INFR-51
Mean Amount Dispensed Between Failures



NREL cdpRETAIL_infr_51

Created: Jan-08-21 9:34 AM | Data Range: 2014Q3-2020Q2

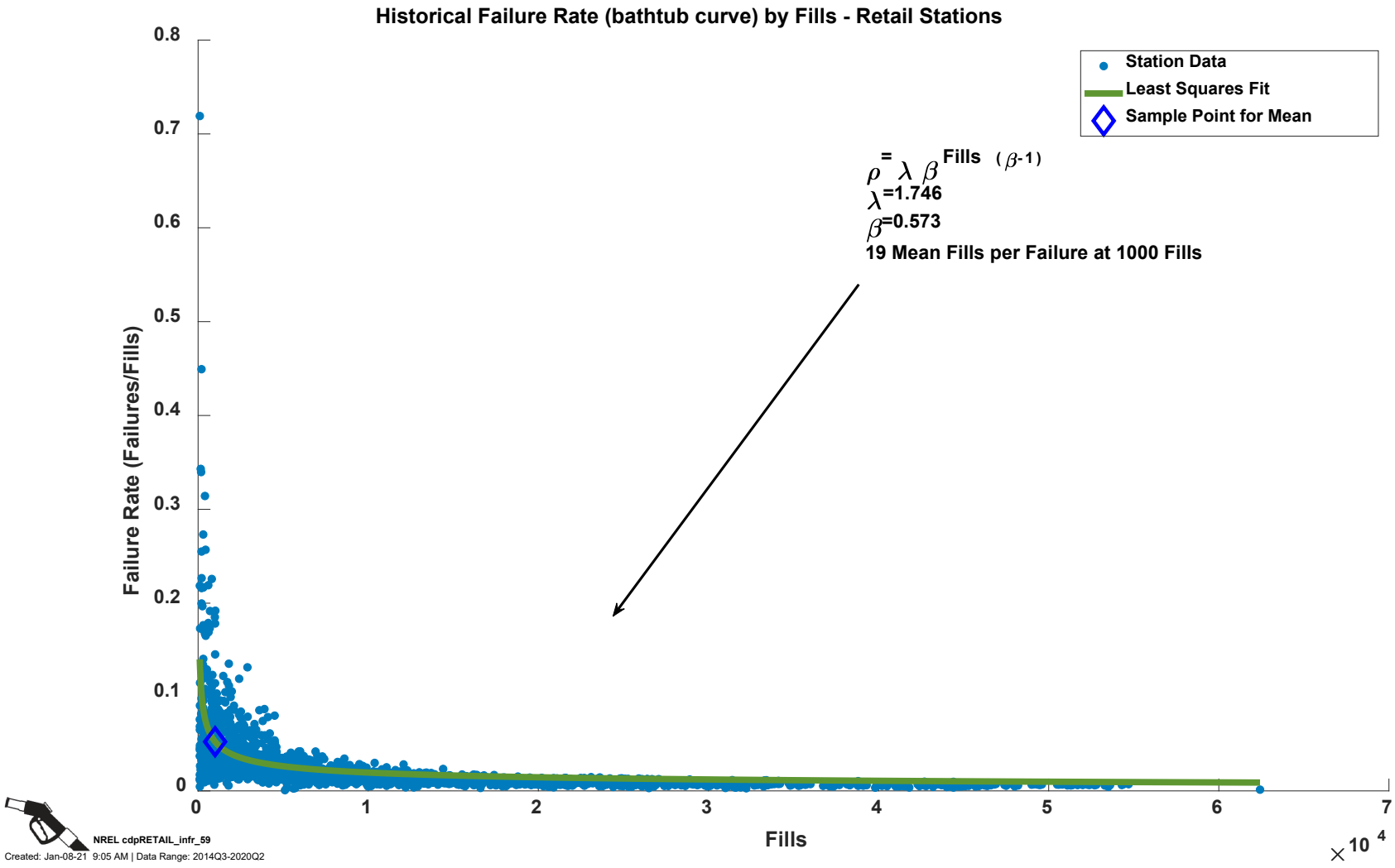
CDP-INFR-52
Reliability Growth by Amount Dispensed



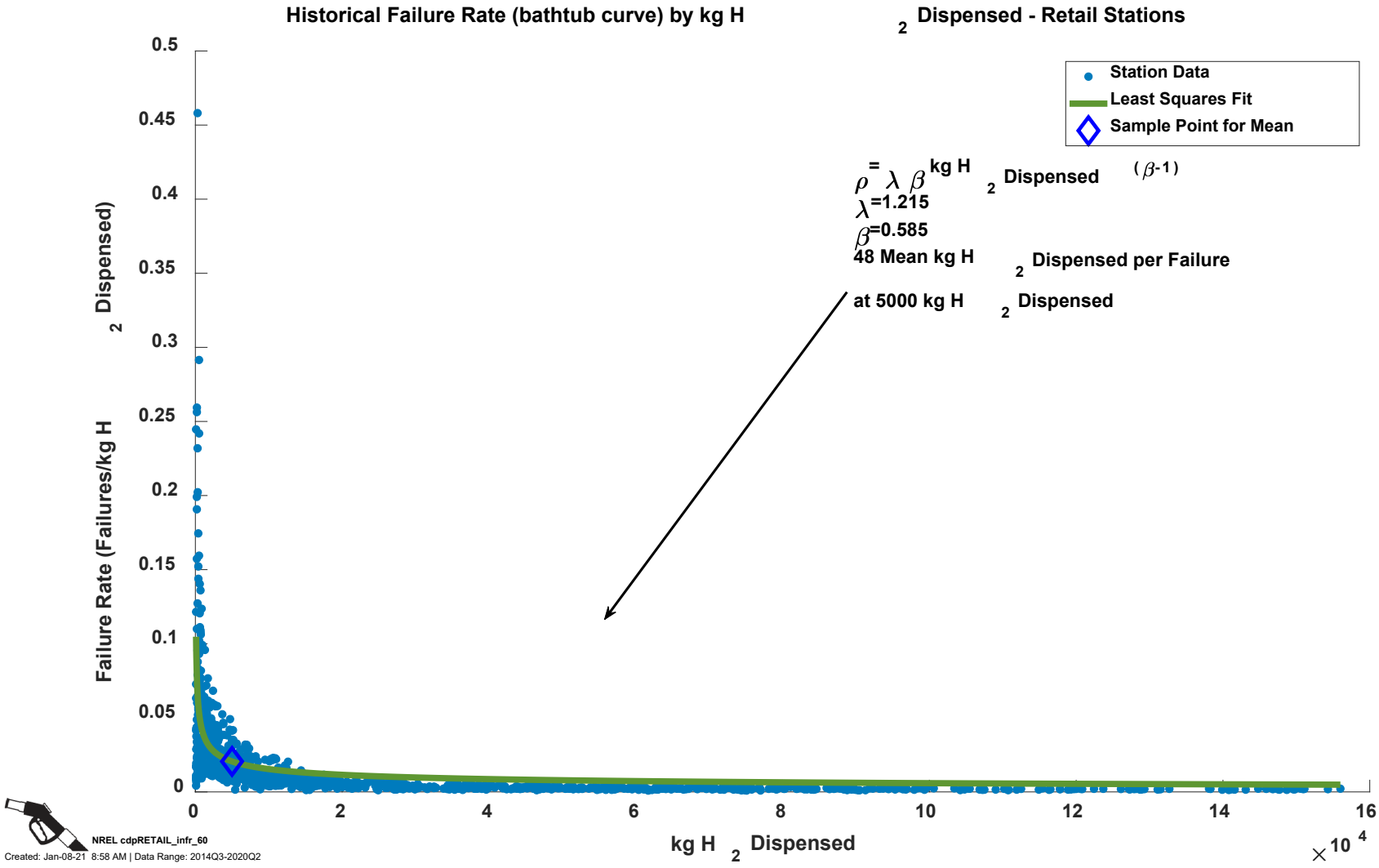
NREL cdpRETAIL_infr_52
Created: Jan-08-21 9:20 AM | Data Range: 2014Q3-2020Q2

1. IEC 61164:2004(E)., Reliability Growth - Statistical Test and Evaluation Methods, IEC. 2004.
2. % change in instantaneous mean H2 Dispensed (kg) between failures

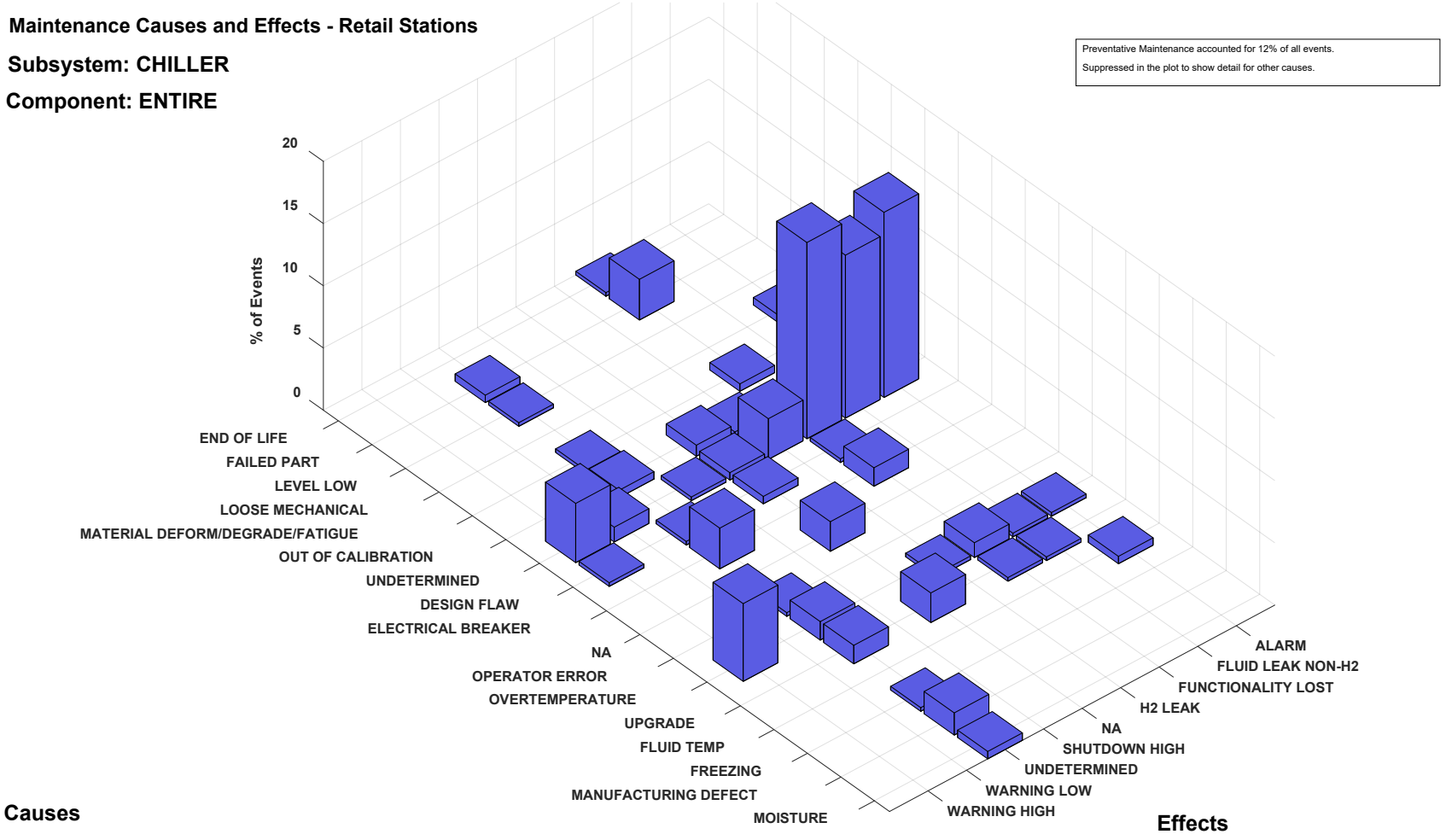
CDP-INFR-59
Historical Failure Rate by Fills



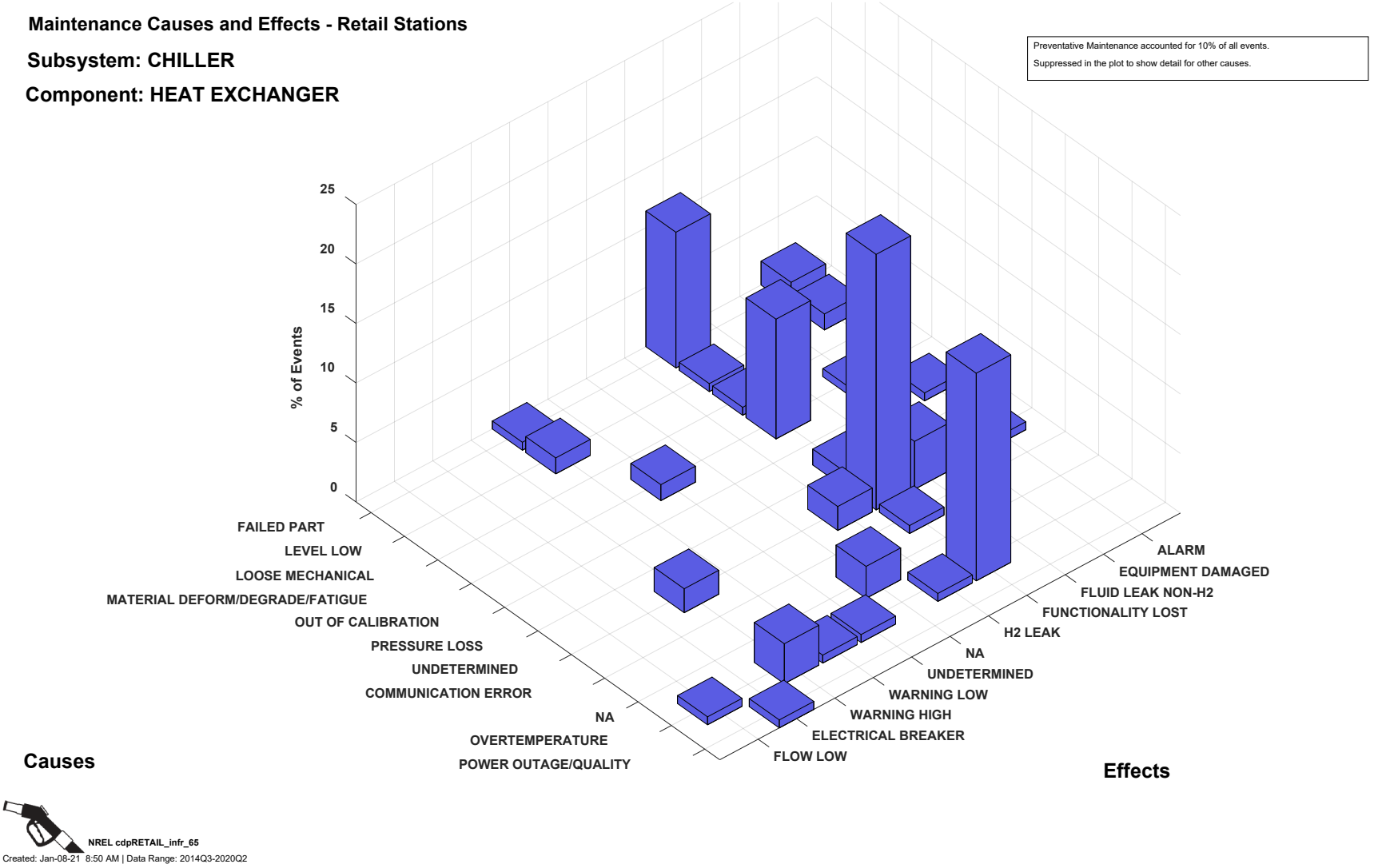
CDP-INFR-60
Historical Failure Rate by Amount Dispensed



CDP-INFR-64
Maintenance Causes and Effects: Chiller (Entire)



CDP-INFR-65
Maintenance Causes and Effects: Chiller (Valve)



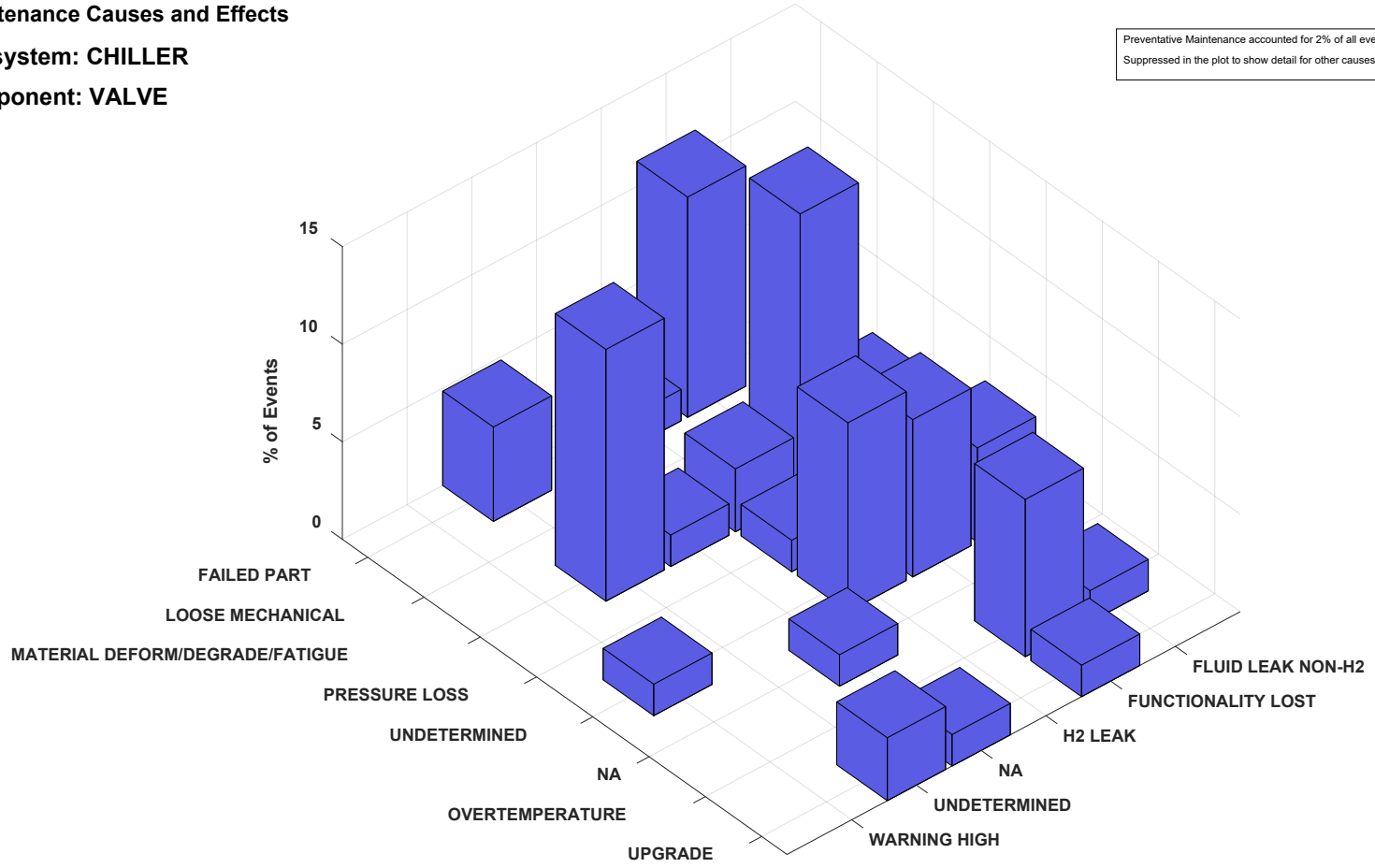
CDP-INFR-66
Maintenance Causes and Effects: Chiller (Refrigerant)

Maintenance Causes and Effects

Subsystem: CHILLER

Component: VALVE

Preventative Maintenance accounted for 2% of all events.
Suppressed in the plot to show detail for other causes.

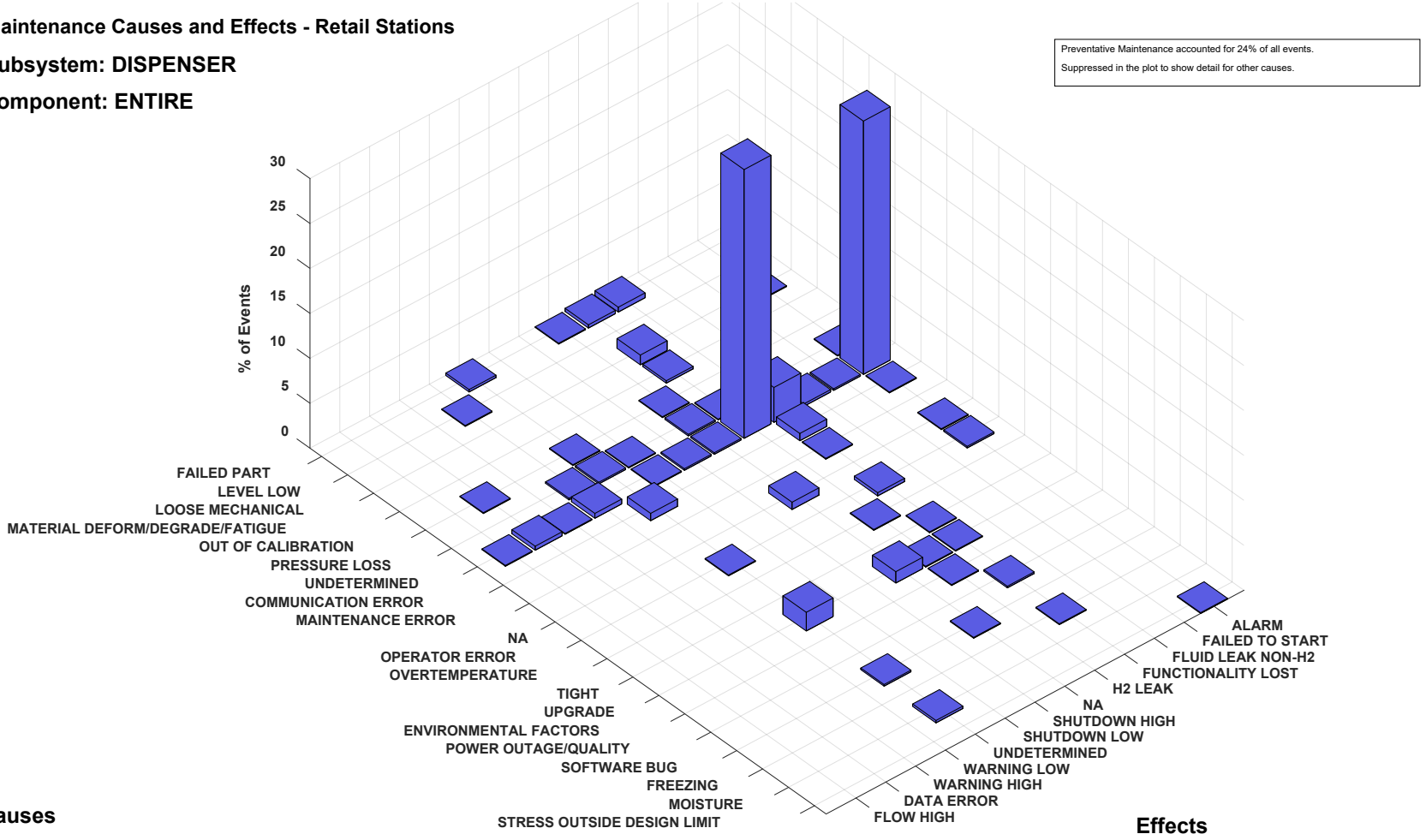


Causes

Effects

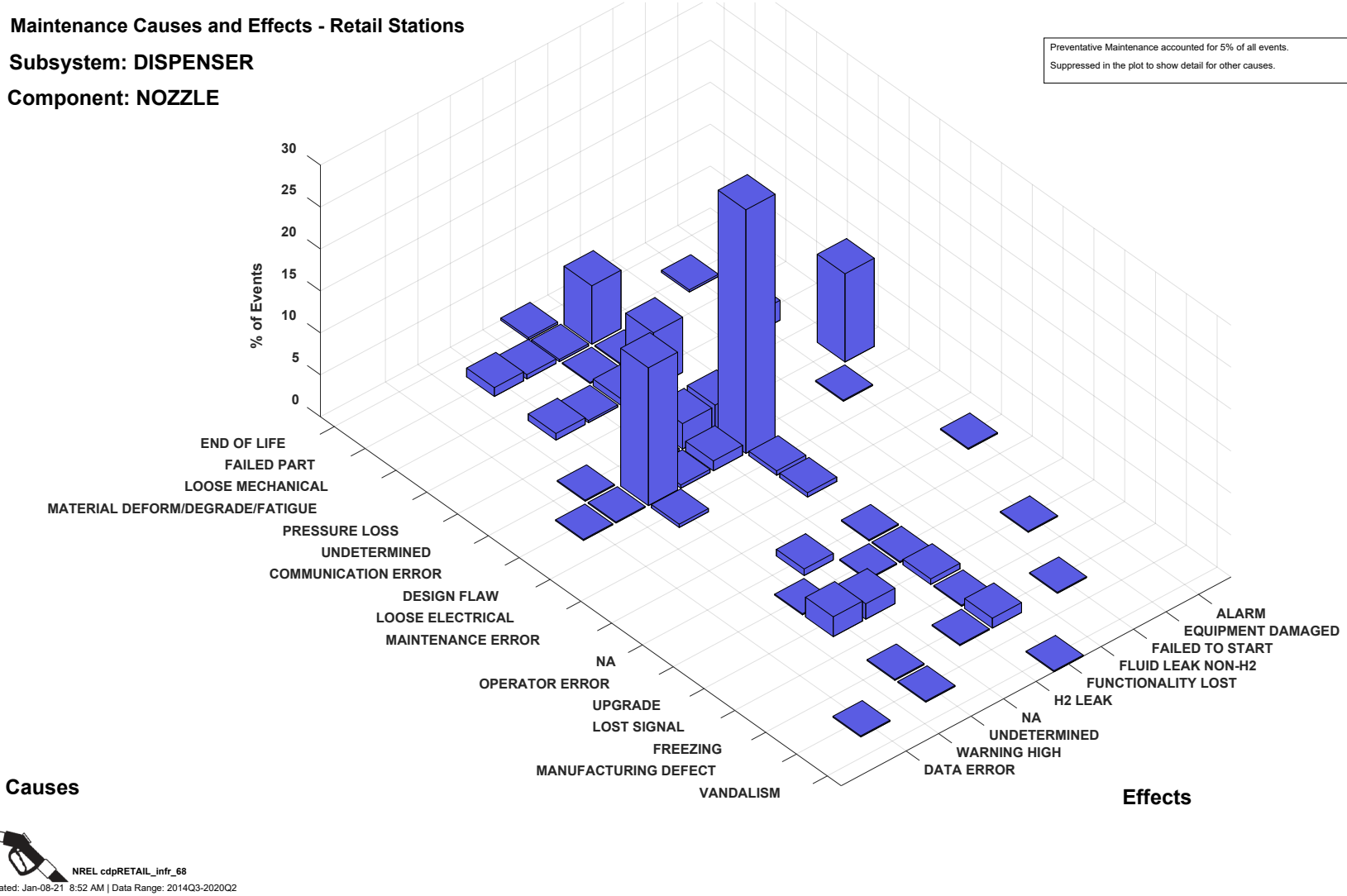
NREL cdpRETAIL_infr_66
Created: Jan-08-21 8:50 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-67
Maintenance Causes and Effects: Dispenser (Entire)



NREL cdpRETAIL_infr_67
Created: Jan-08-21 8:51 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-68
Maintenance Causes and Effects: Dispenser (Nozzle)



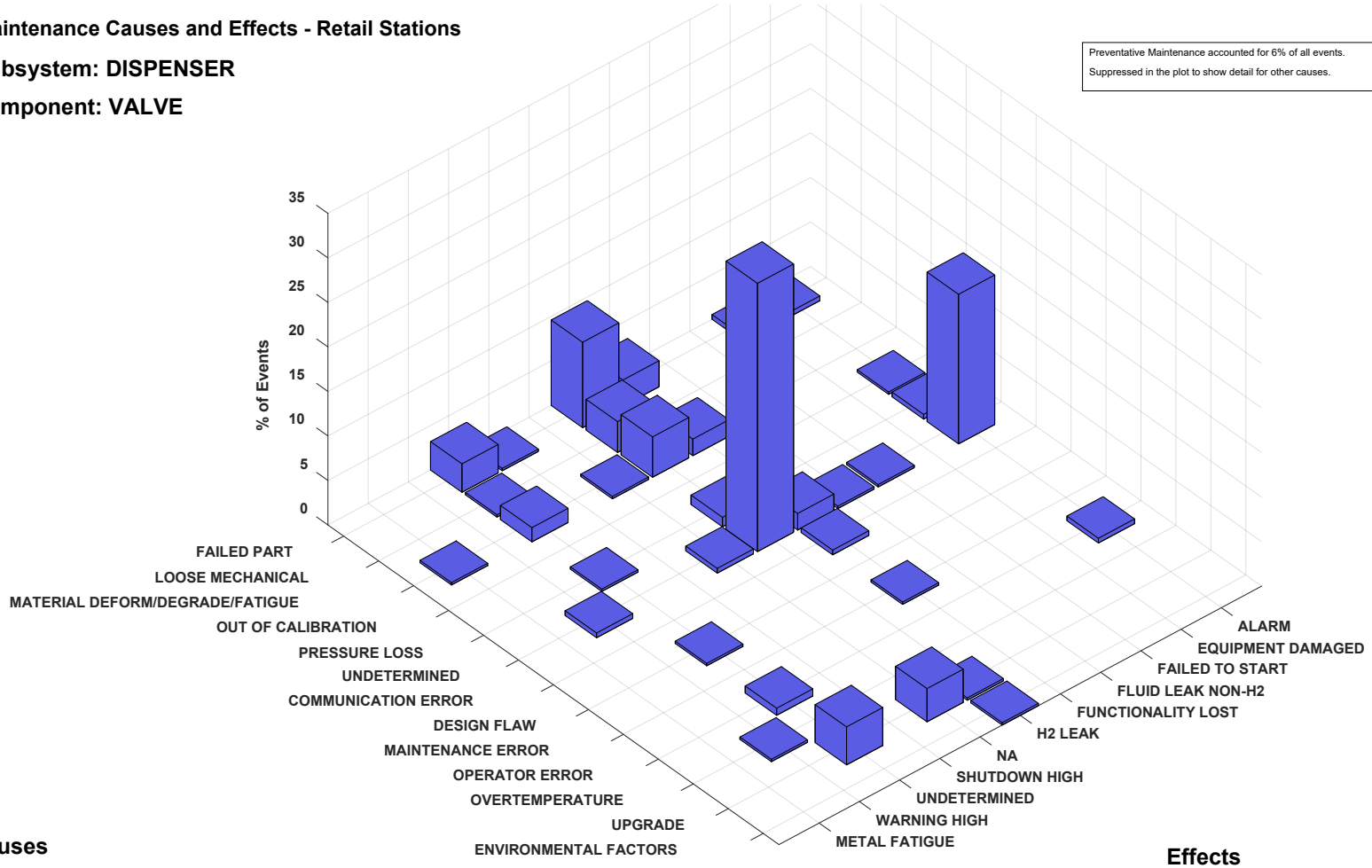
CDP-INFR-69
Maintenance Causes and Effects: Dispenser (Fitting)

Maintenance Causes and Effects - Retail Stations

Subsystem: DISPENSER

Component: VALVE

Preventative Maintenance accounted for 6% of all events.
Suppressed in the plot to show detail for other causes.



Causes

Effects

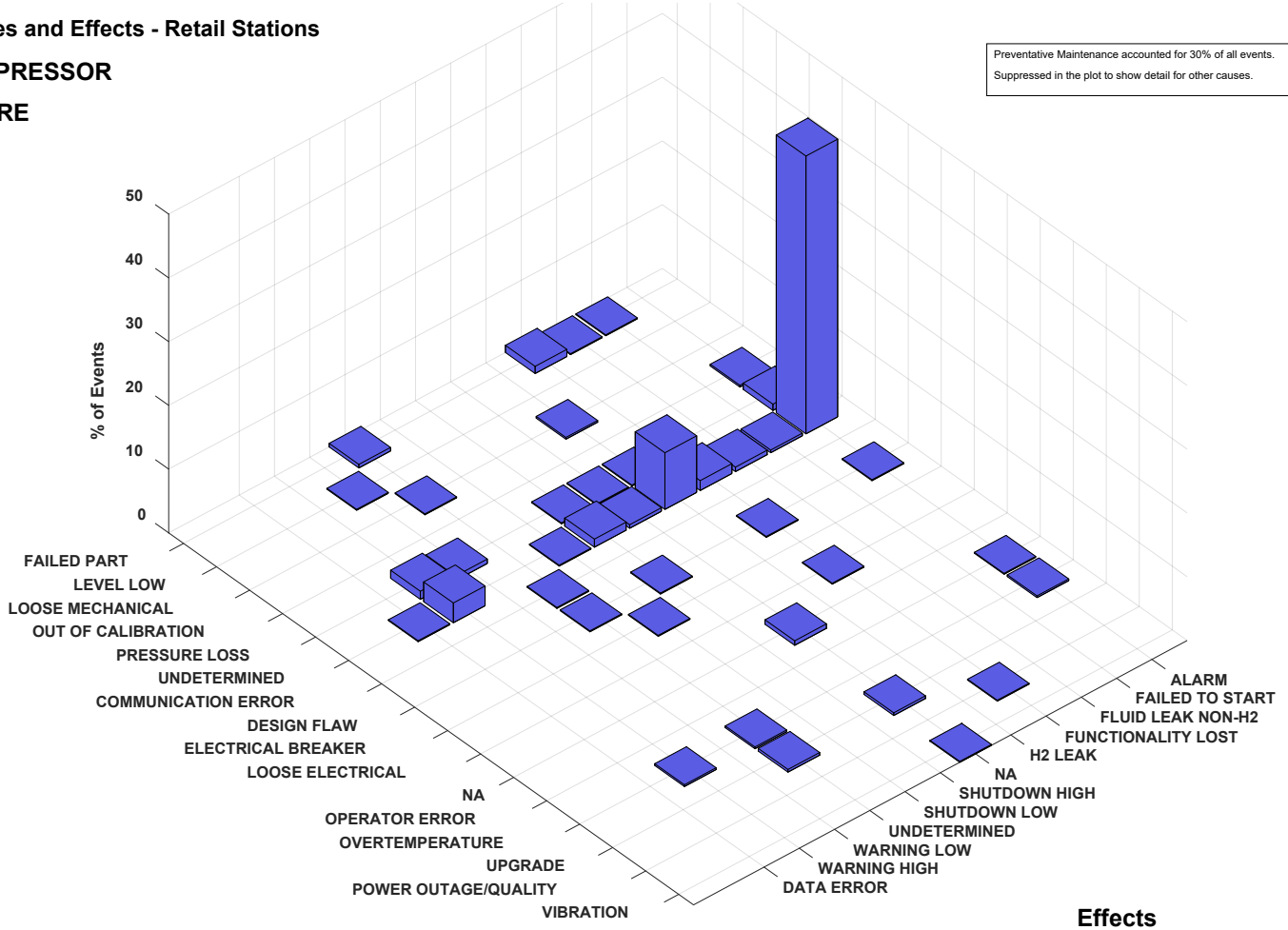
NREL cdpRETAIL_infr_69
Created: Jan-08-21 8:53 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-70
Maintenance Causes and Effects: Compressor (Entire)

Maintenance Causes and Effects - Retail Stations

Subsystem: COMPRESSOR

Component: ENTIRE



NREL cdpRETAIL_infr_70

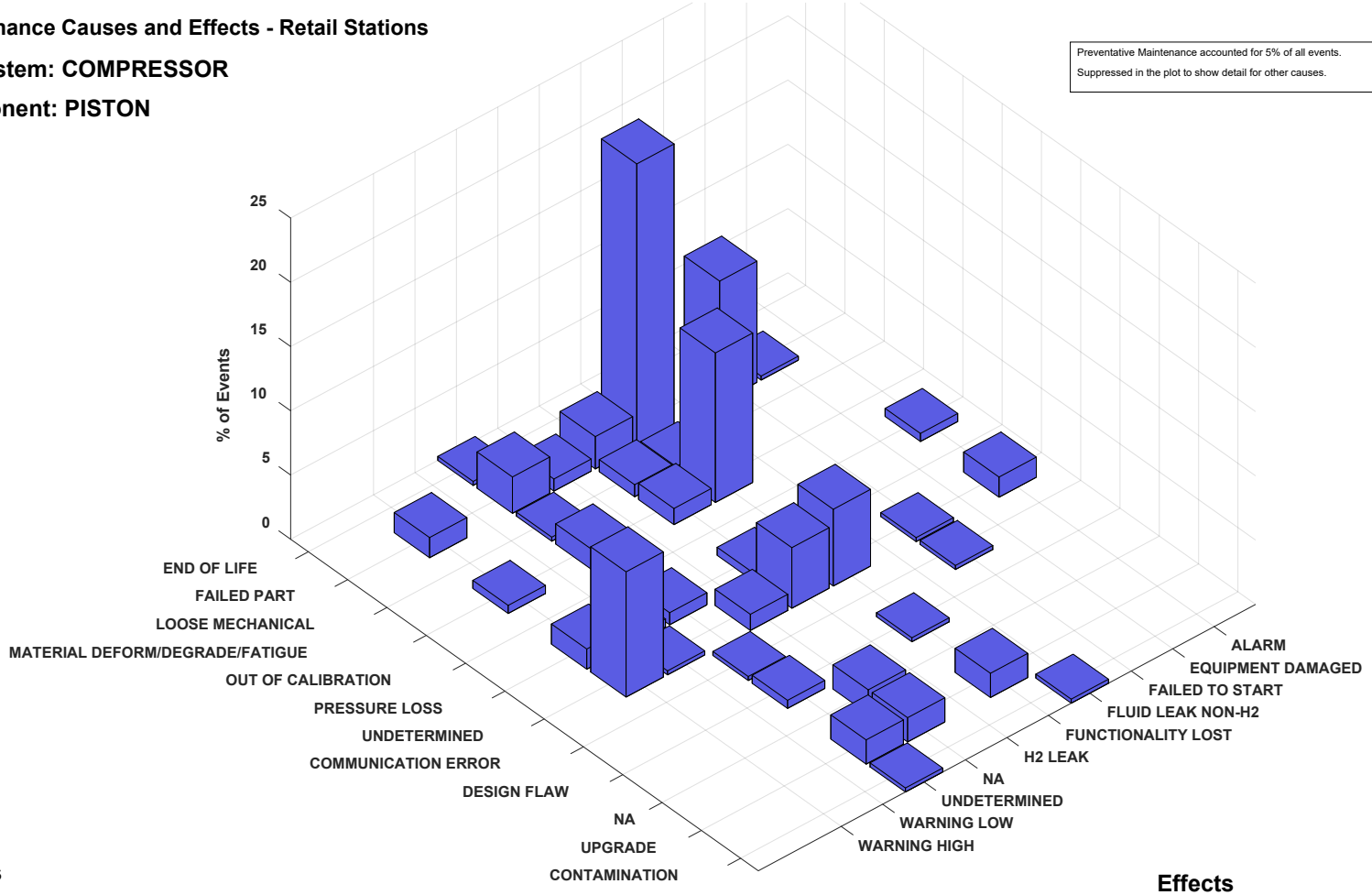
Created: Jan-08-21 8:55 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-71
Maintenance Causes and Effects: Compressor (Piston)

Maintenance Causes and Effects - Retail Stations

Subsystem: COMPRESSOR

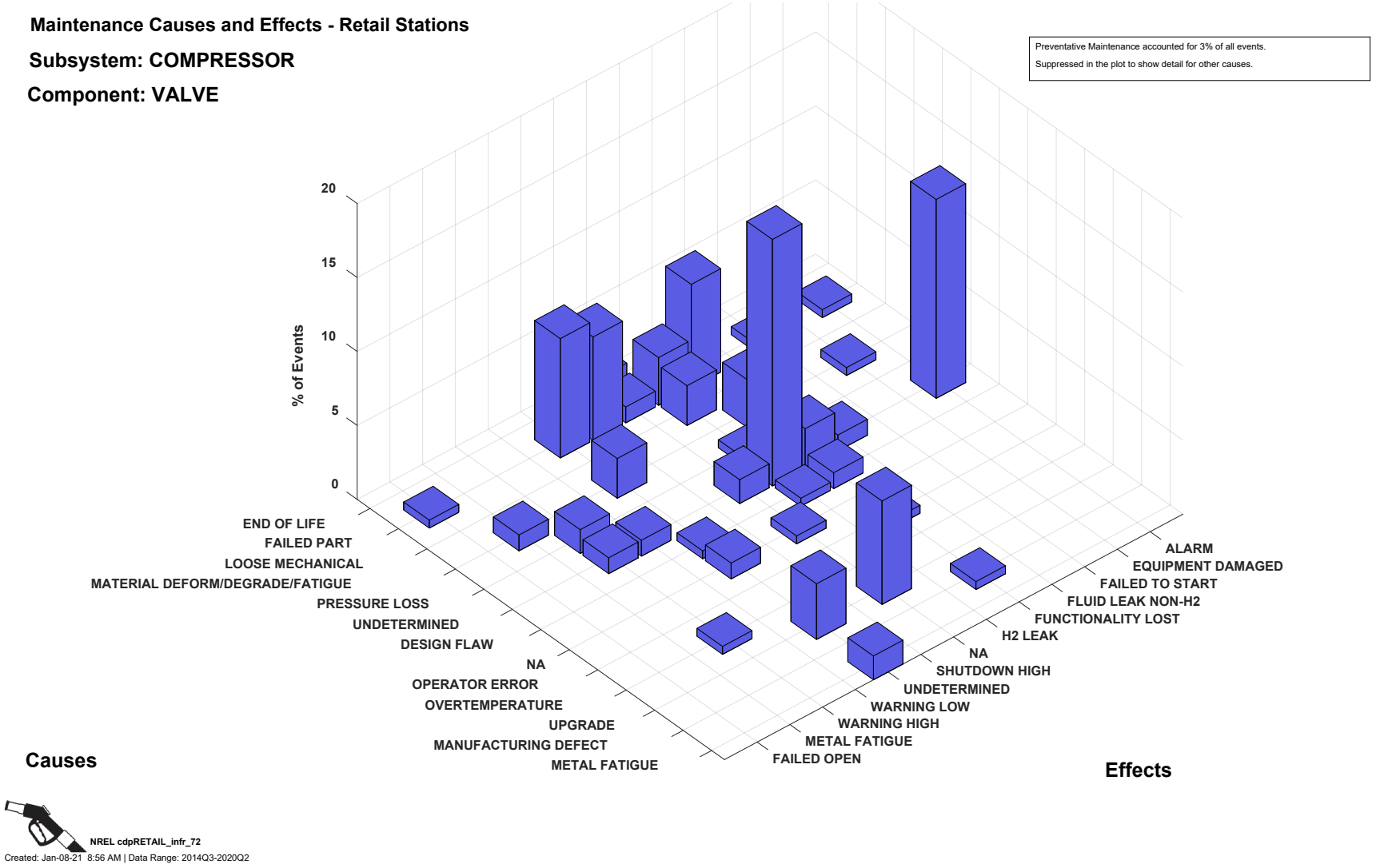
Component: PISTON



NREL cdpRETAIL_infr_71

Created: Jan-08-21 8:56 AM | Data Range: 2014Q3-2020Q2

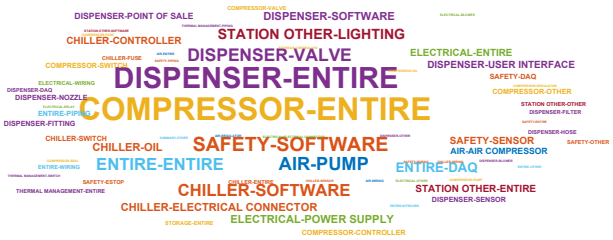
CDP-INFR-72
Maintenance Causes and Effects: Compressor (Valve)



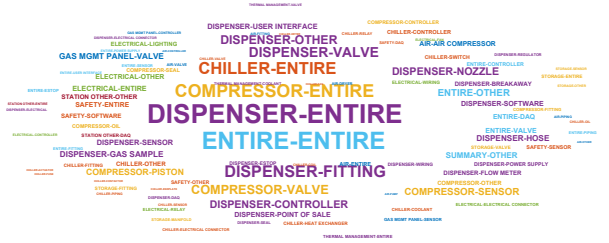
CDP-INFR-98
Maintenance Word Cloud - Retail

Maintenance Systems WordCloud - Retail Stations

2015: Max subsystem occurrence = 38

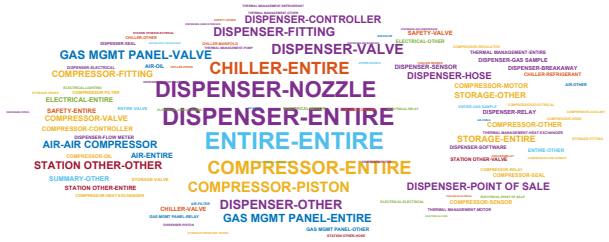


2016: Max subsystem occurrence = 248

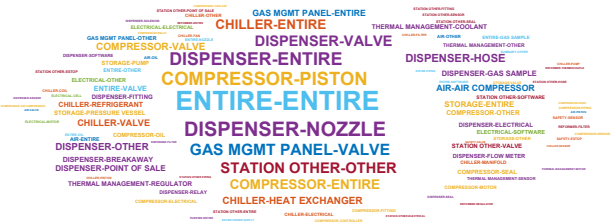


2017: Max subsystem occurrence = 375

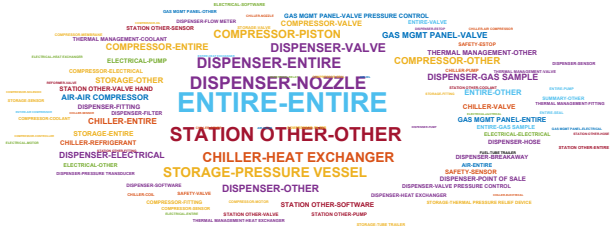
2018: Max subsystem occurrence = 375



2019: Max subsystem occurrence = 433



2020: Max subsystem occurrence = 388

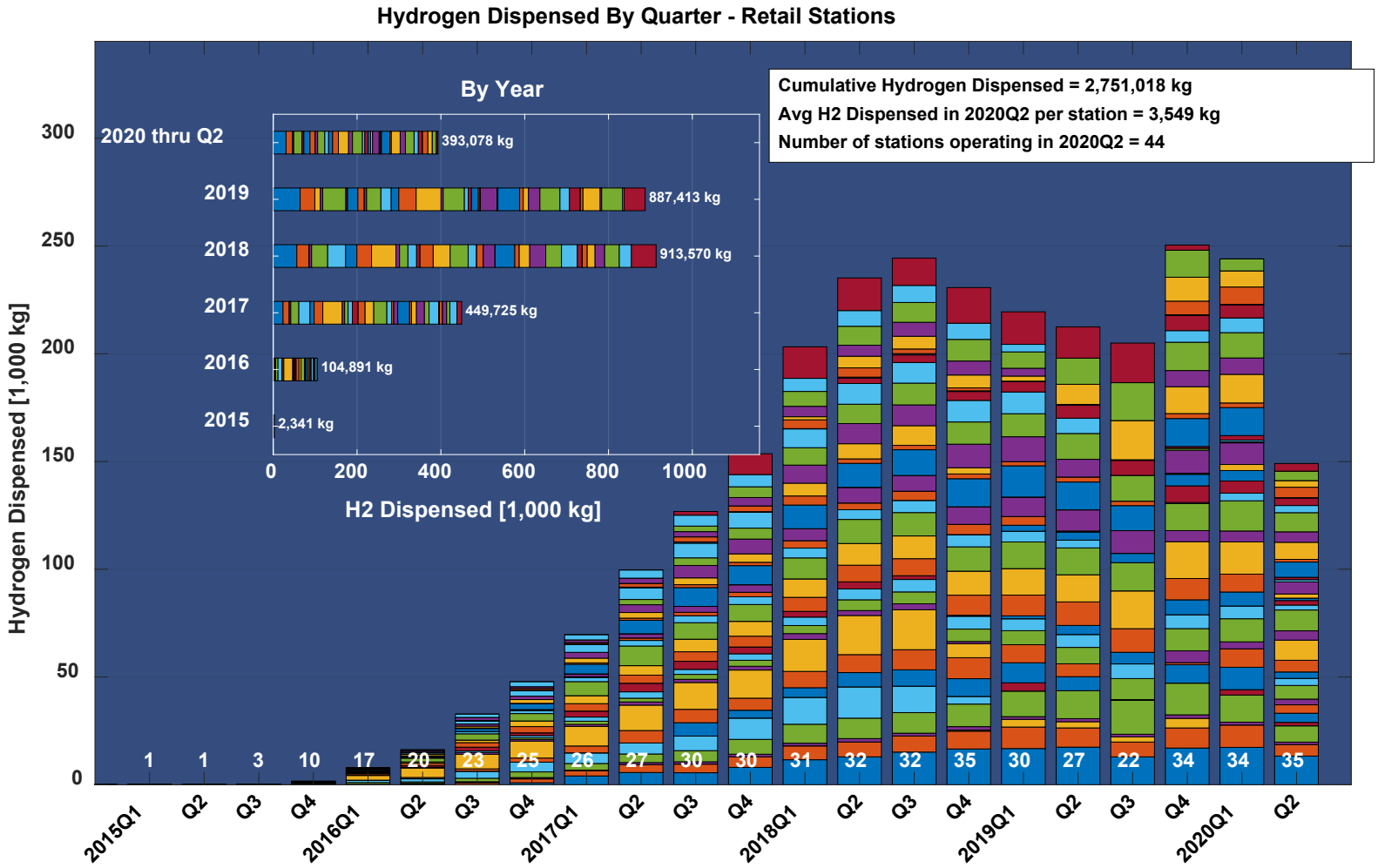


NREL cdpRETAIL_infr_98

Created: Jan-21-21 1:17 PM | Data Range: 2014Q3-2020Q2

Performance

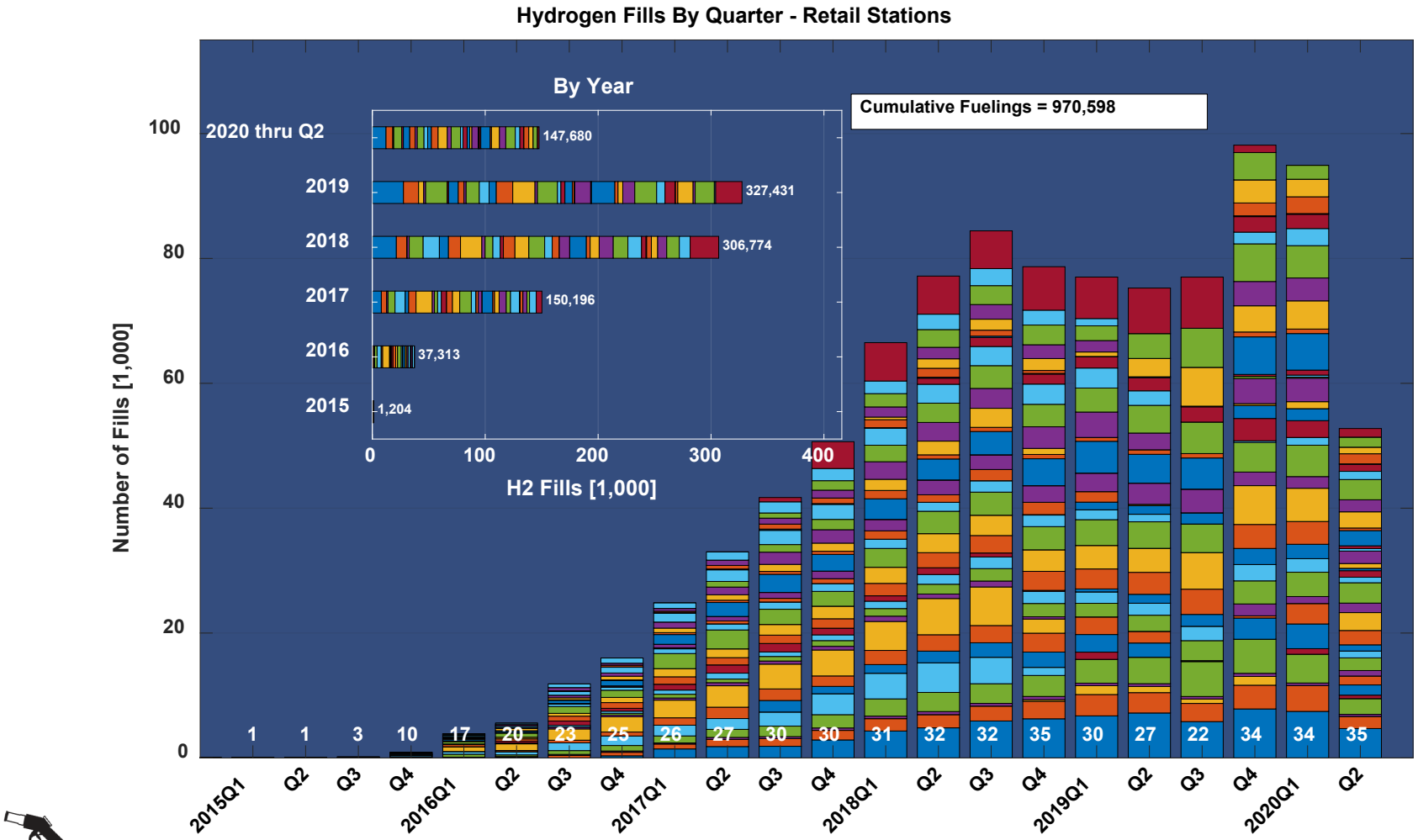
CDP-INFR-01
Hydrogen Dispensed by Quarter



NREL cdpRETAIL_infr_01
Created: Oct-30-20 4:44 AM | Data Range: 2014Q3-2020Q2

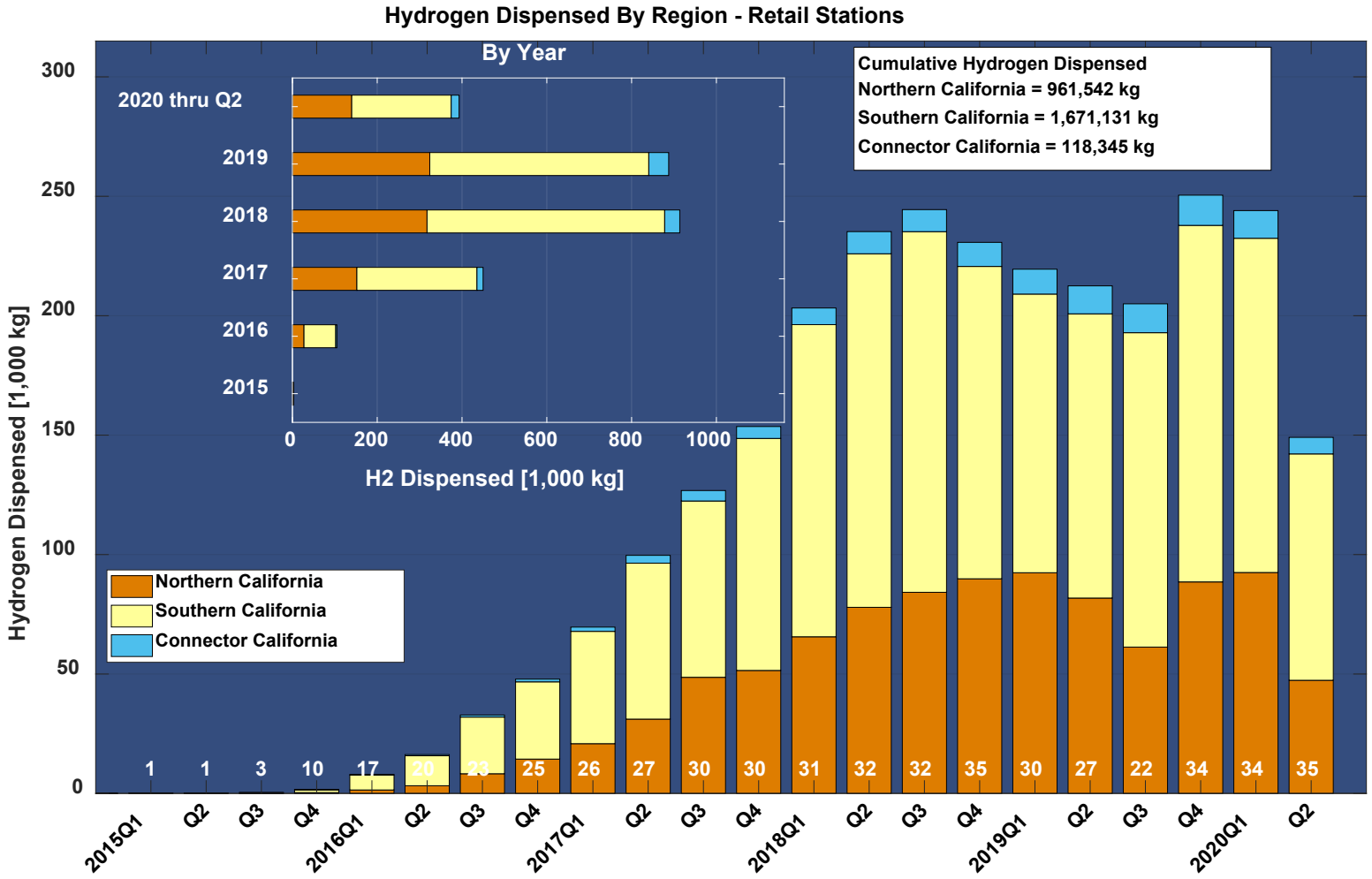
Note: Colors represent individual stations. Station count is number at bottom of bar.

CDP-INFR-58
Hydrogen Fills by Quarter



Note: Colors represent individual stations. Station count is number at bottom of bar.

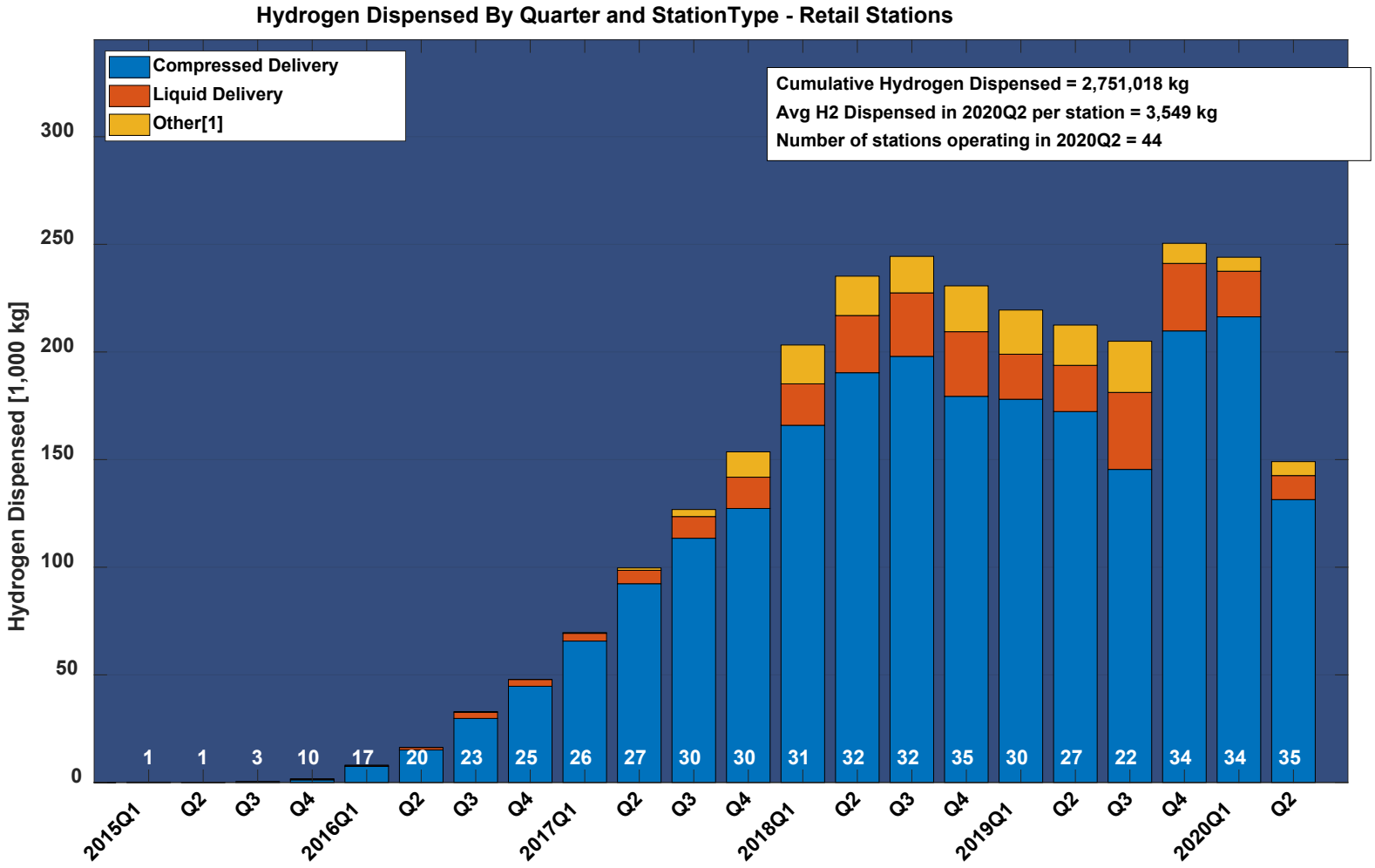
CDP-INFR-81
H2 Dispensed by Region



NREL cdpRETAIL_infr_81
Created: Oct-29-20 4:41 PM | Data Range: 2014Q3-2020Q2

Note: Station count is number at bottom of bar.

CDP-INFR-97
Hydrogen Dispensed By Quarter and Station Type- Retail Stations

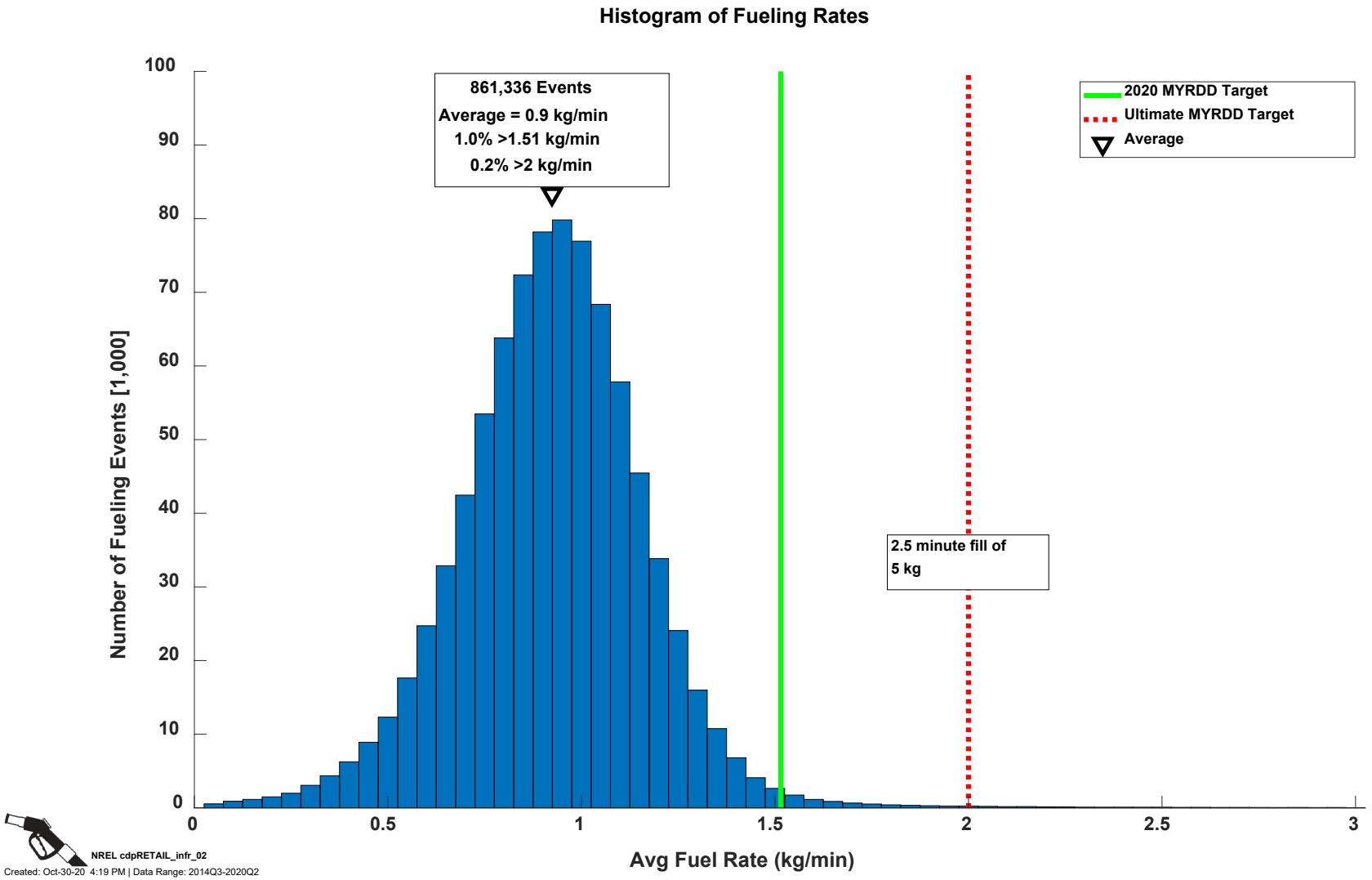


NREL cdpRETAIL_infr_97
Created: Jan-21-21 2:35 PM | Data Range: 2014Q3-2020Q2

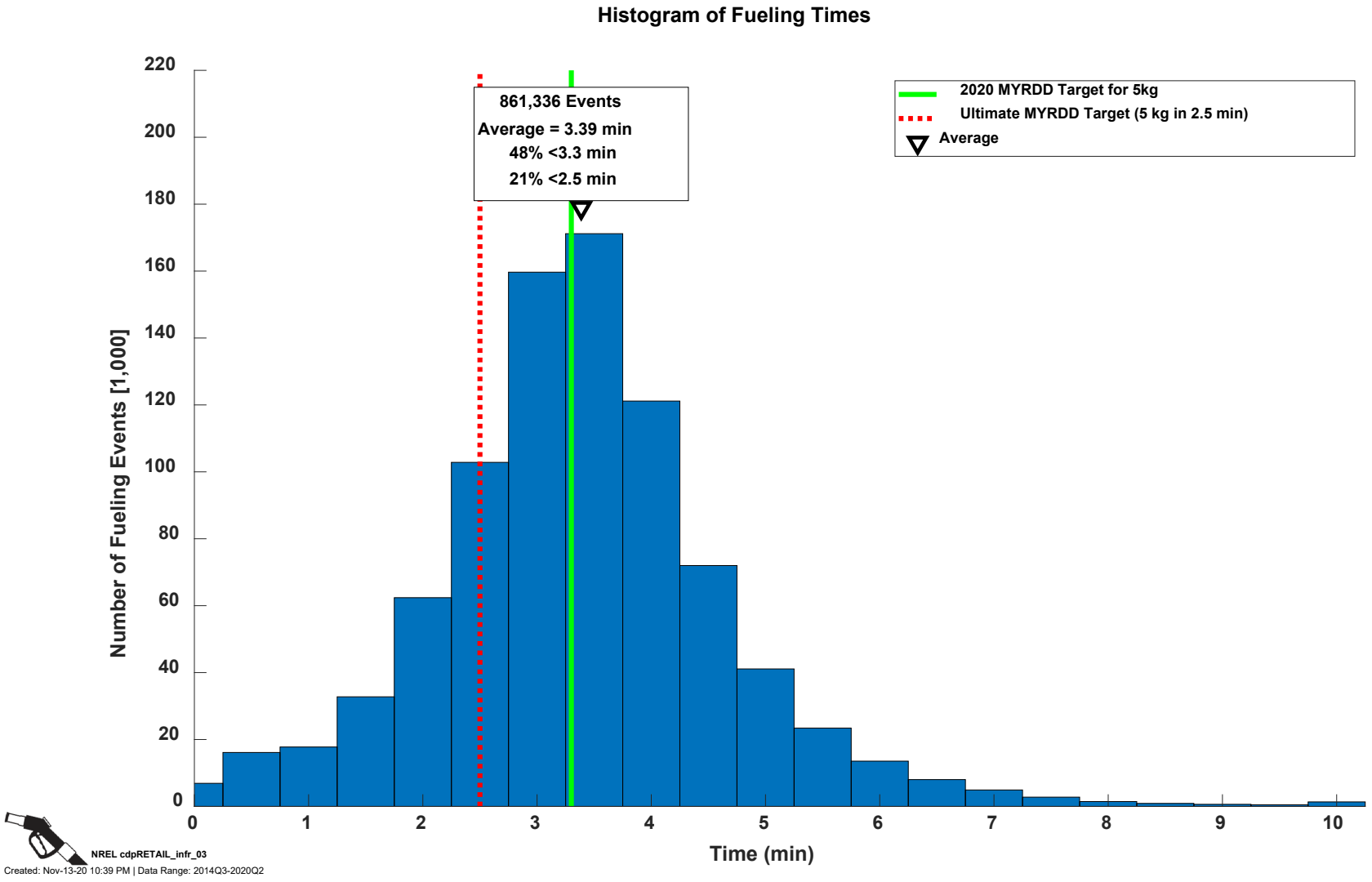
Note: Stations reporting data count is number at bottom of bar.

[1] Other includes pipeline and stations with multiple hydrogen sources.

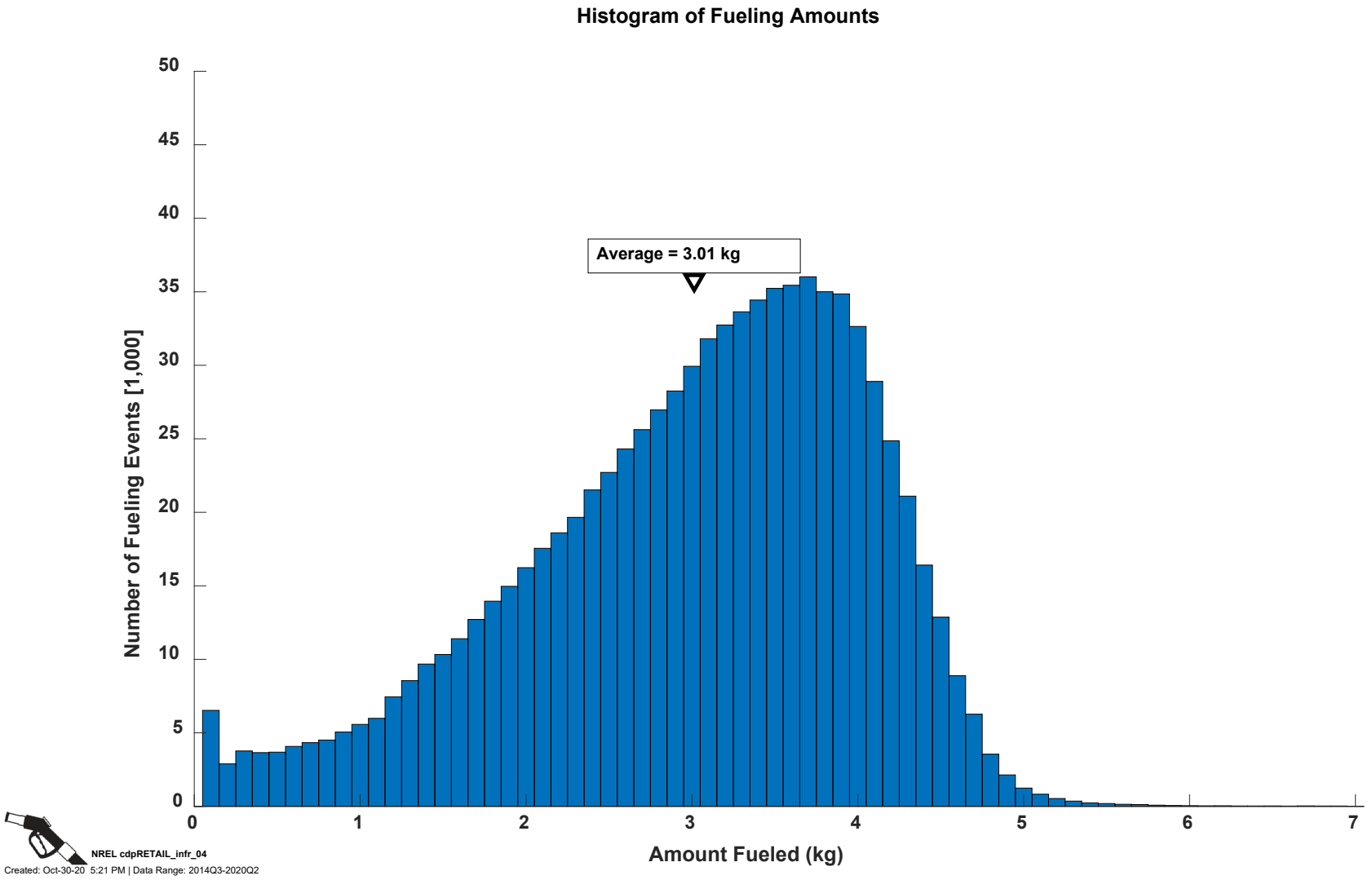
CDP-INFR-02
Histogram of Fueling Rates



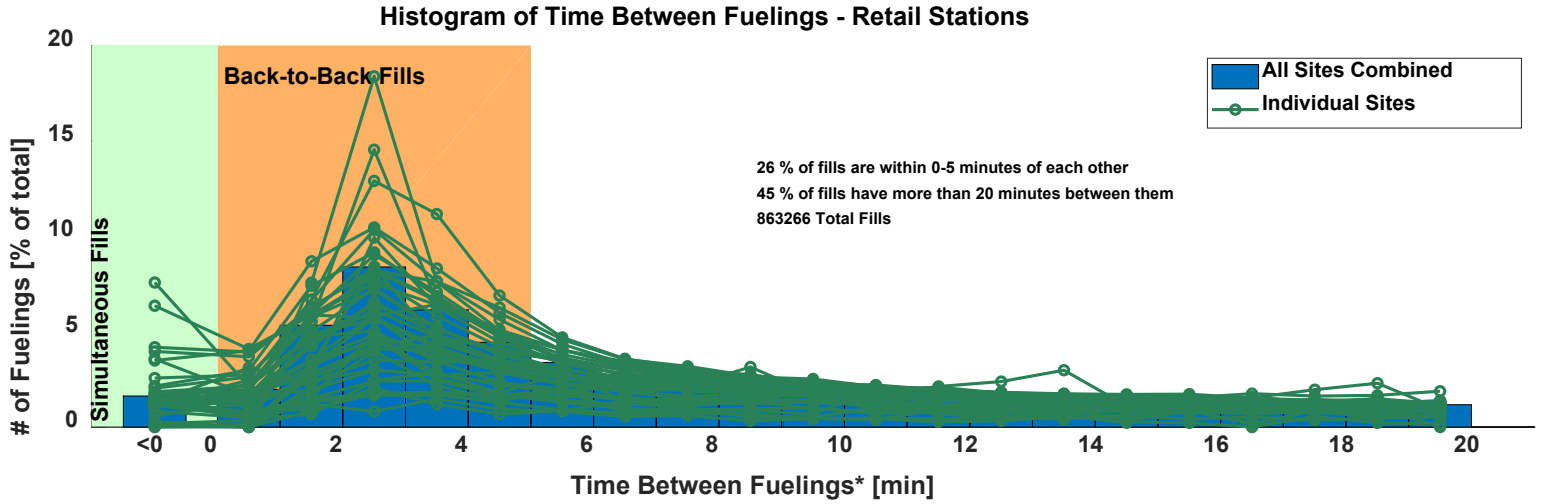
CDP-INFR-03
Histogram of Fueling Times

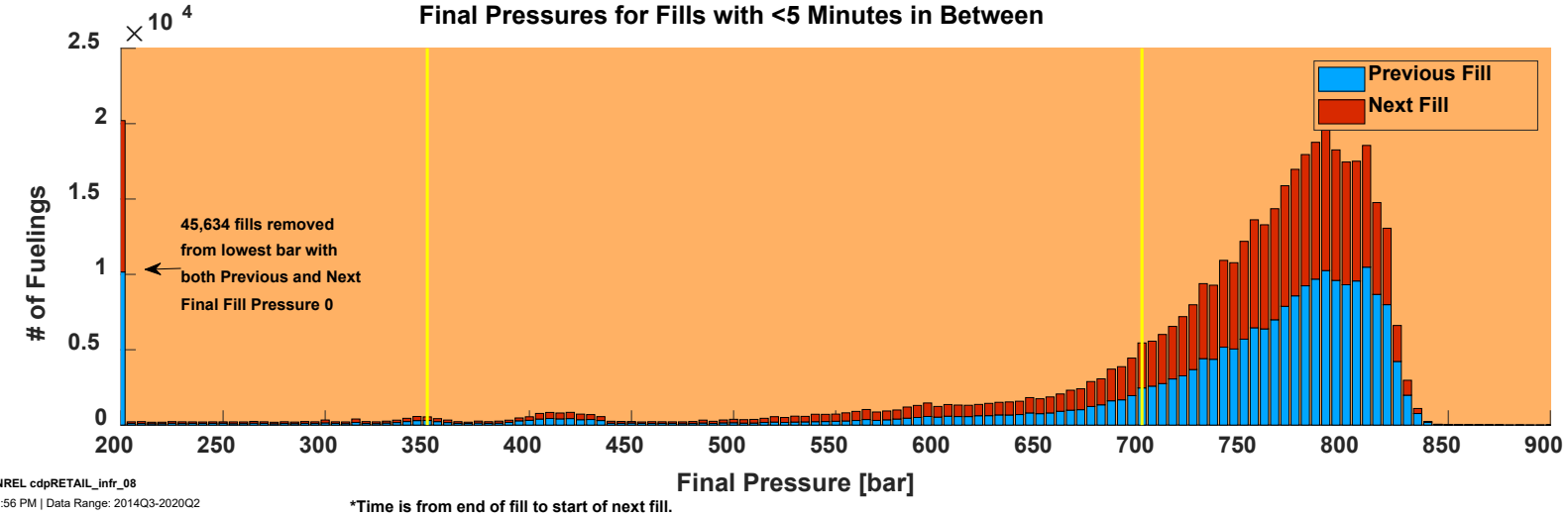


CDP-INFR-04
Histogram of Fueling Amounts



CDP-INFR-08
Time Between Fueling

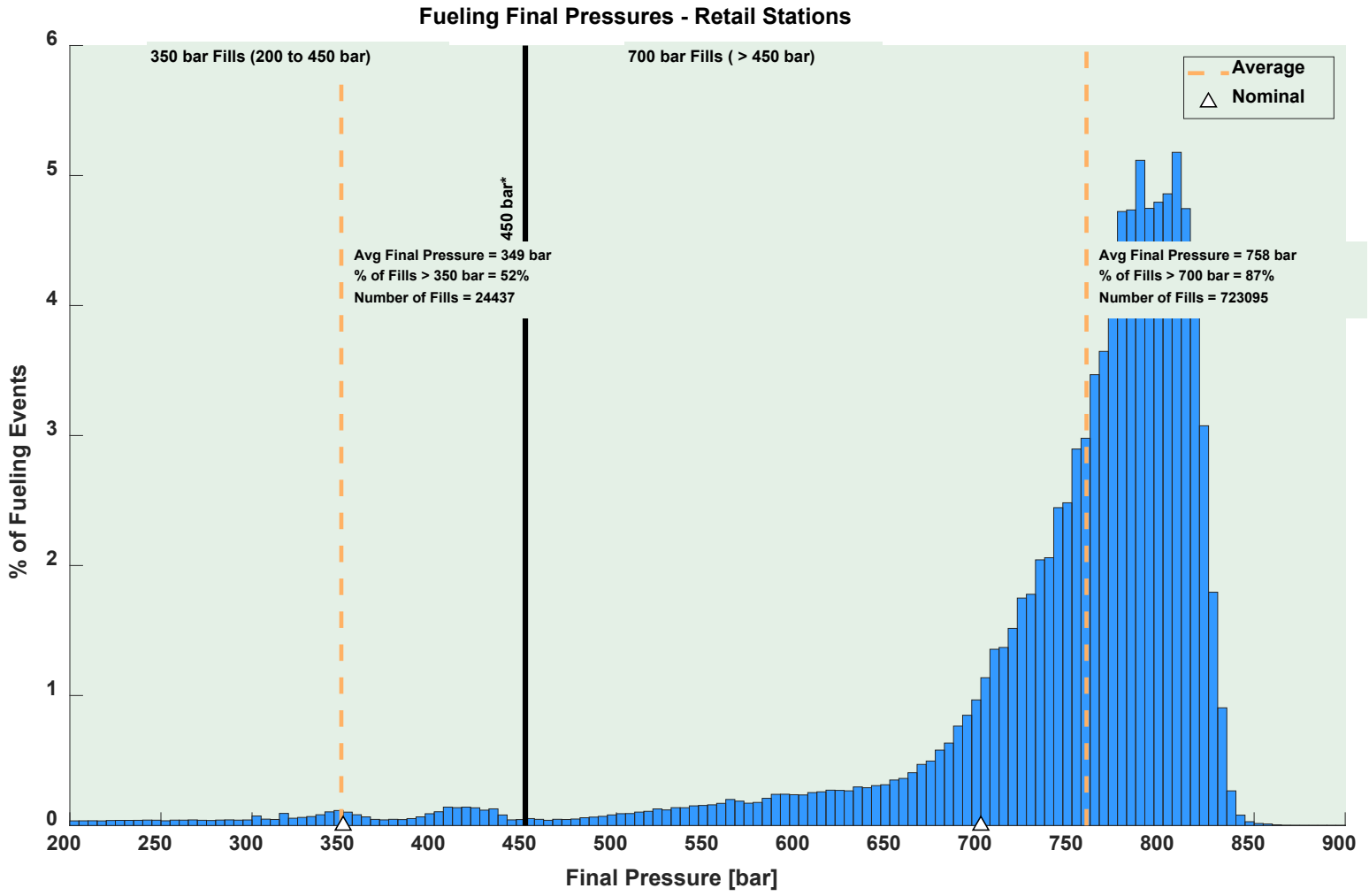




NREL cdpRETAIL_infr_08
Created: Oct-30-20 5:56 PM | Data Range: 2014Q3-2020Q2

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

CDP-INFR-09
Fueling Final Pressures

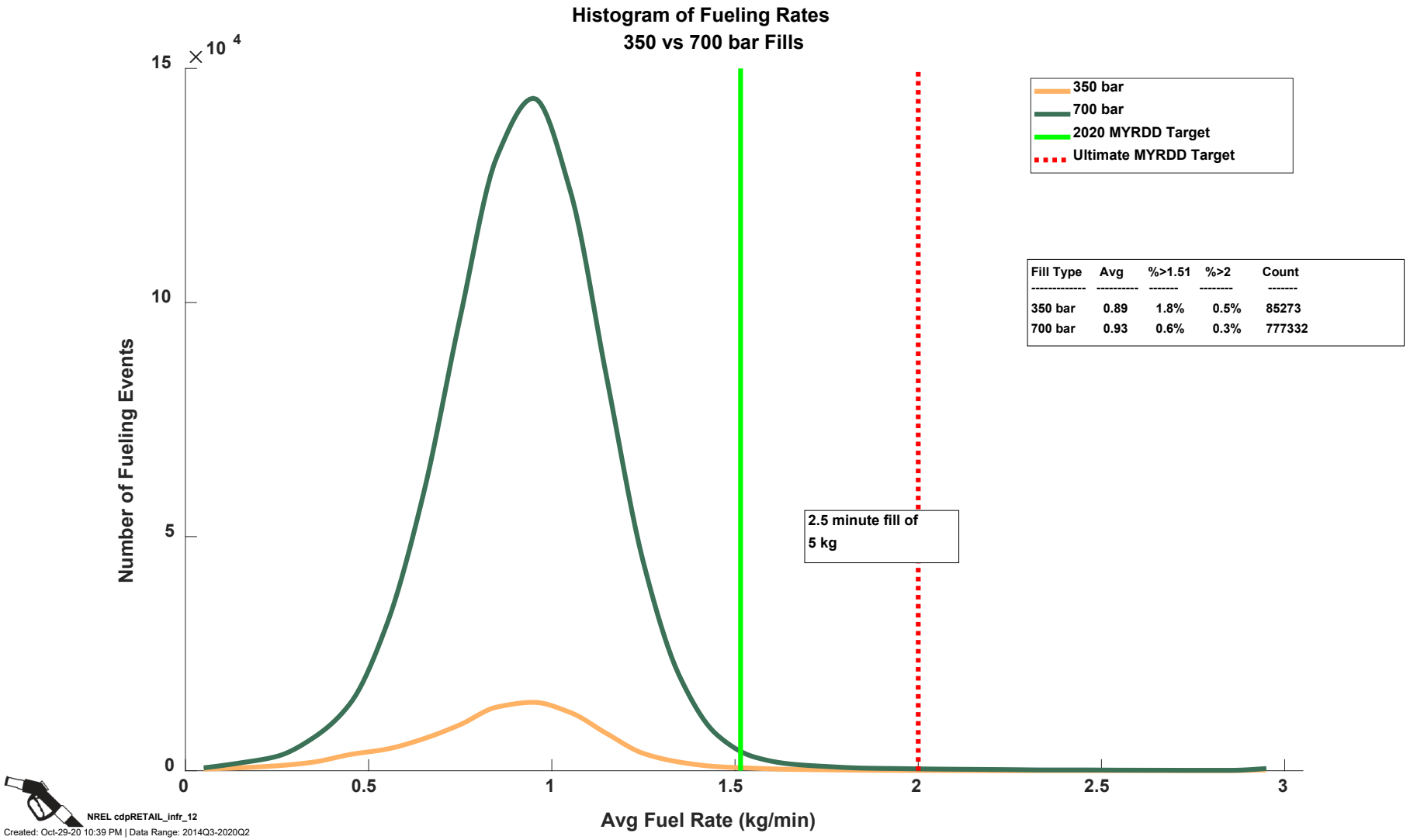


NREL cdpRETAIL_infr_09

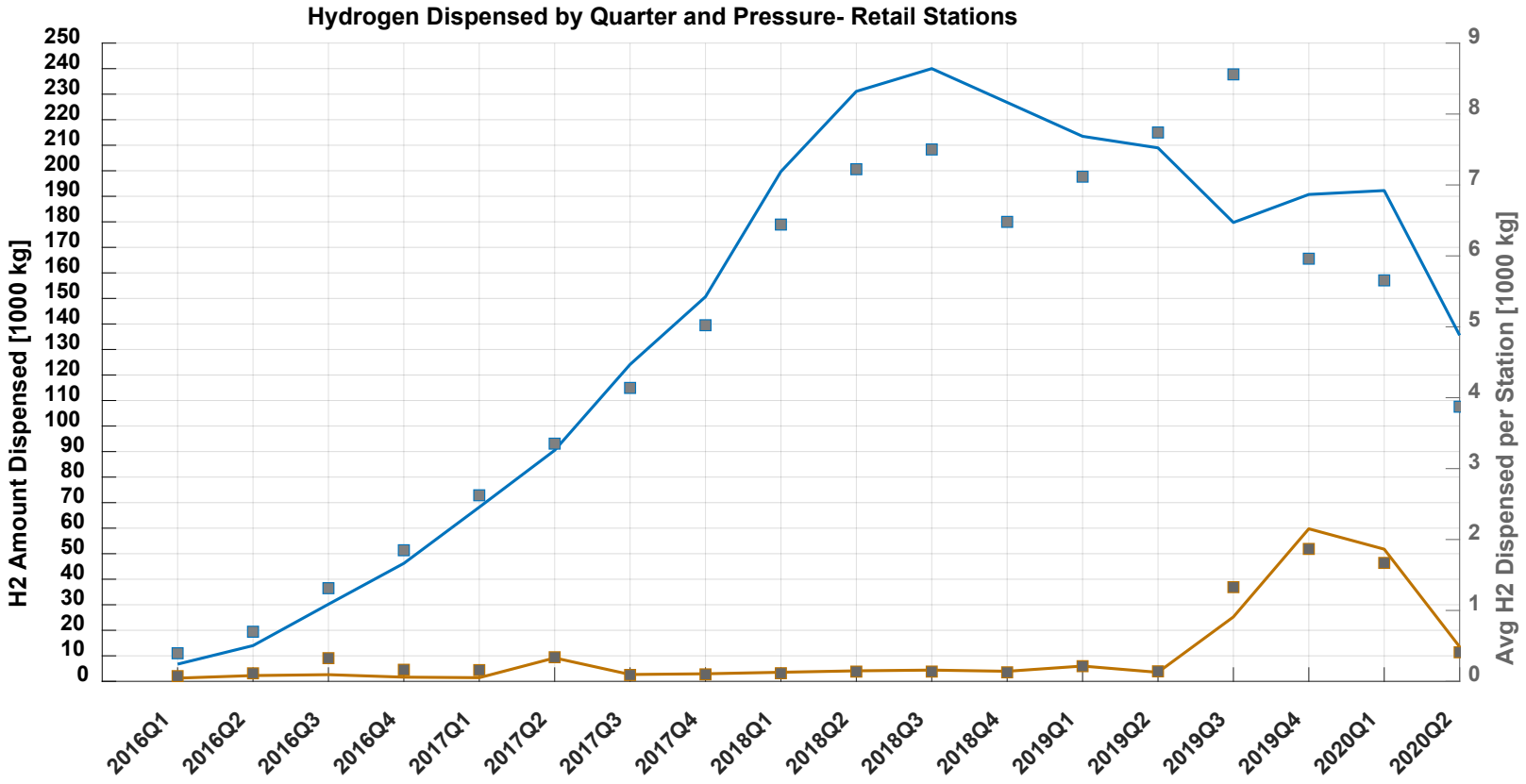
Created: Oct-29-20 11:31 PM | Data Range: 2014Q3-2020Q2

*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.

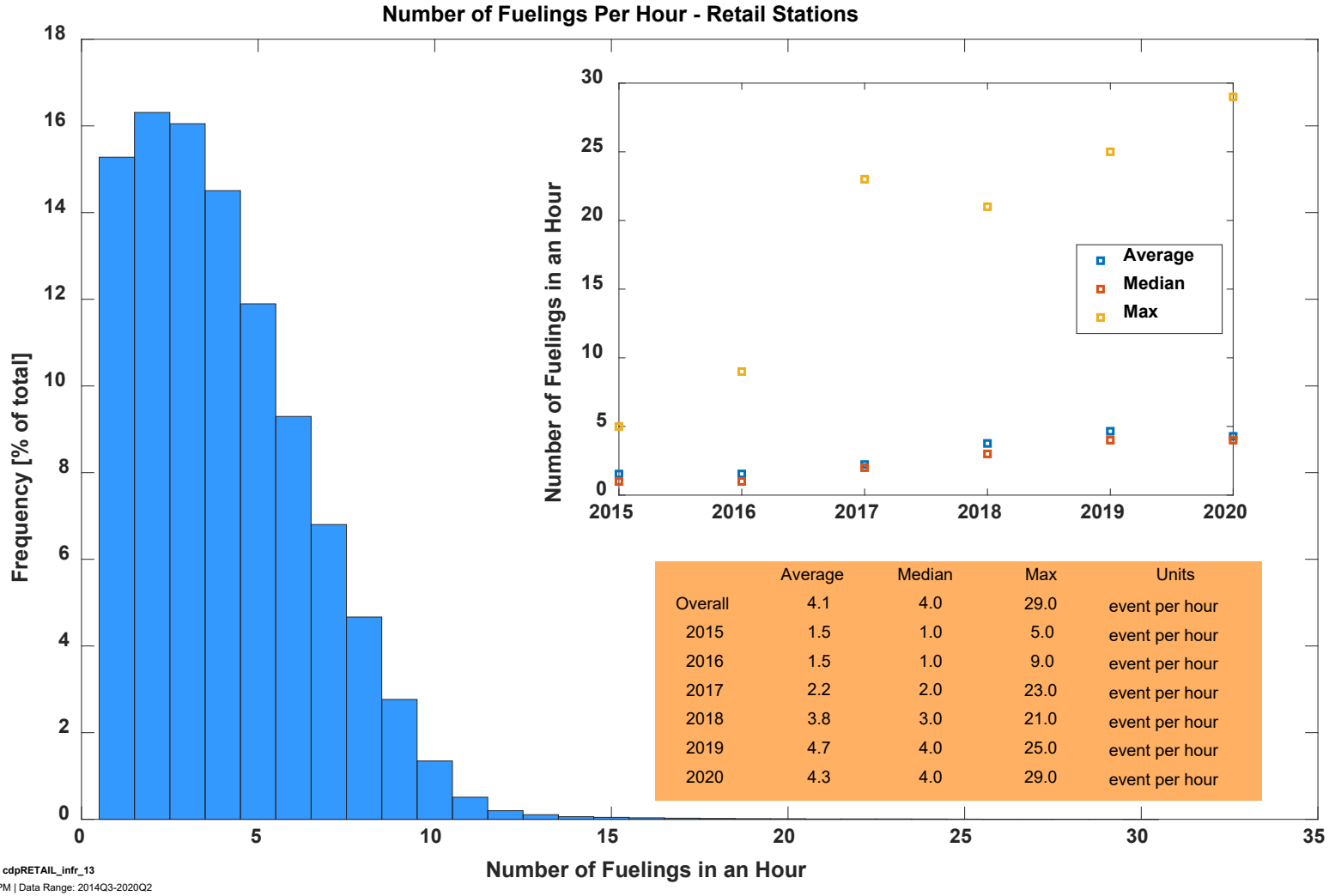
CDP-INFR-12
Fueling Rates 350 bar vs. 700 bar



CDP-INFR-90
Hydrogen Dispensed by Quarter and Pressure



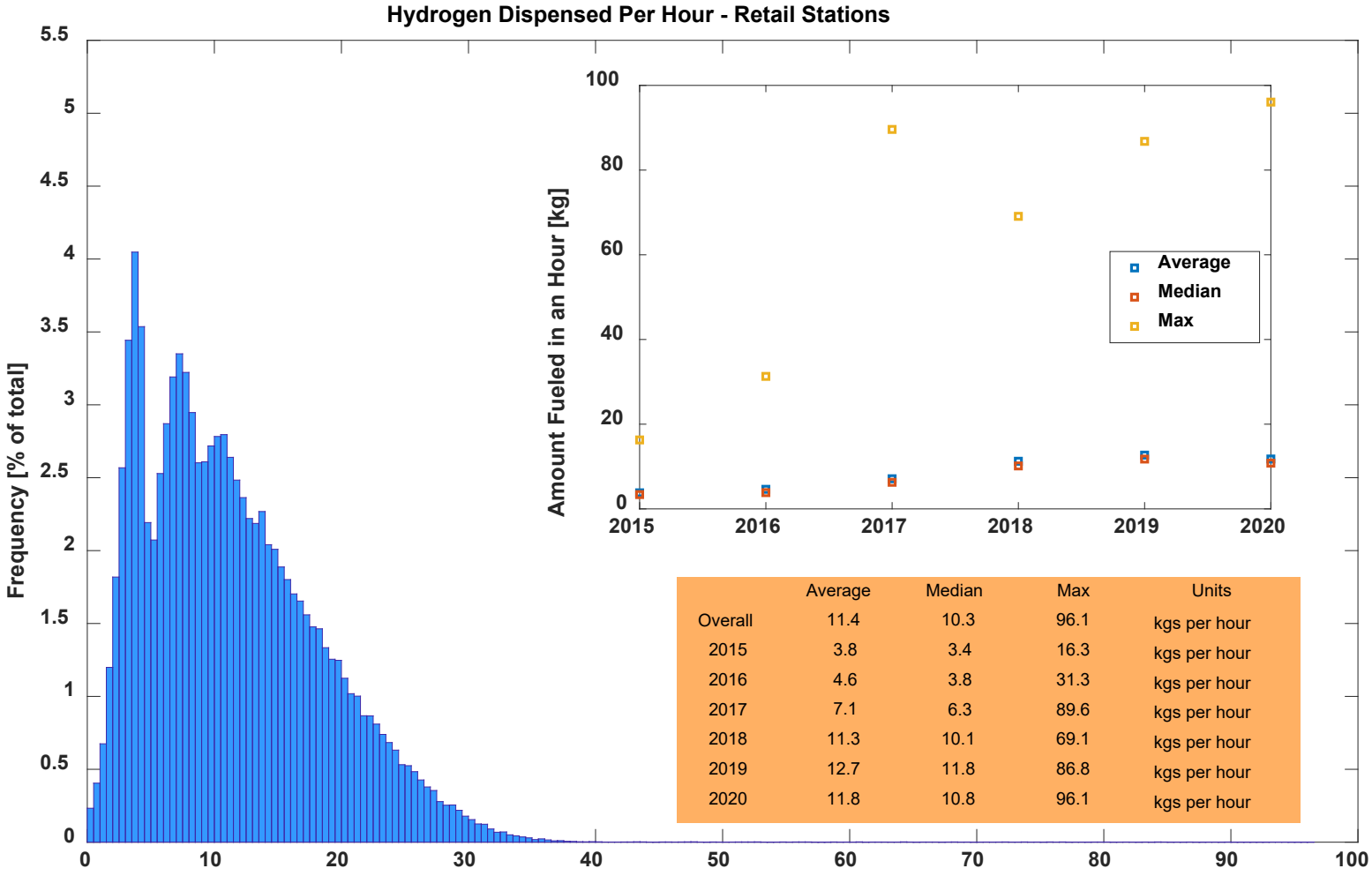
CDP-INFR-13
Number of Fueling Events per Hour



	Average	Median	Max	Units
Overall	4.1	4.0	29.0	event per hour
2015	1.5	1.0	5.0	event per hour
2016	1.5	1.0	9.0	event per hour
2017	2.2	2.0	23.0	event per hour
2018	3.8	3.0	21.0	event per hour
2019	4.7	4.0	25.0	event per hour
2020	4.3	4.0	29.0	event per hour

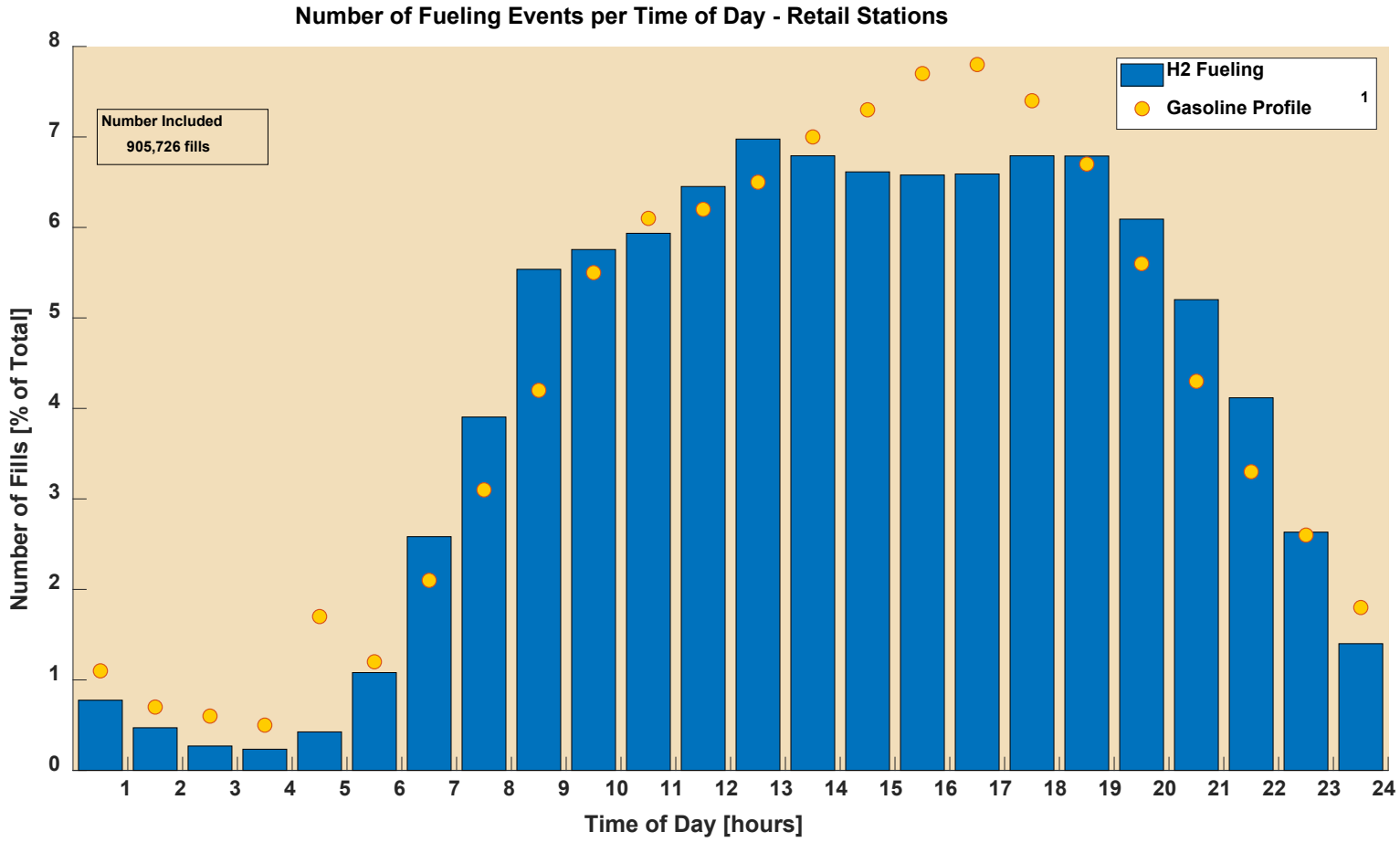
NREL cdpRETAIL_infr_13
Created: Nov-05-20 4:36 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-14
Hydrogen Dispensed per Hour



	Average	Median	Max	Units
Overall	11.4	10.3	96.1	kgs per hour
2015	3.8	3.4	16.3	kgs per hour
2016	4.6	3.8	31.3	kgs per hour
2017	7.1	6.3	89.6	kgs per hour
2018	11.3	10.1	69.1	kgs per hour
2019	12.7	11.8	86.8	kgs per hour
2020	11.8	10.8	96.1	kgs per hour

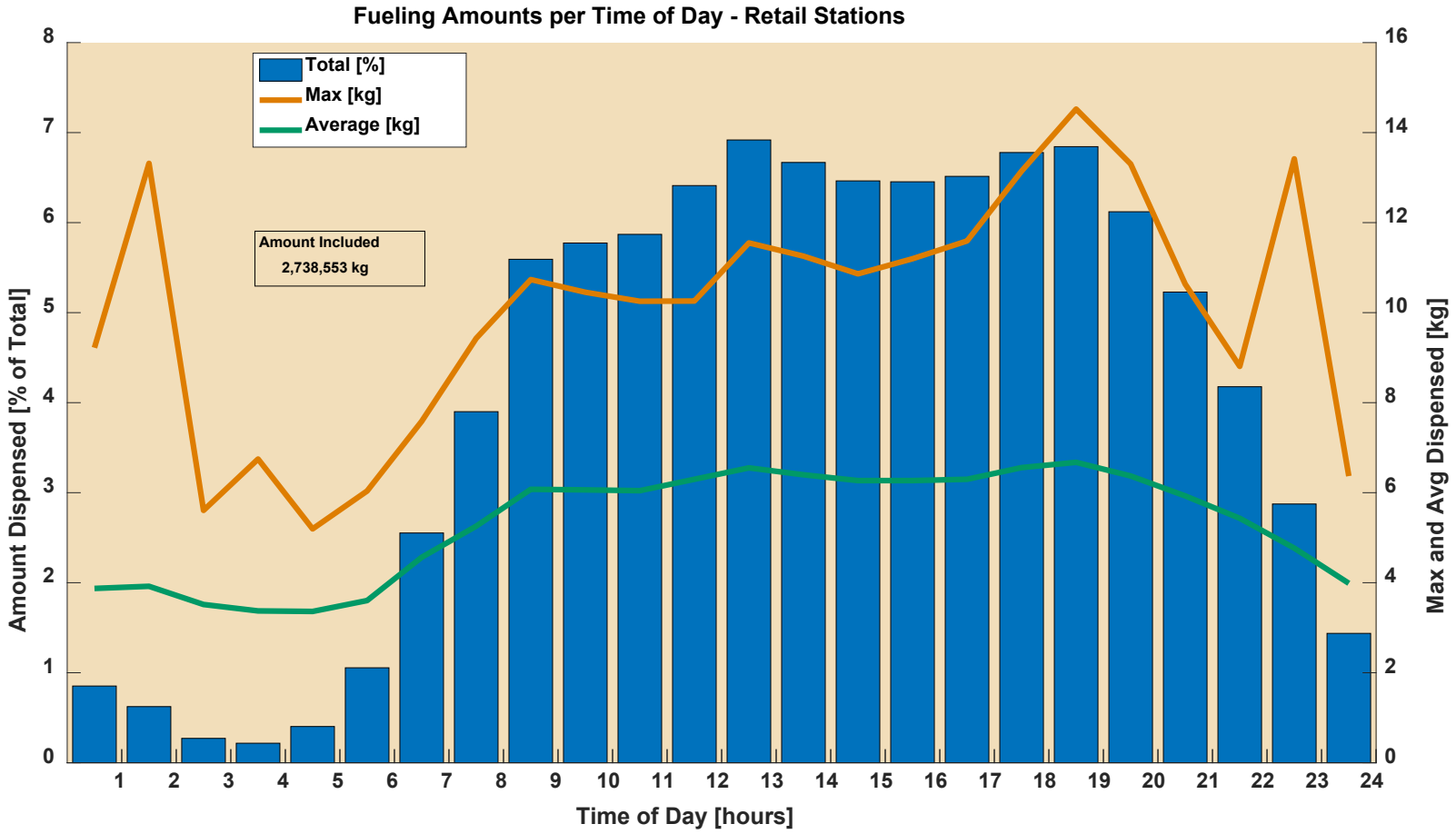
CDP-INFR-15
Number of Fills by Time of Day



NREL cdpRETAIL_infr_15
Created: Oct-29-20 8:01 PM | Data Range: 2014Q3-2020Q2

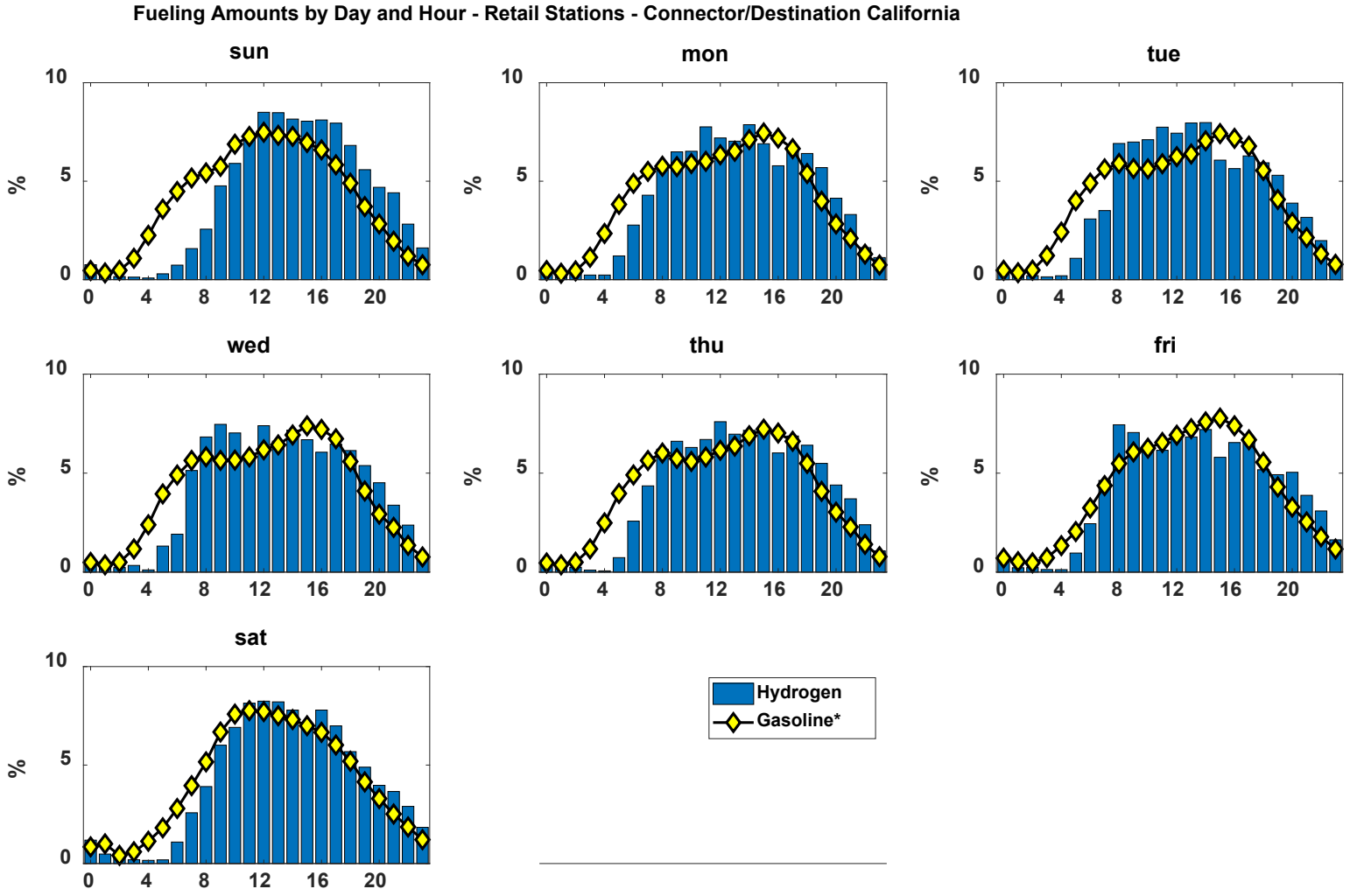
1. Friday Chevron profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

CDP-INFR-16
Fueling Amounts per Time of Day



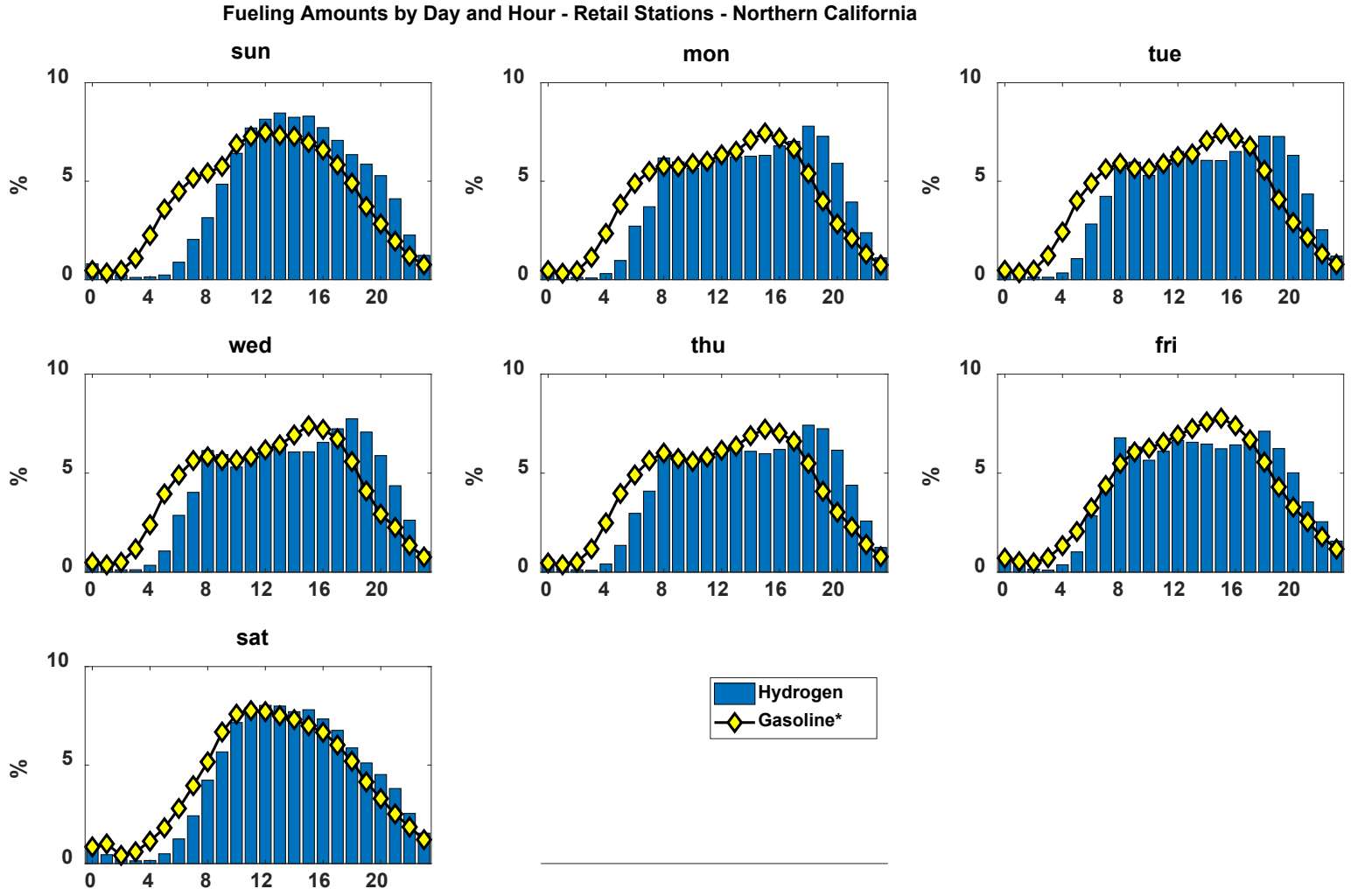
NREL cdpRETAIL_infr_16
Created: Oct-29-20 6:31 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-88a Connector/Destination Stations Fueling Profile by Day and Hour



*Chevron gasoline profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

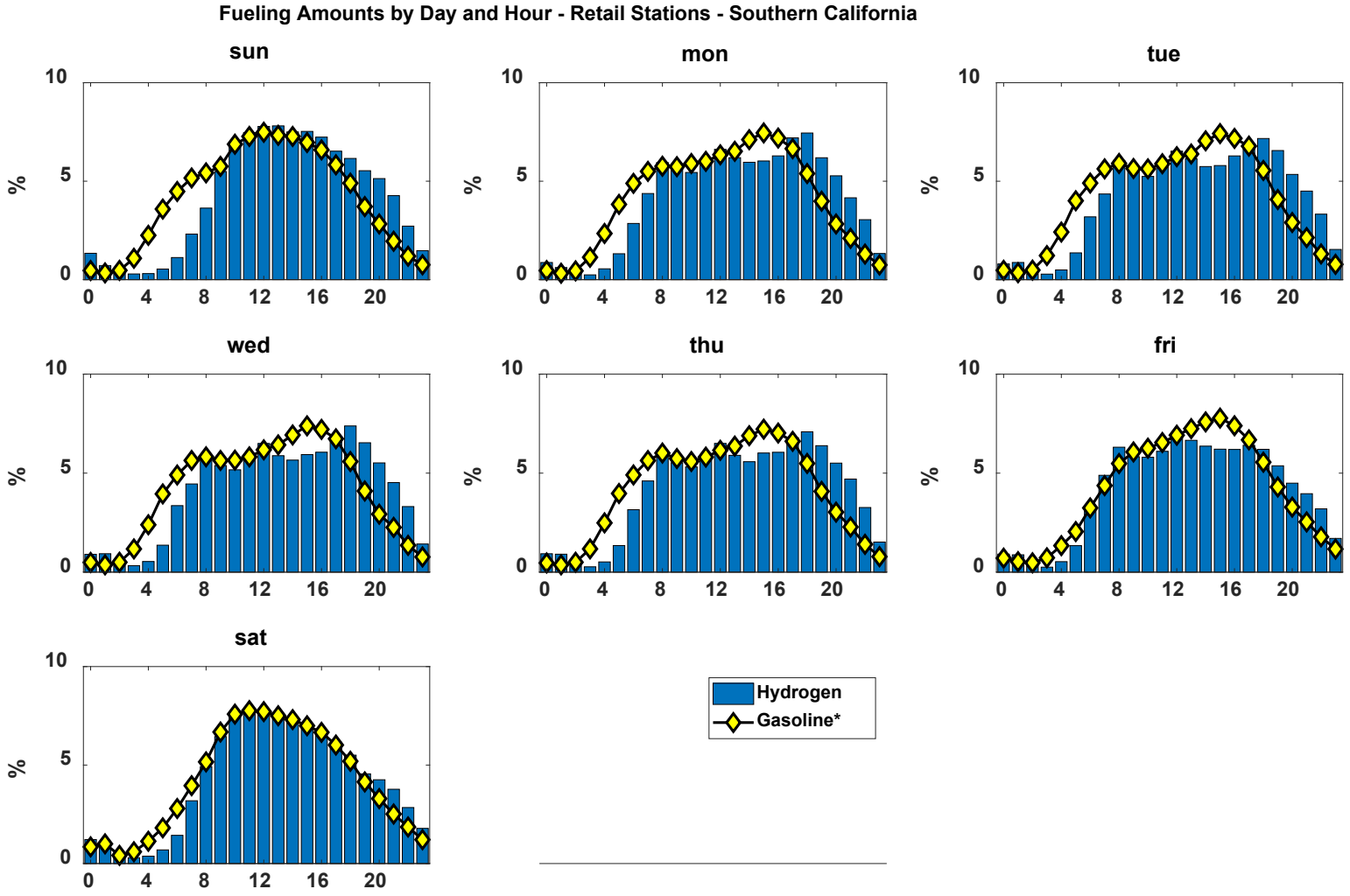
CDP-INFR-88b Northern California Fueling Profile by Day and Hour



NREL cdpRETAIL_infr_88b
Created: Nov-13-20 4:51 PM | Data Range: 2014Q3-2020Q2

*Chevron gasoline profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

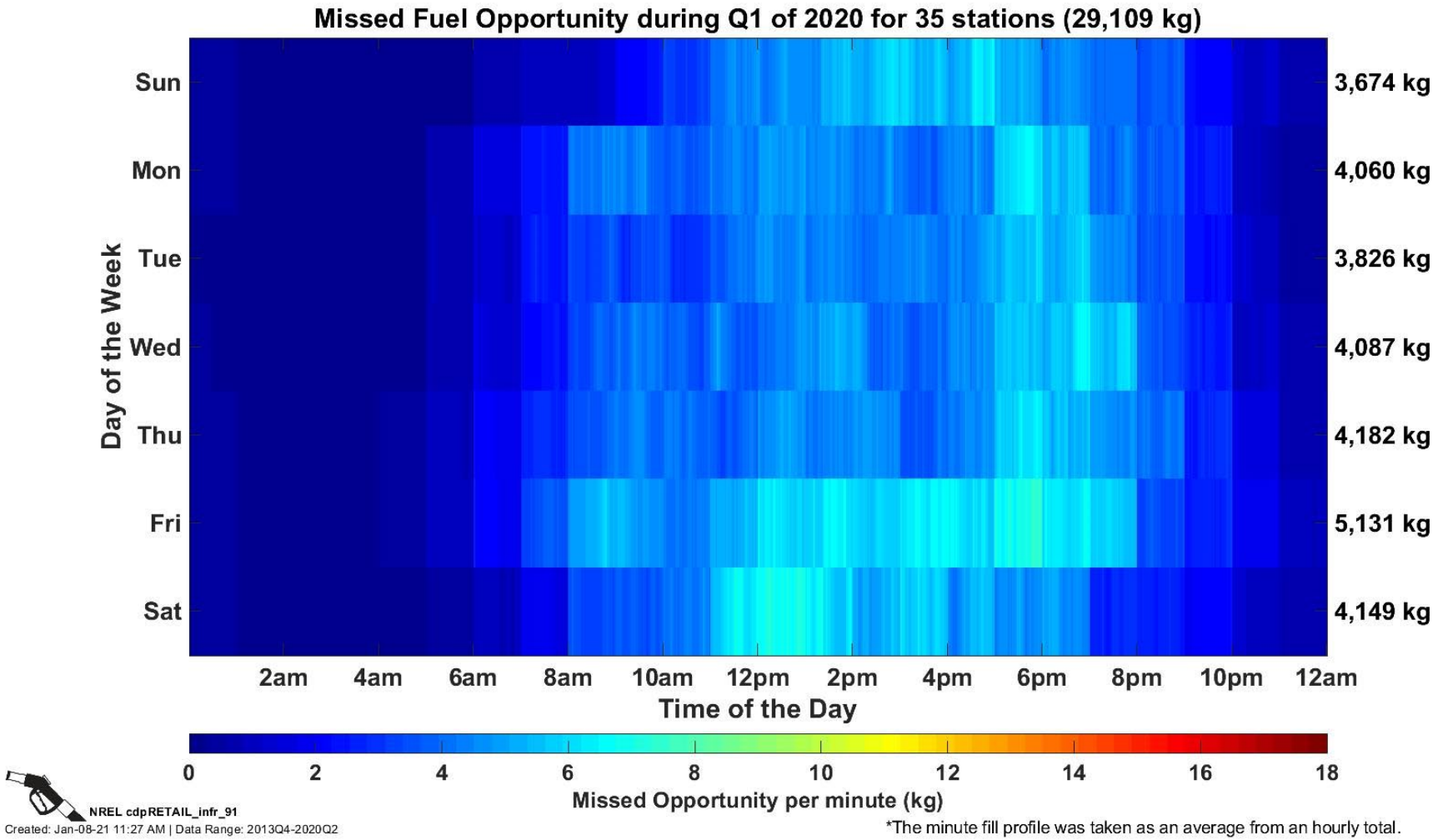
CDP-INFR-88c Southern California Fueling Profile by Day and Hour



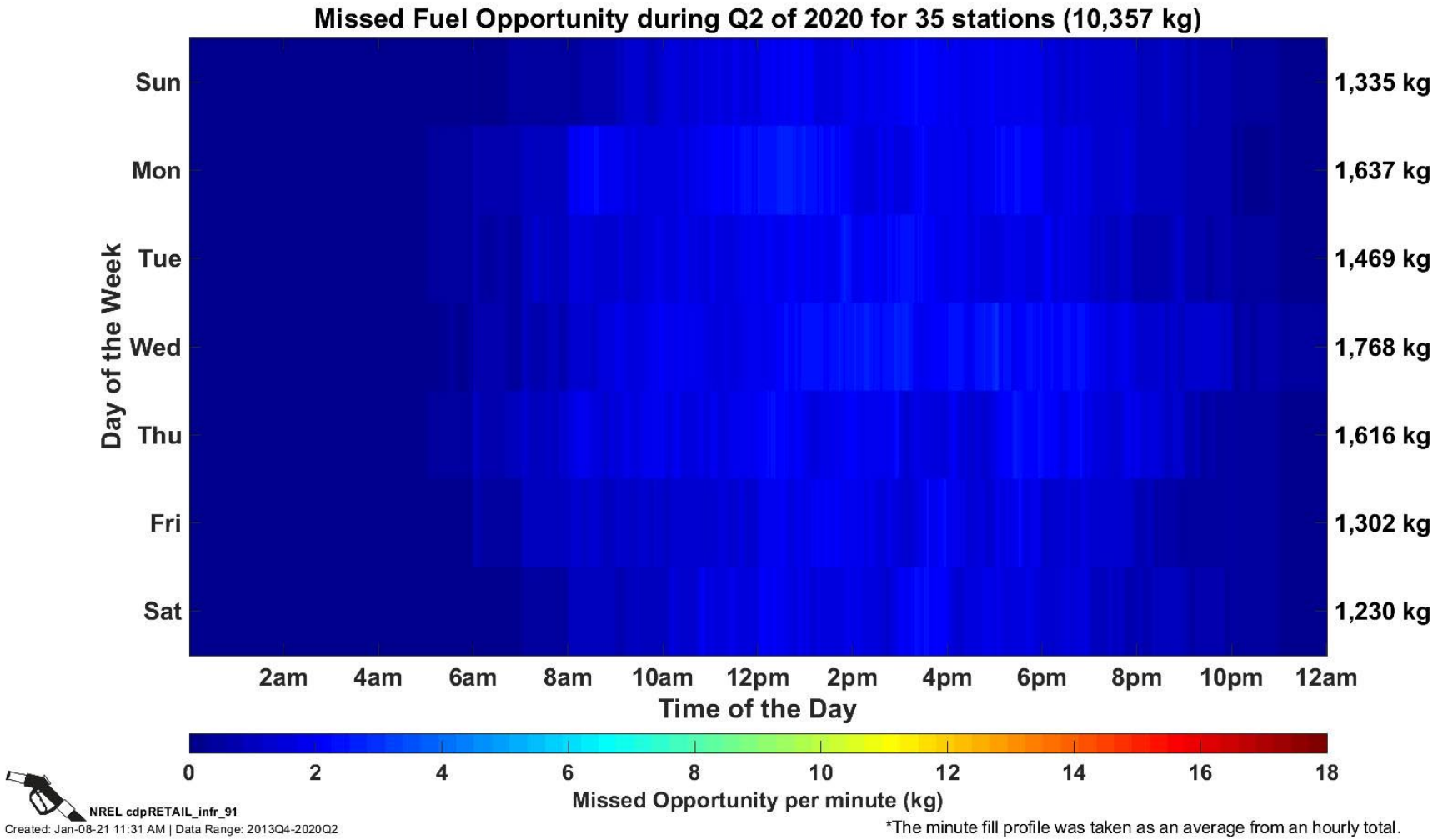
NREL cdpRETAIL_infr_88c
Created: Nov-13-20 4:51 PM | Data Range: 2014Q3-2020Q2

*Chevron gasoline profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

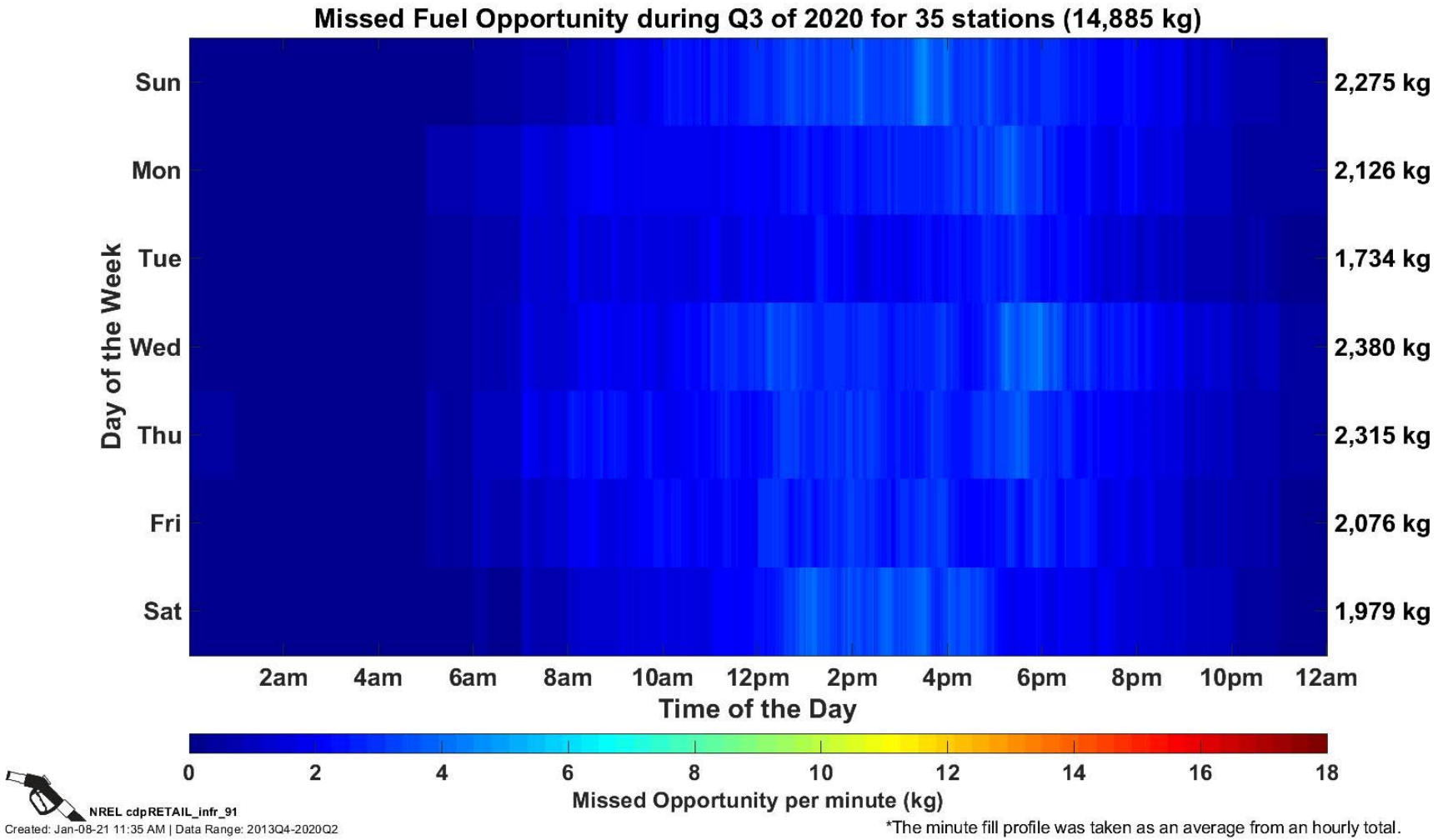
CDP-INFR-91
Missed Fuel Opportunity



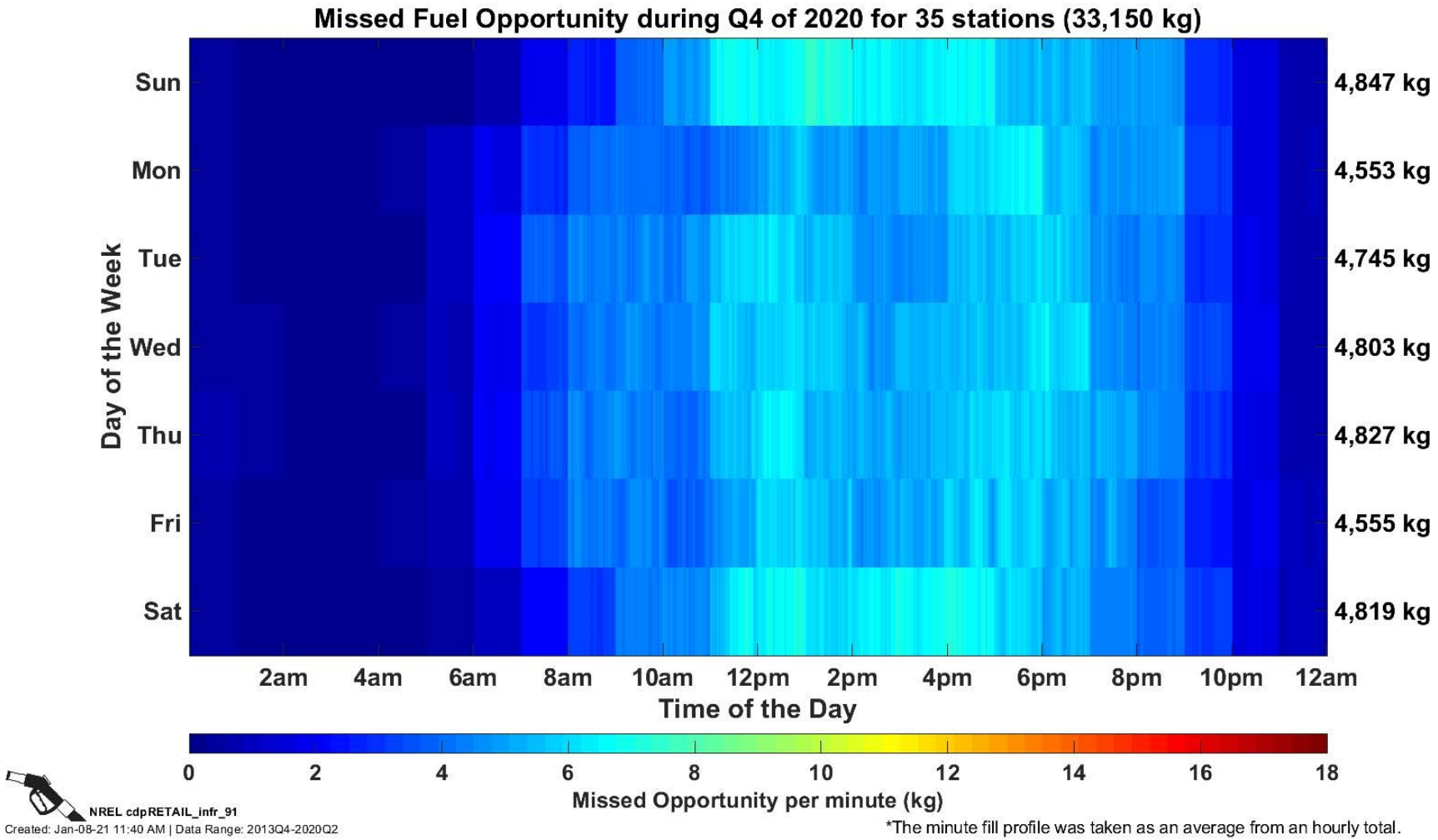
CDP-INFR-91
Missed Fuel Opportunity



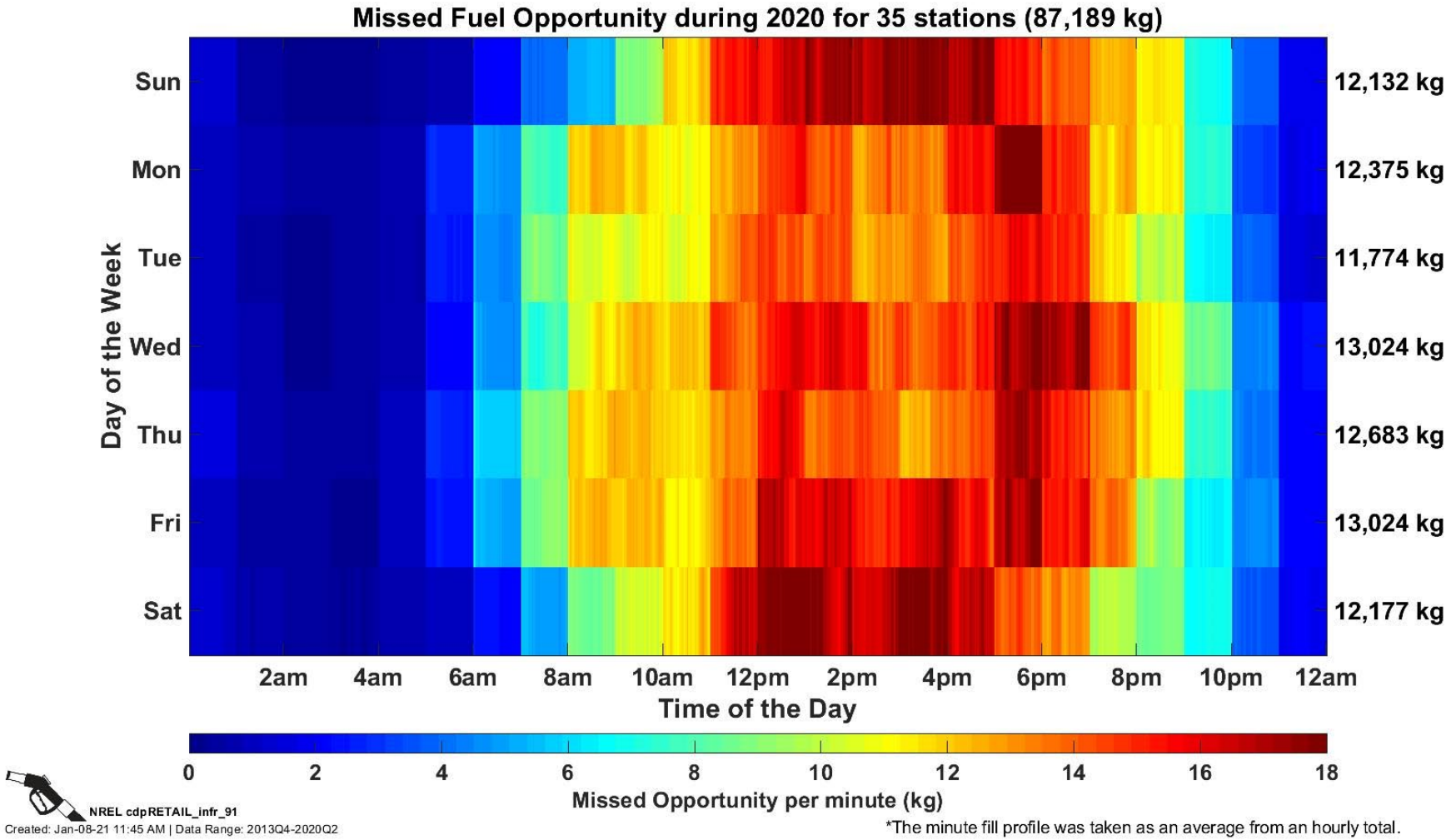
CDP-INFR-91
Missed Fuel Opportunity



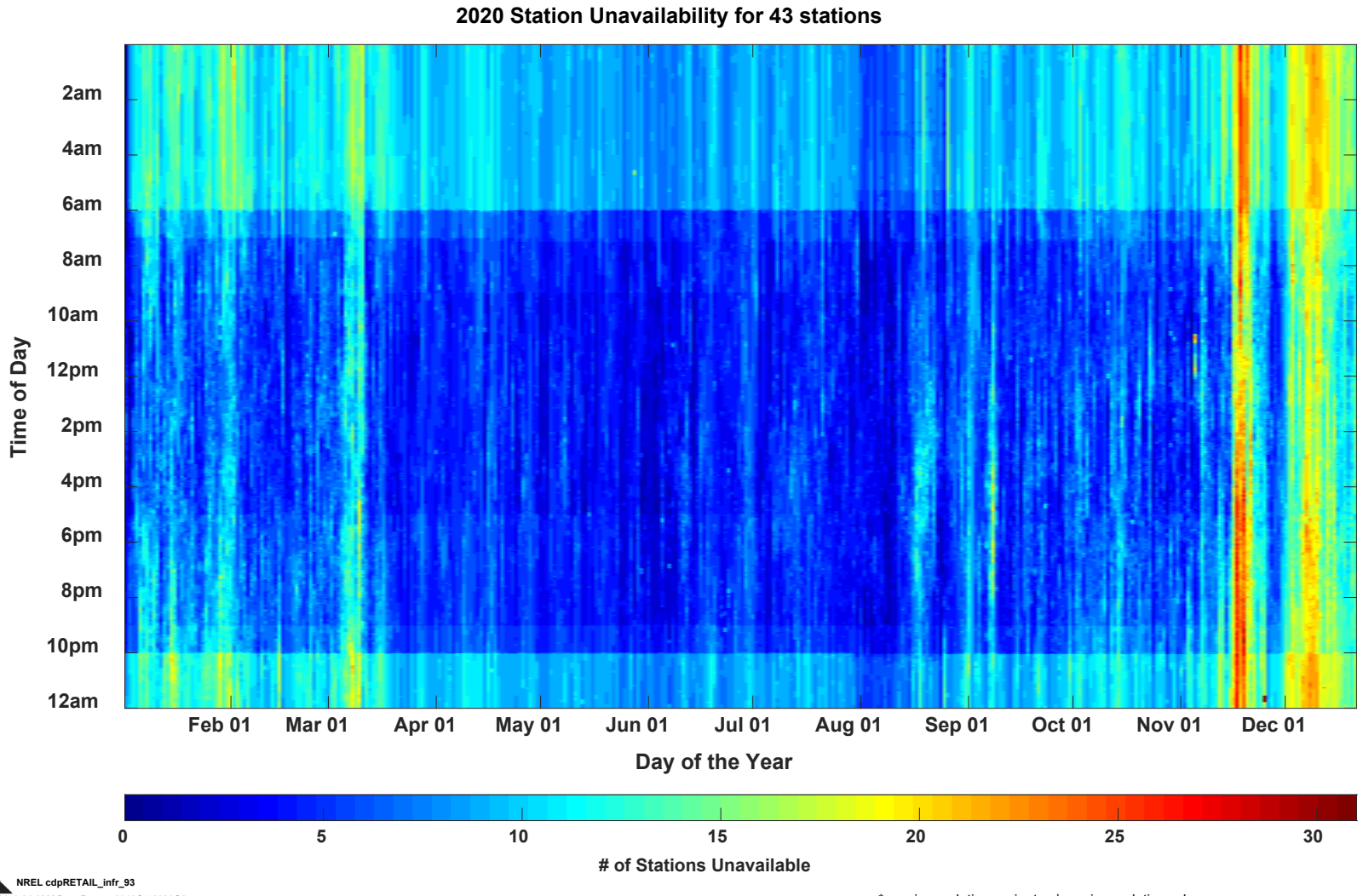
CDP-INFR-91
Missed Fuel Opportunity



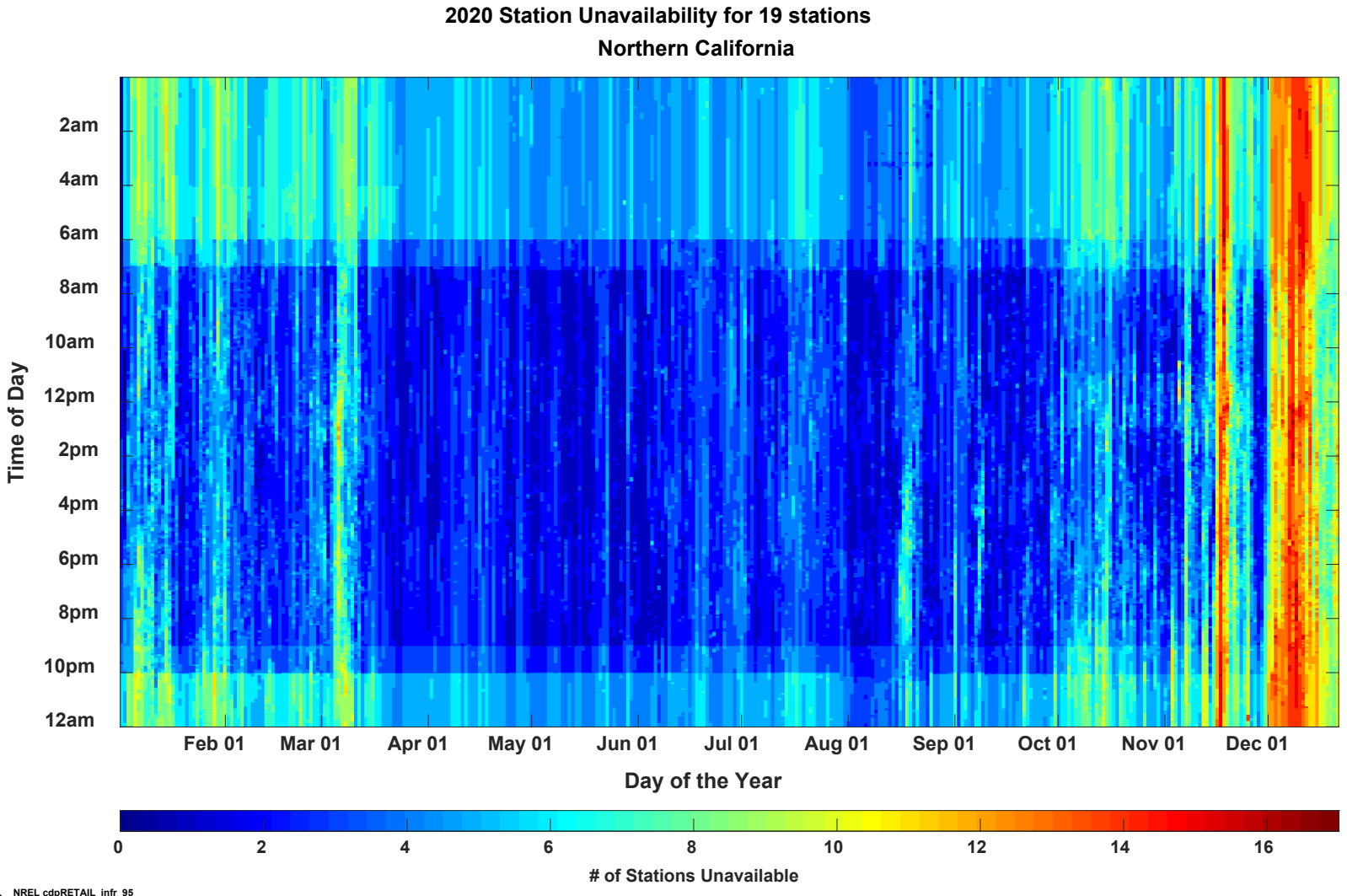
CDP-INFR-91
Missed Fuel Opportunity



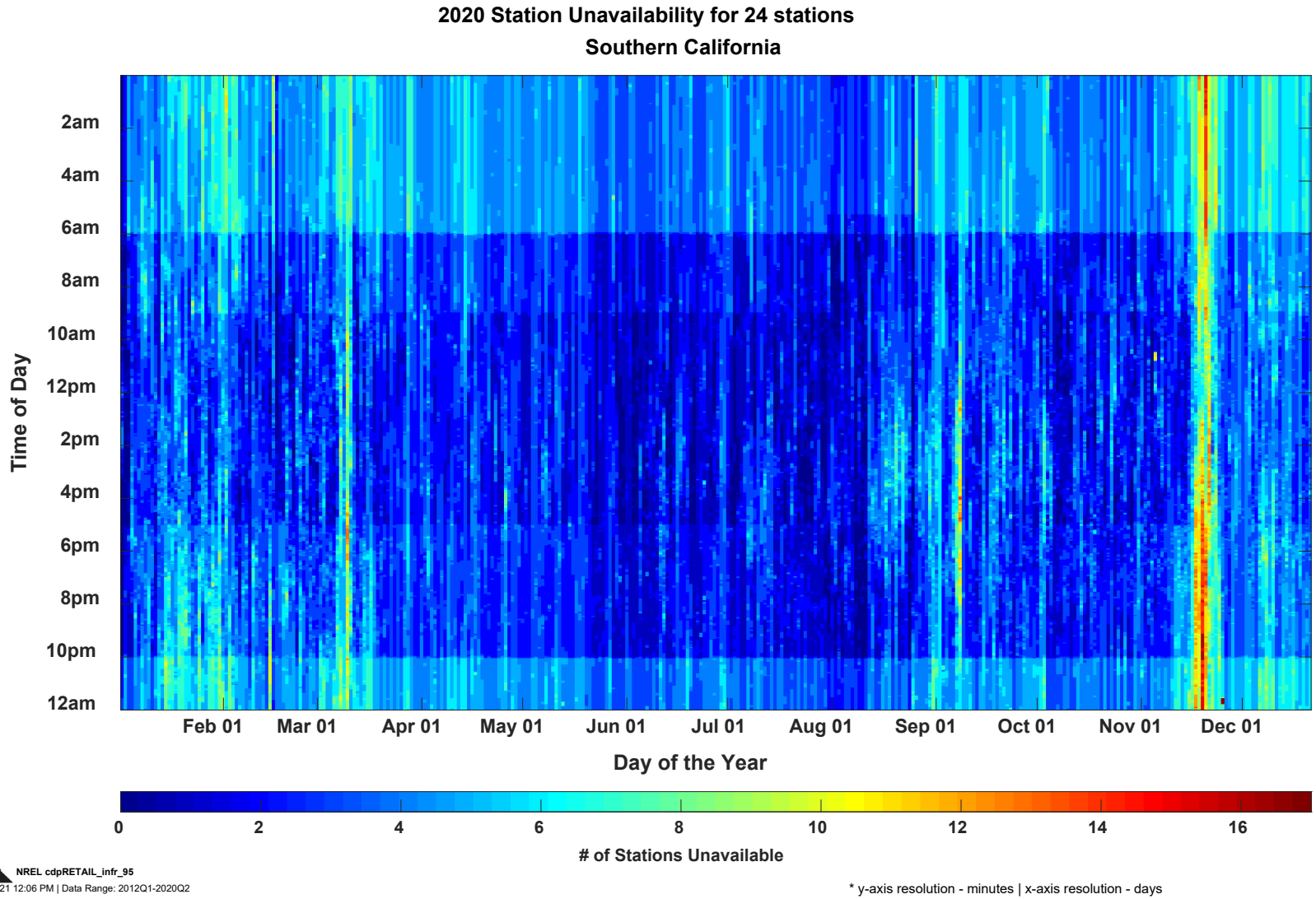
CDP-INFR-93
Station Unavailability



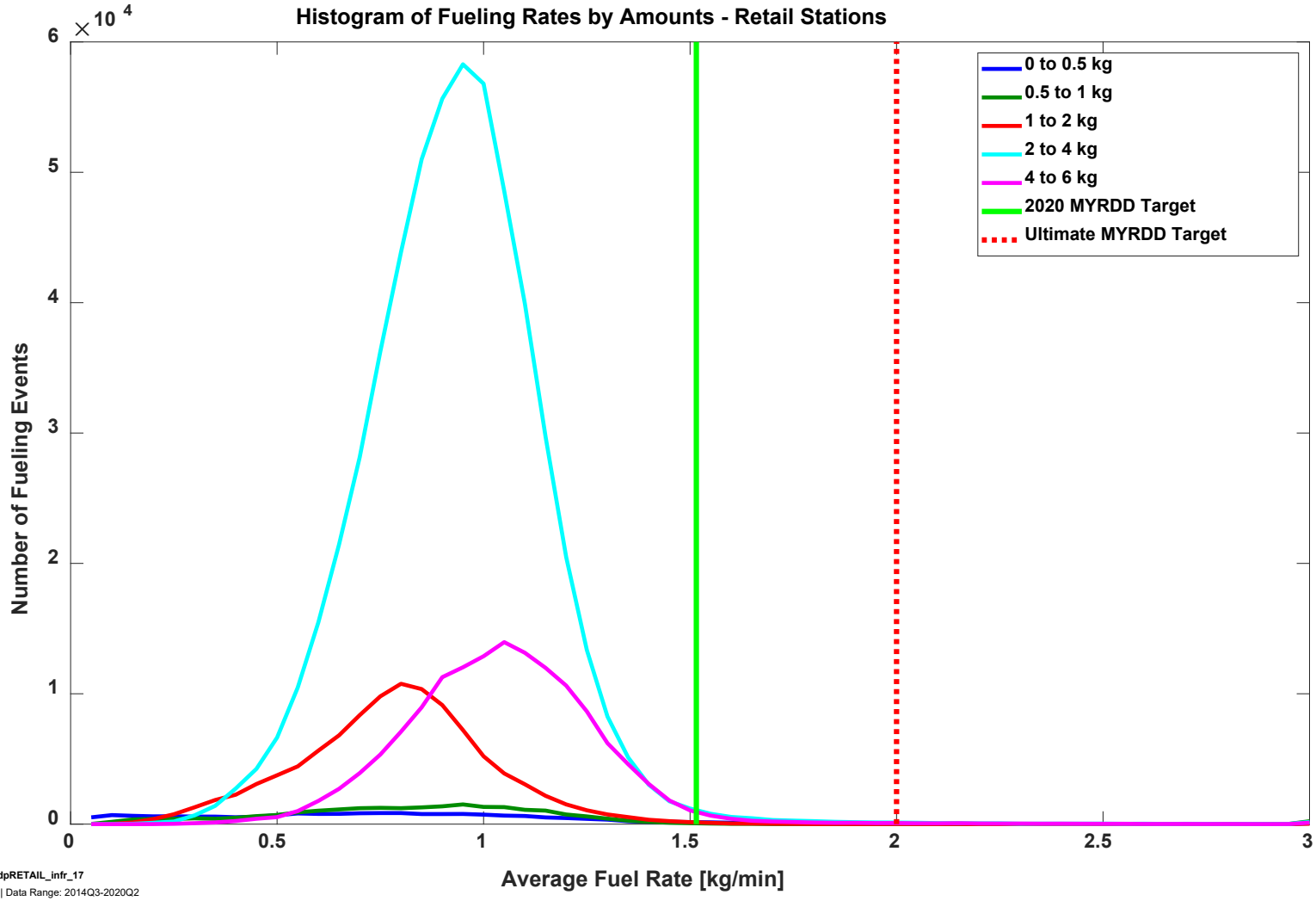
CDP-INFR-95
Station Unavailability



CDP-INFR-95
Station Unavailability

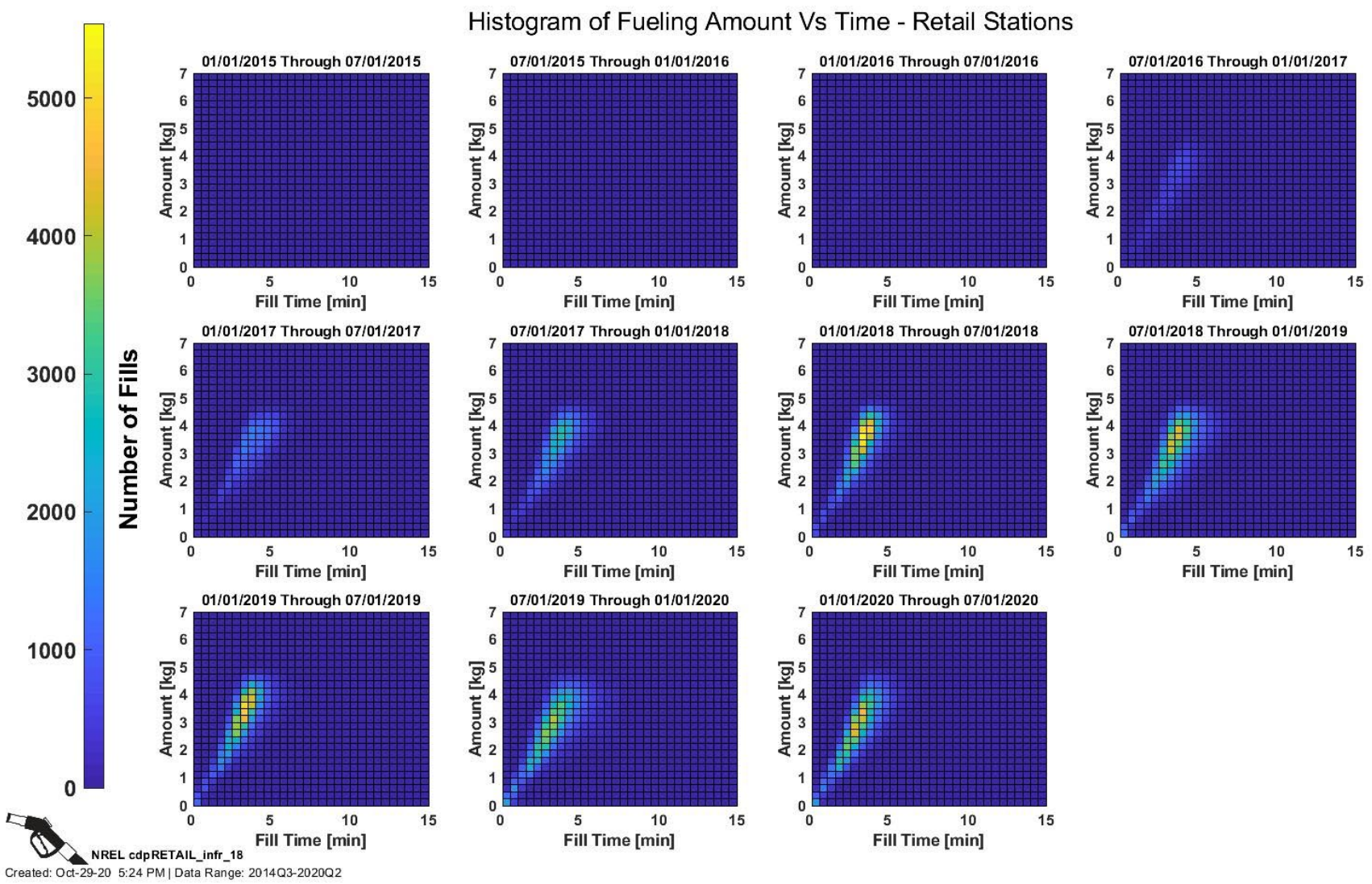


CDP-INFR-17
Fueling Rates by Amount Filled

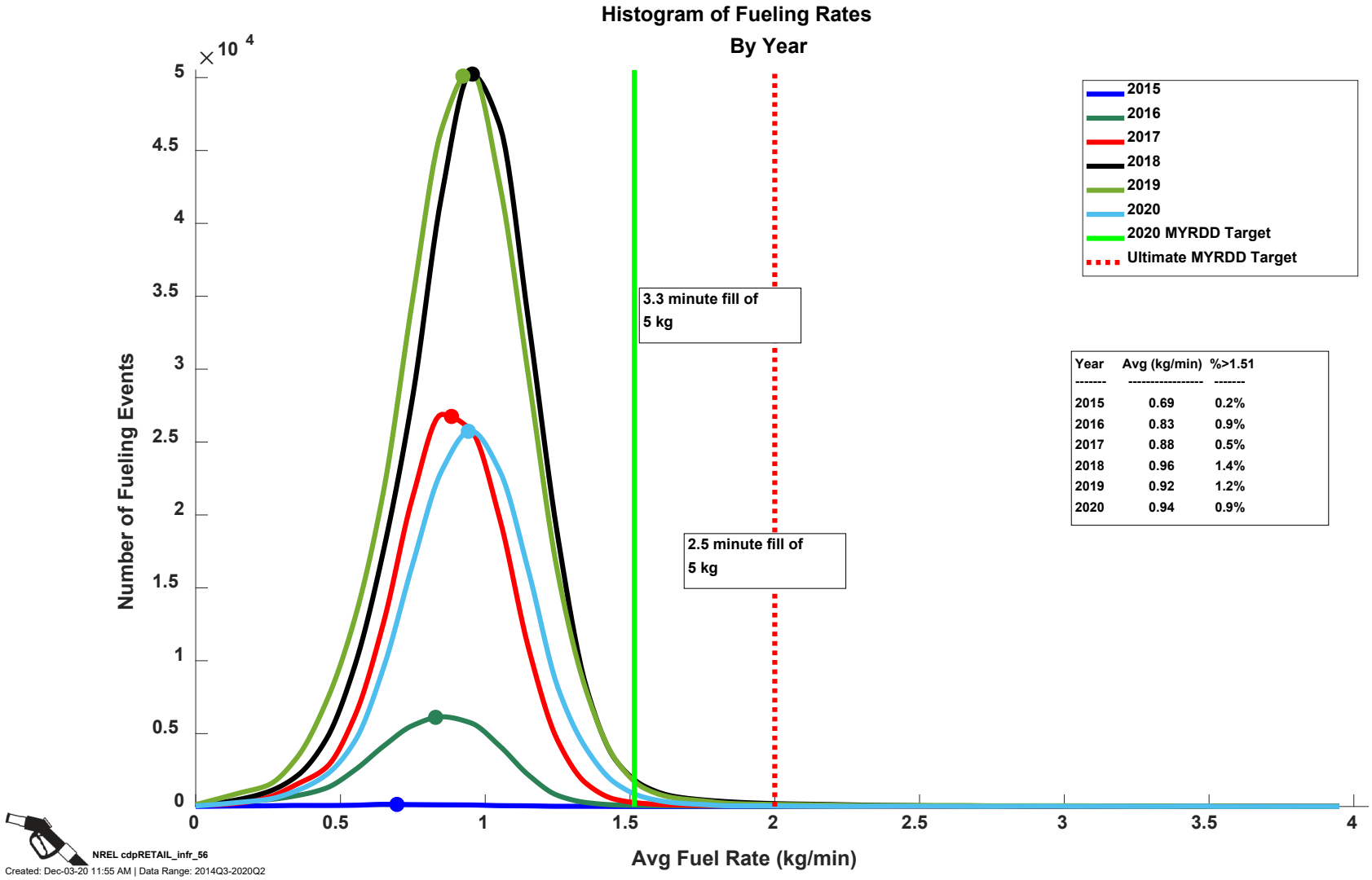


NREL cdpRETAIL_infr_17
Created: Oct-29-20 5:58 PM | Data Range: 2014Q3-2020Q2

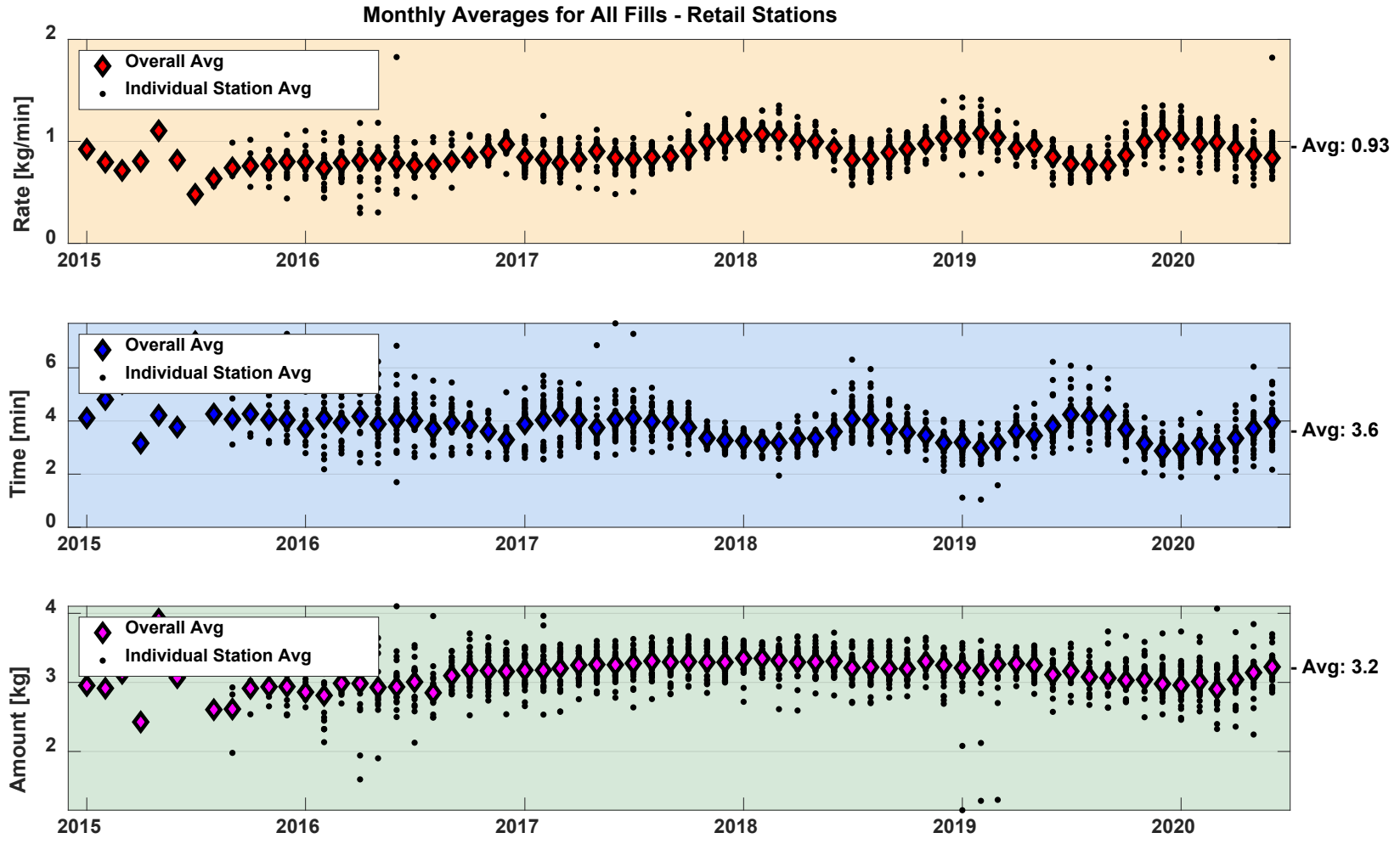
CDP-INFR-18
Fueling Amount vs. Time to Fill



CDP-INFR-56
Fueling Rates by Year

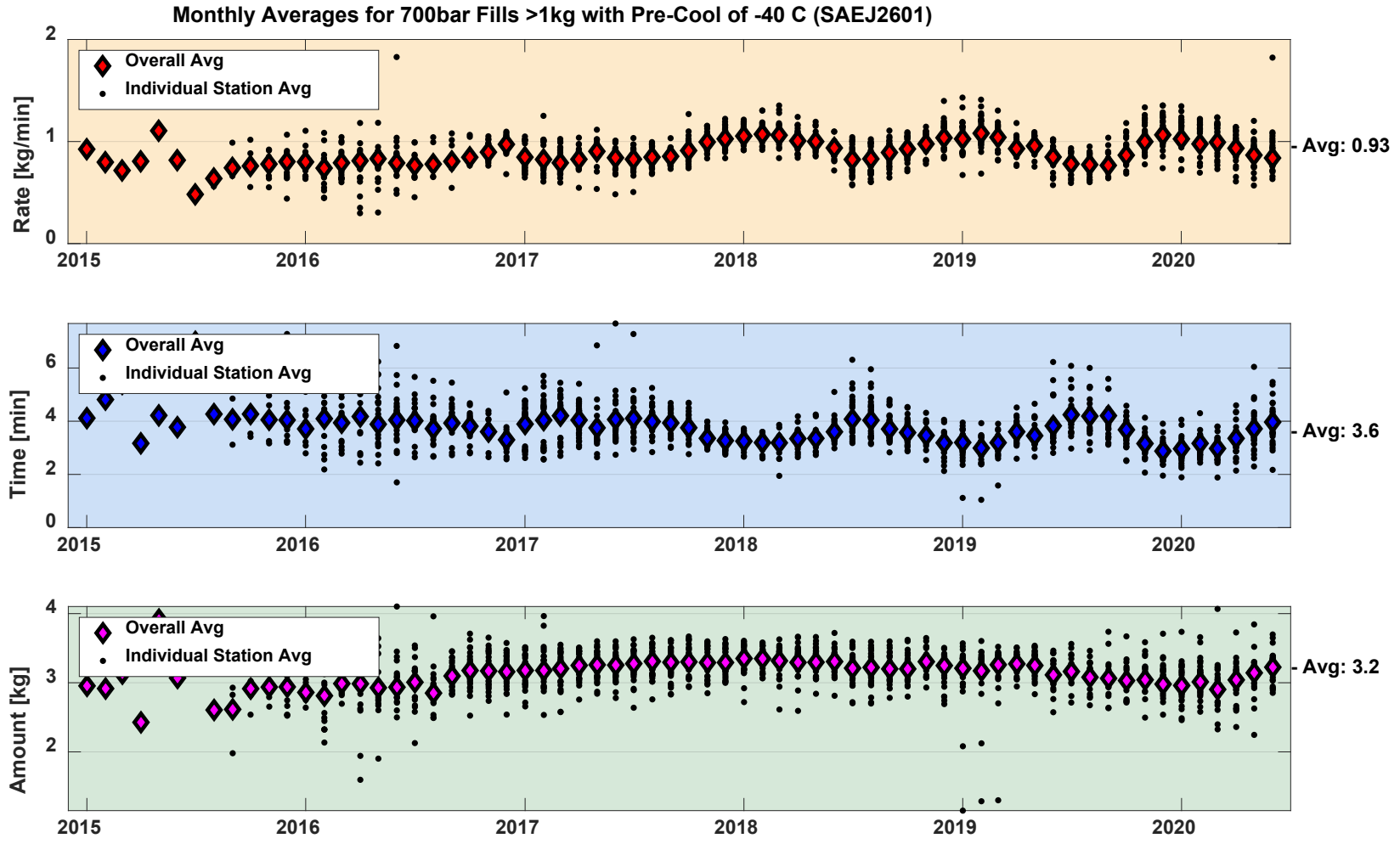


CDP-INFR-55
Monthly Averages: All Fills



NREL cdpRETAIL_infr_55
Created: Nov-13-20 8:29 PM | Data Range: 2014Q3-2020Q2

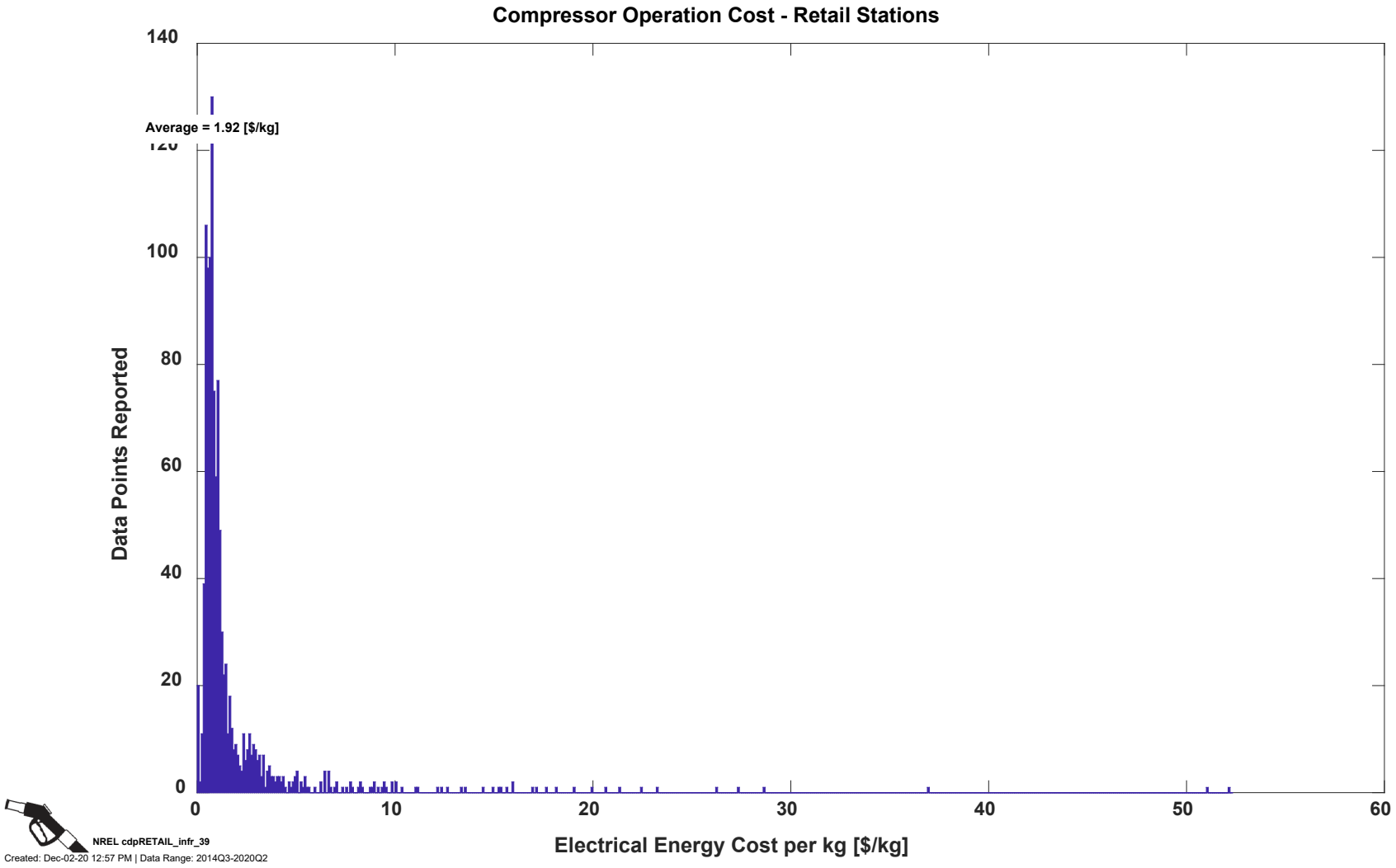
CDP-INFR-57
Monthly Averages: 700 bar Fills >1 kg with Pre-Cool of -40°C



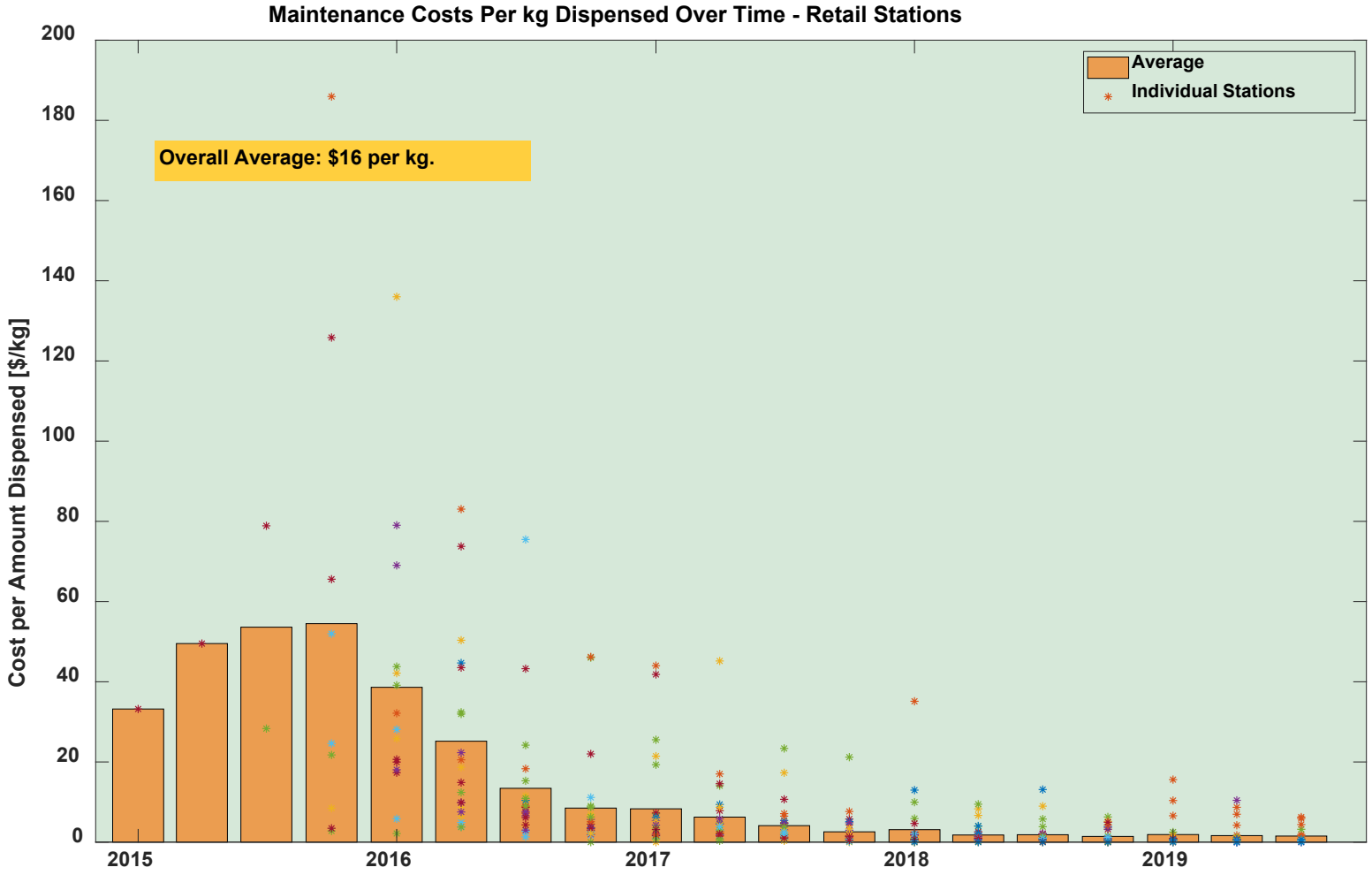
NREL cdpRETAIL_infr_57
Created: Nov-13-20 7:38 PM | Data Range: 2014Q3-2020Q2

Cost

CDP-INFR-39
Compressor Operation Cost



CDP-INFR-53
Maintenance Cost per kg of Hydrogen Dispensed

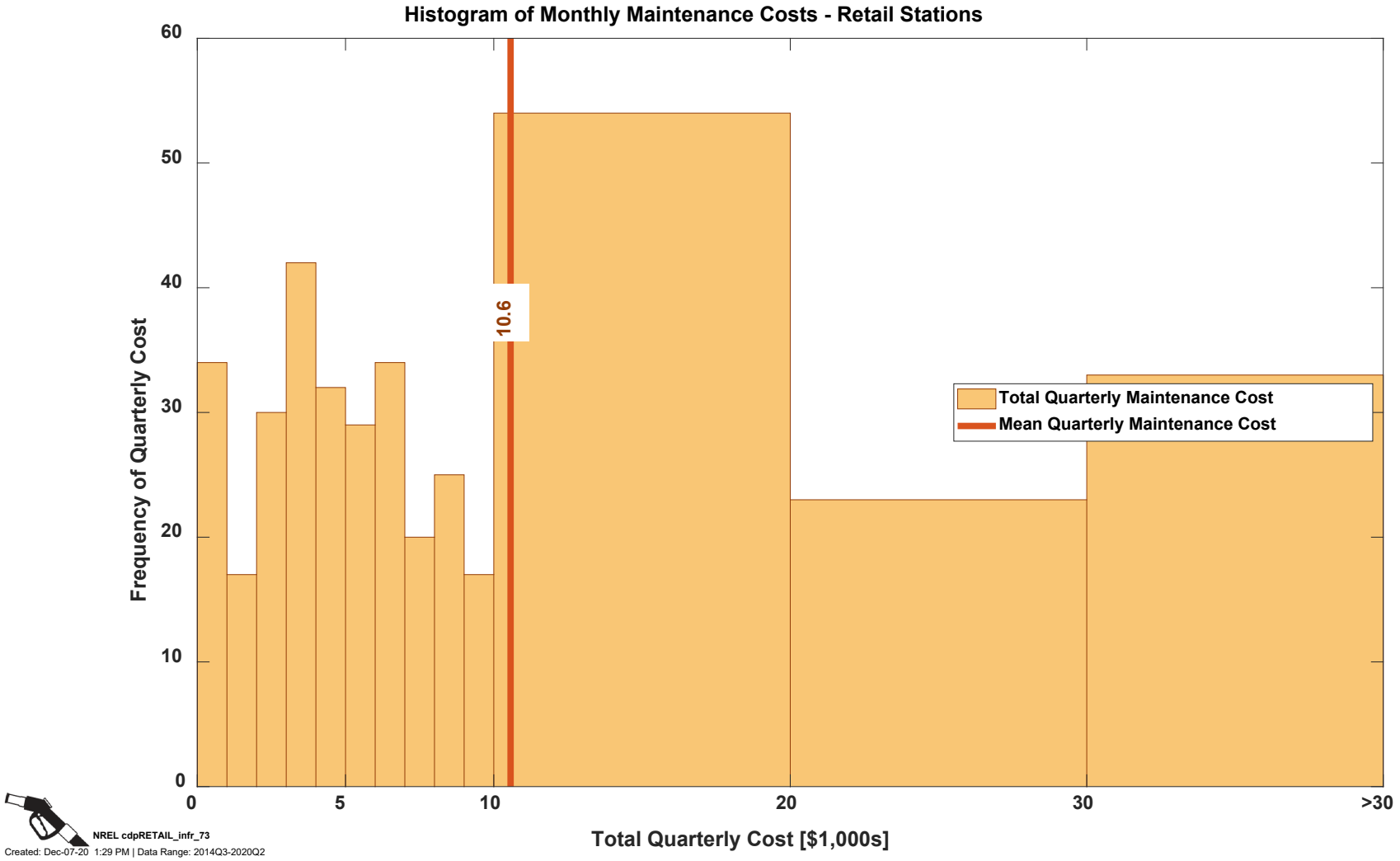


NREL cdpRETAIL_infr_53

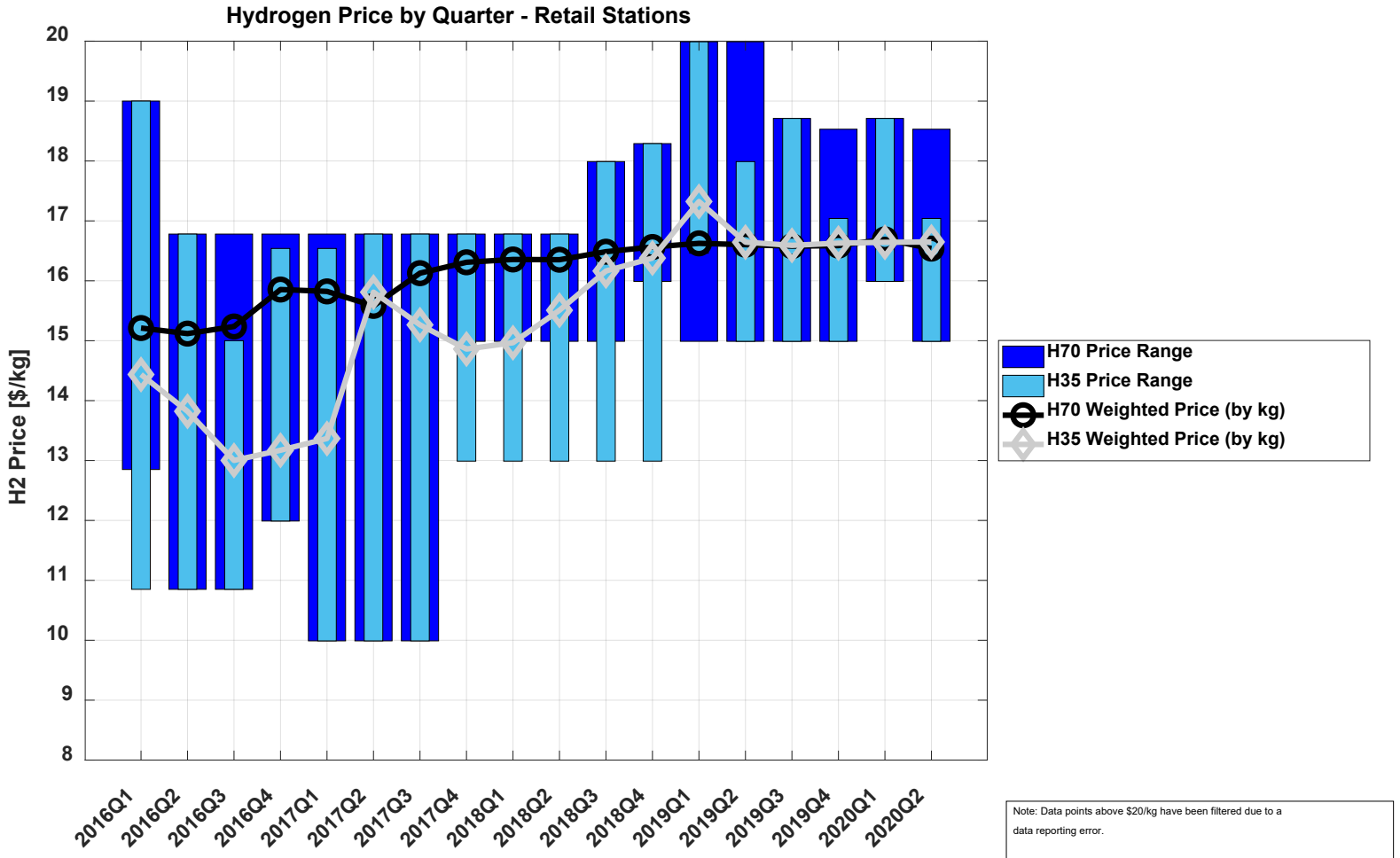
Created: Dec-02-20 3:19 PM | Data Range: 2014Q3-2020Q2

*Each color represents a unique station. 0 data points excluded that were over $1000/kg

CDP-INFR-73
Histogram of Monthly Maintenance Costs



CDP-INFR-89
Hydrogen Price by Quarter

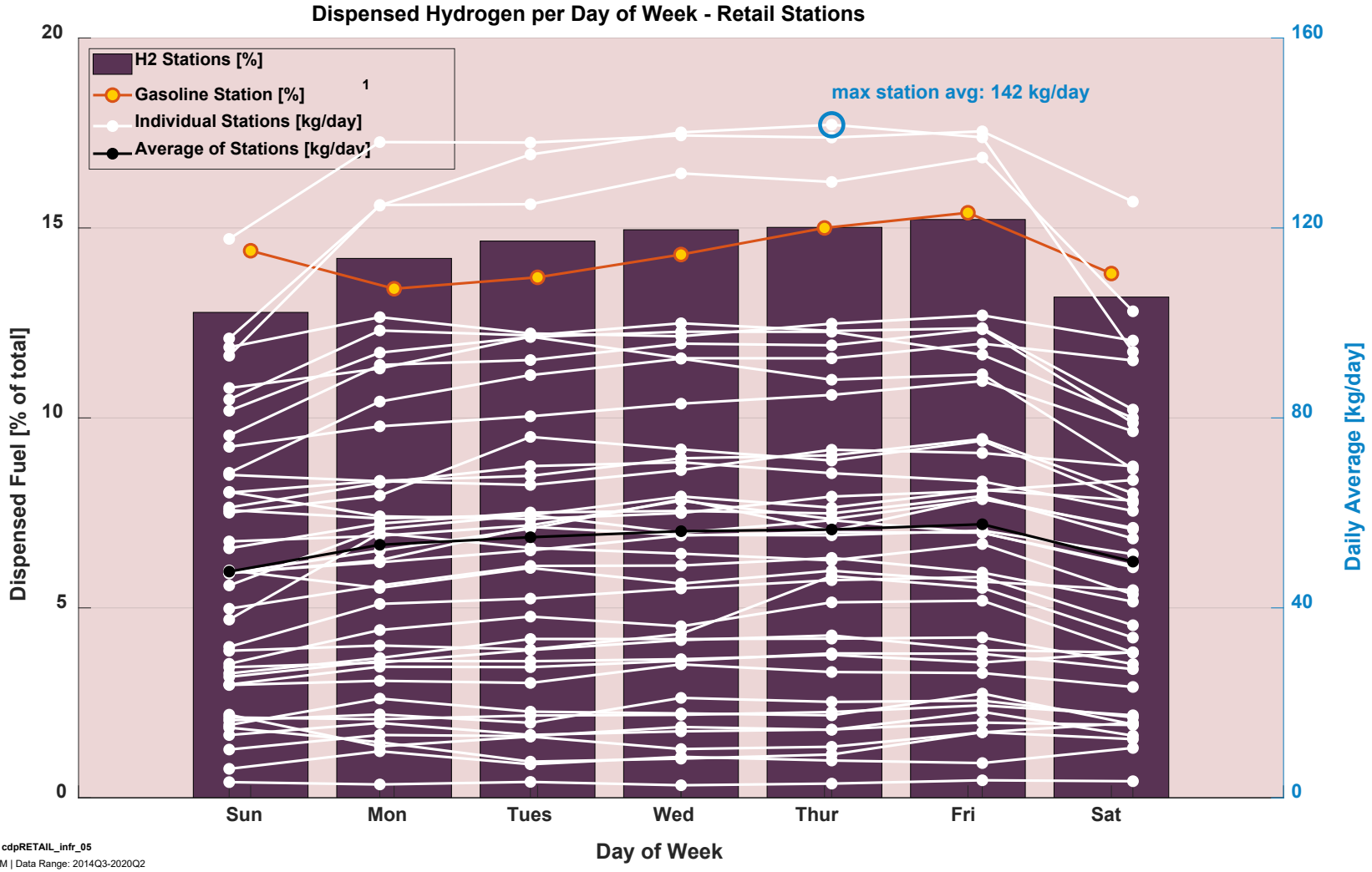


Note: Data points above $20/kg have been filtered due to a data reporting error.

NREL cdpRETAIL_infr_89
Created: Dec-03-20 3:18 PM | Data Range: 2014Q3-2020Q2

Utilization

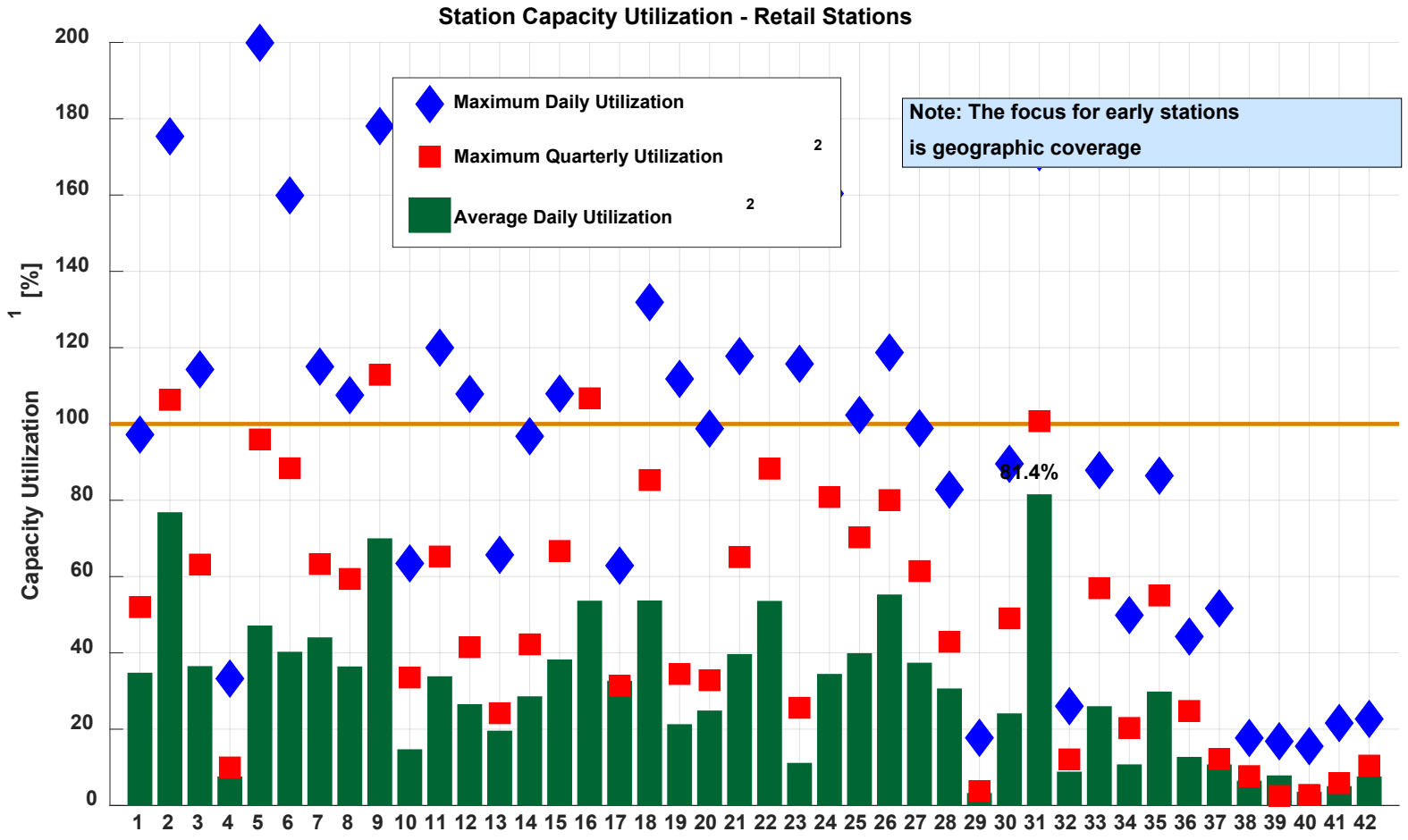
CDP-INFR-05
Dispensed Hydrogen per Day of Week



NREL cdpRETAIL_infr_05
Created: Oct-30-20 1:41 AM | Data Range: 2014Q3-2020Q2

1. Chevron weekly demand profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen.

CDP-INFR-06
Station Capacity Utilization

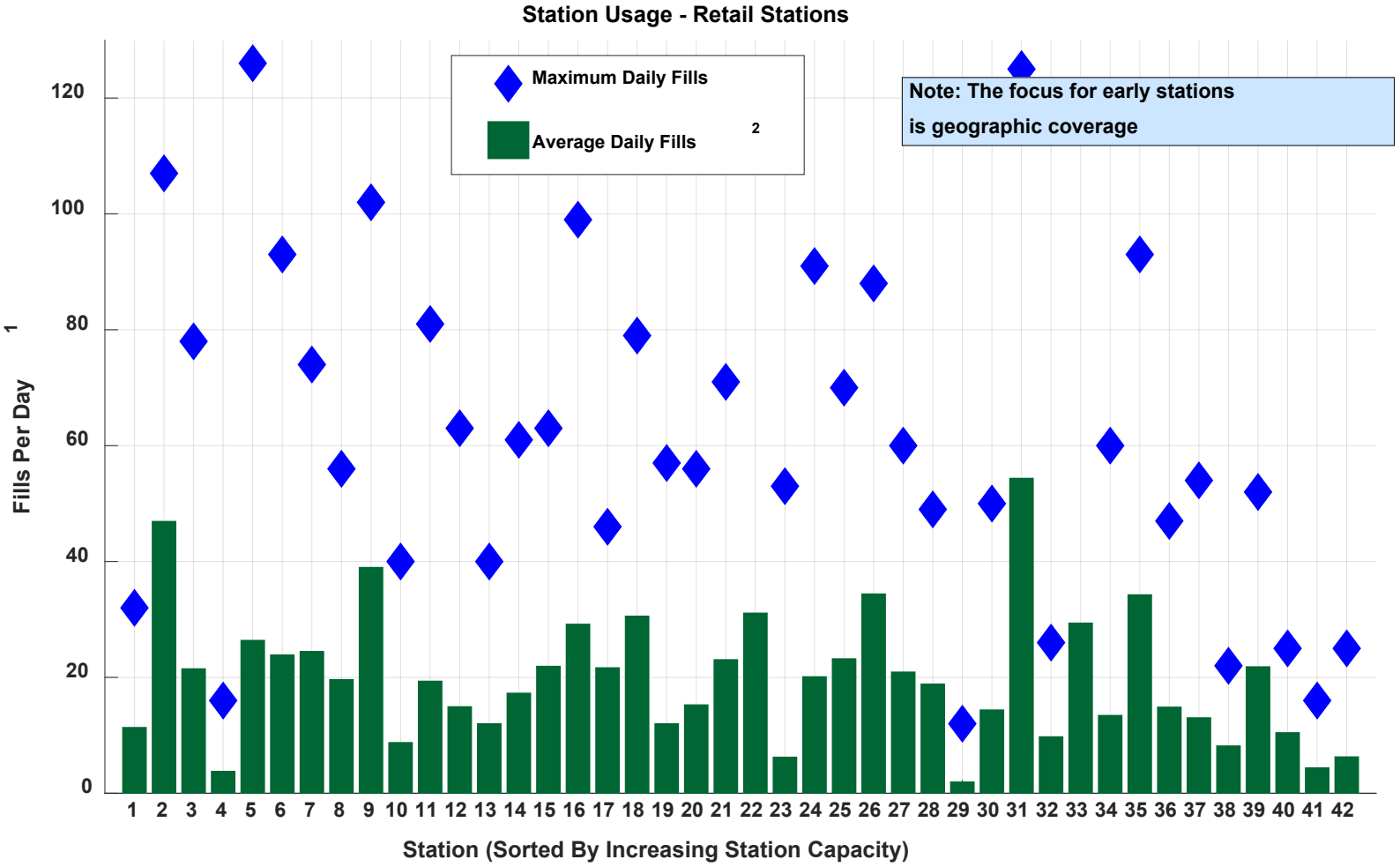


NREL cdpRETAIL_infr_06
Created: Dec-03-20 3:30 PM | Data Range: 2014Q3-2020Q2

[1] Station nameplate capacity reflects a variety of system design consderations 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

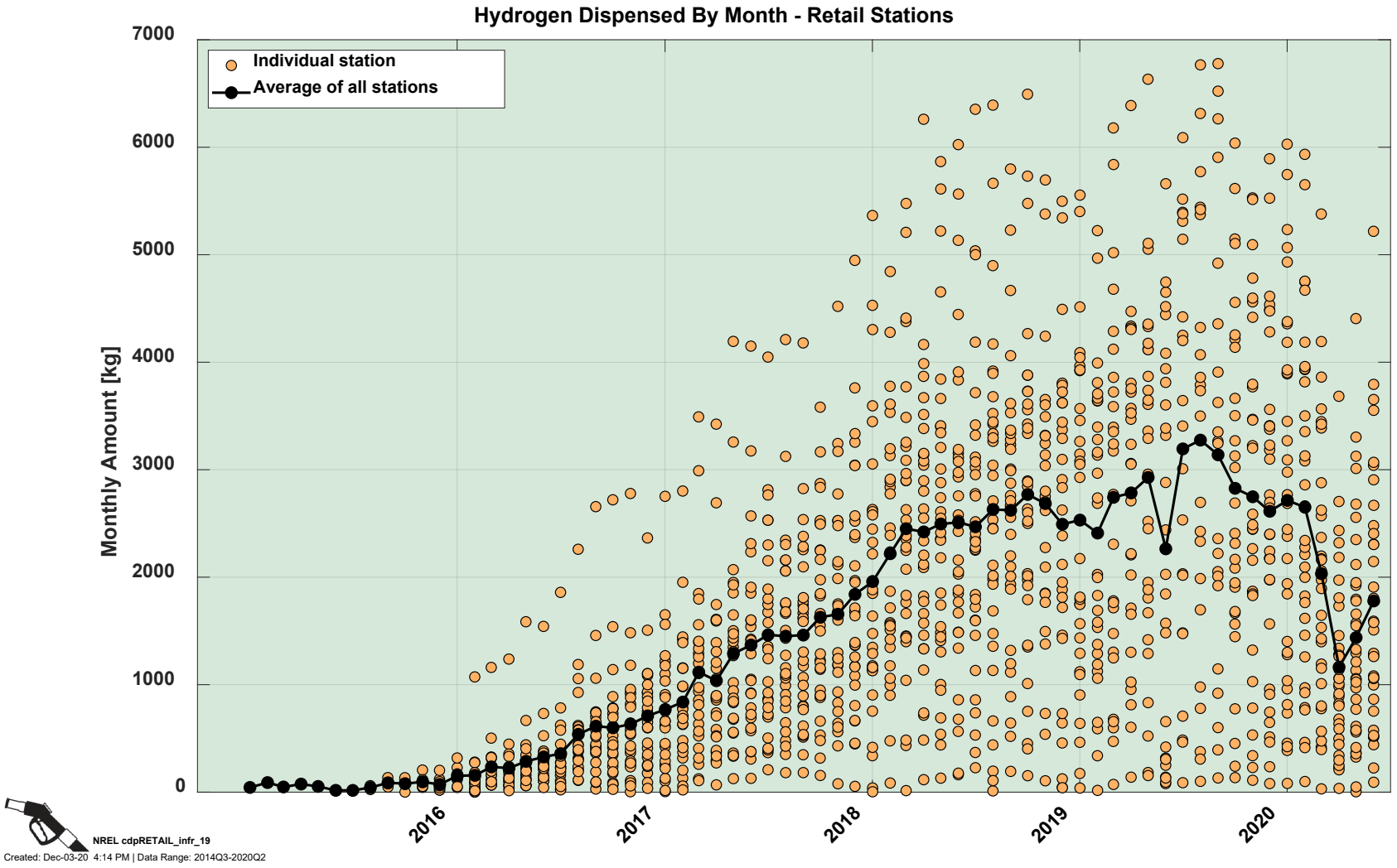


NREL cdpRETAIL_infr_07
Created: Oct-30-20 12:47 AM | Data Range: 2014Q3-2020Q2

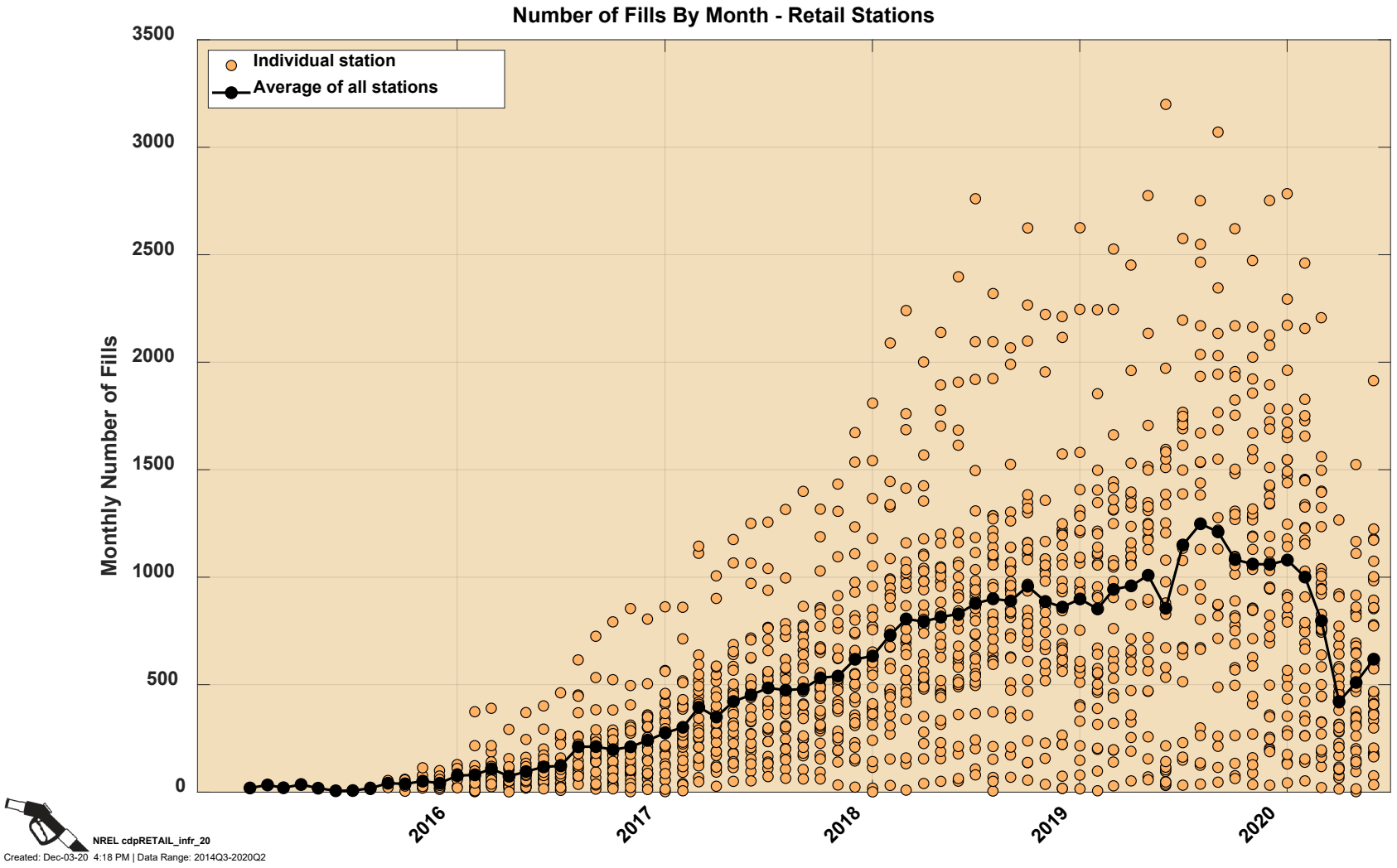
[1] Excludes hydrogen fills of < 0.5 kg

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

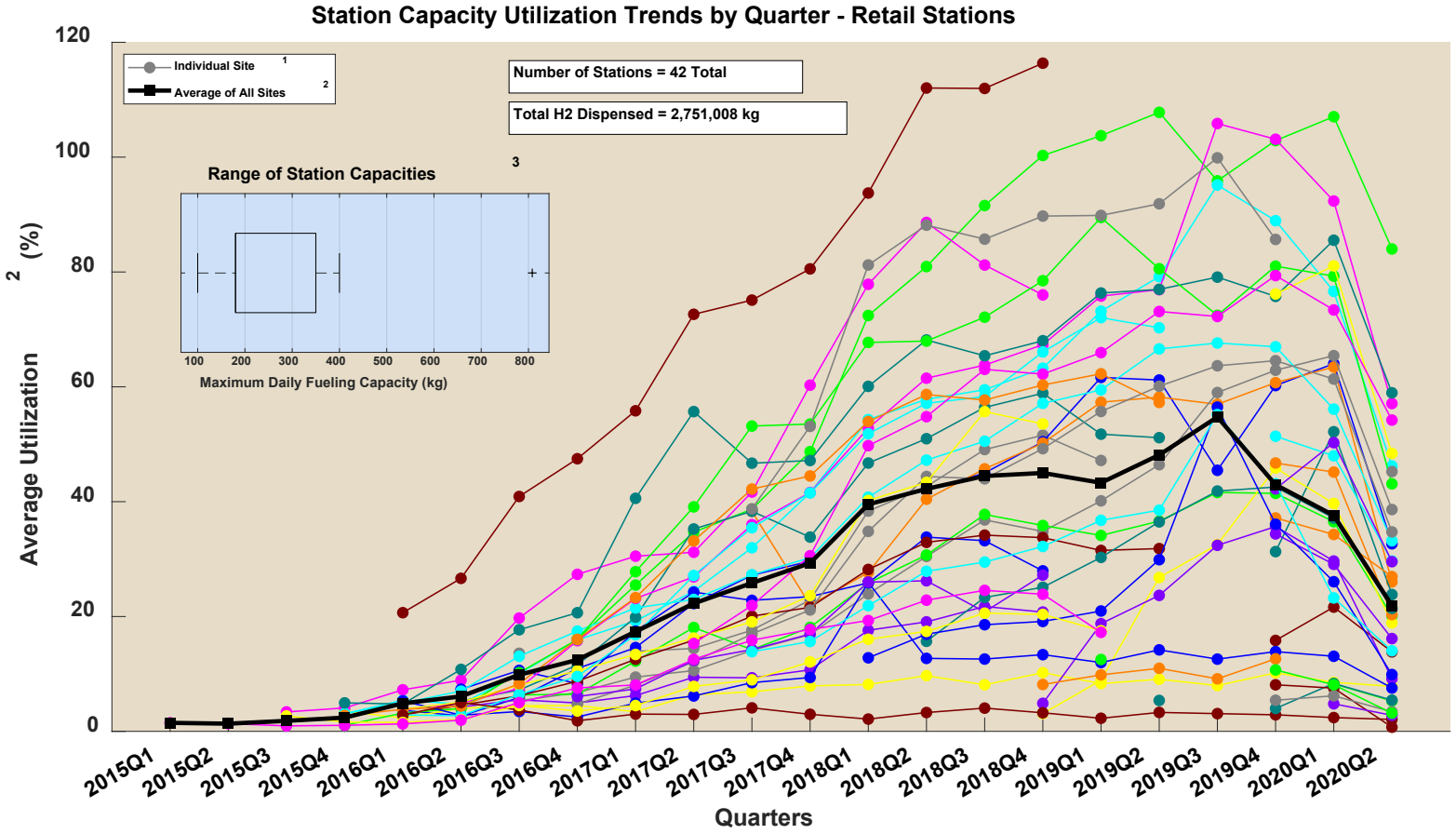
CDP-INFR-19
Hydrogen Dispensed by Month



CDP-INFR-20
Number of Fills by Month



CDP-INFR-44
Station Capacity Utilization Trends by Quarter



[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station was offline or missing data. Each station is represented by a unique color.

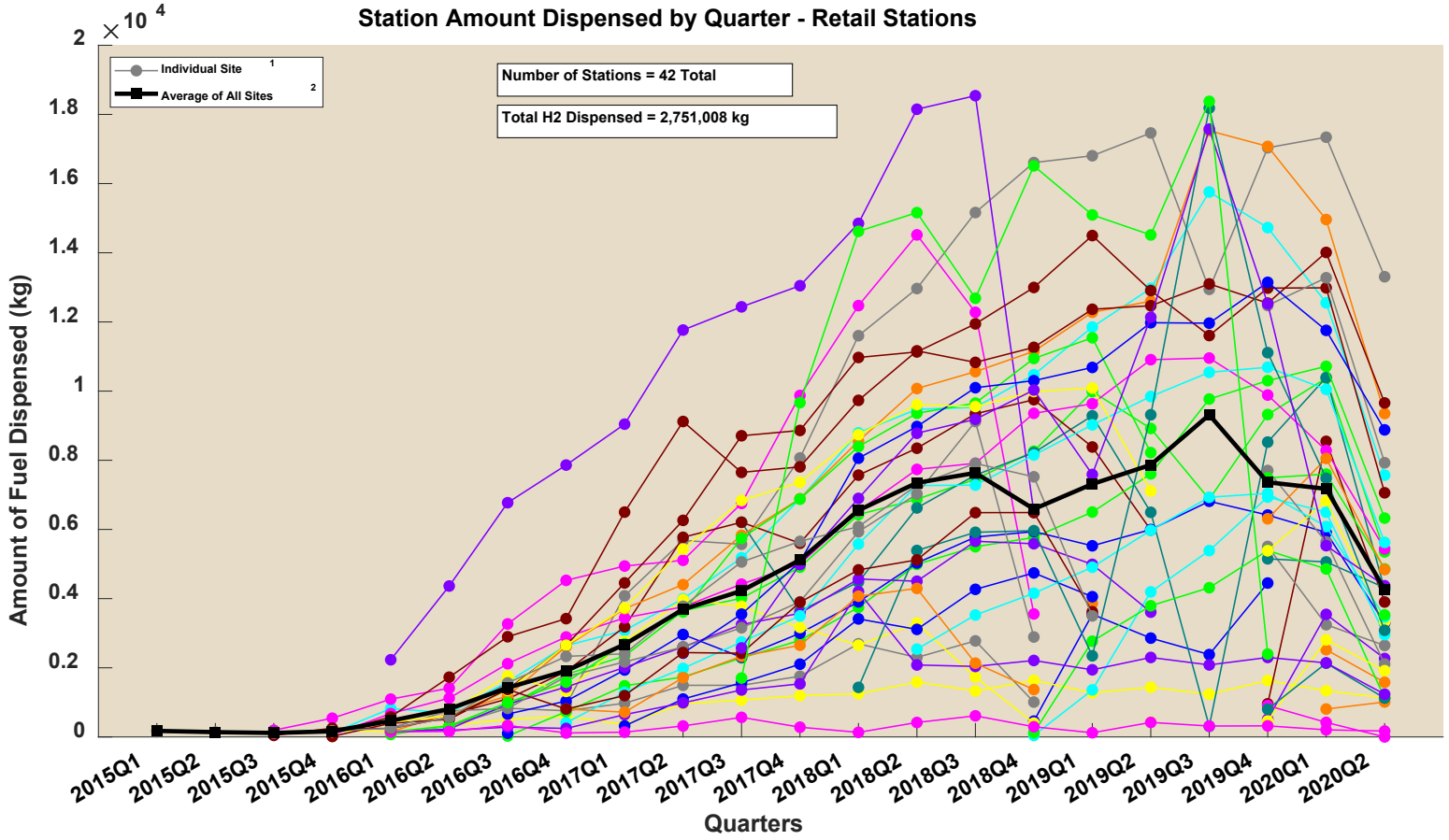
[2] Average quarterly utilization only considers quarters when at least one fill occurred.

[3] Station nameplate capacity is as reported to NREL and reflects a variety of system design considerations including: system capacity, throughput, system reliability, and maintenance. Actual daily usage may exceed nameplate capacity.

NREL cdpRETAIL_infr_44

Created: Dec-03-20 10:51 AM | Data Range: 2014Q3-2020Q2

CDP-INFR-45
Station Amount Dispensed by Quarter

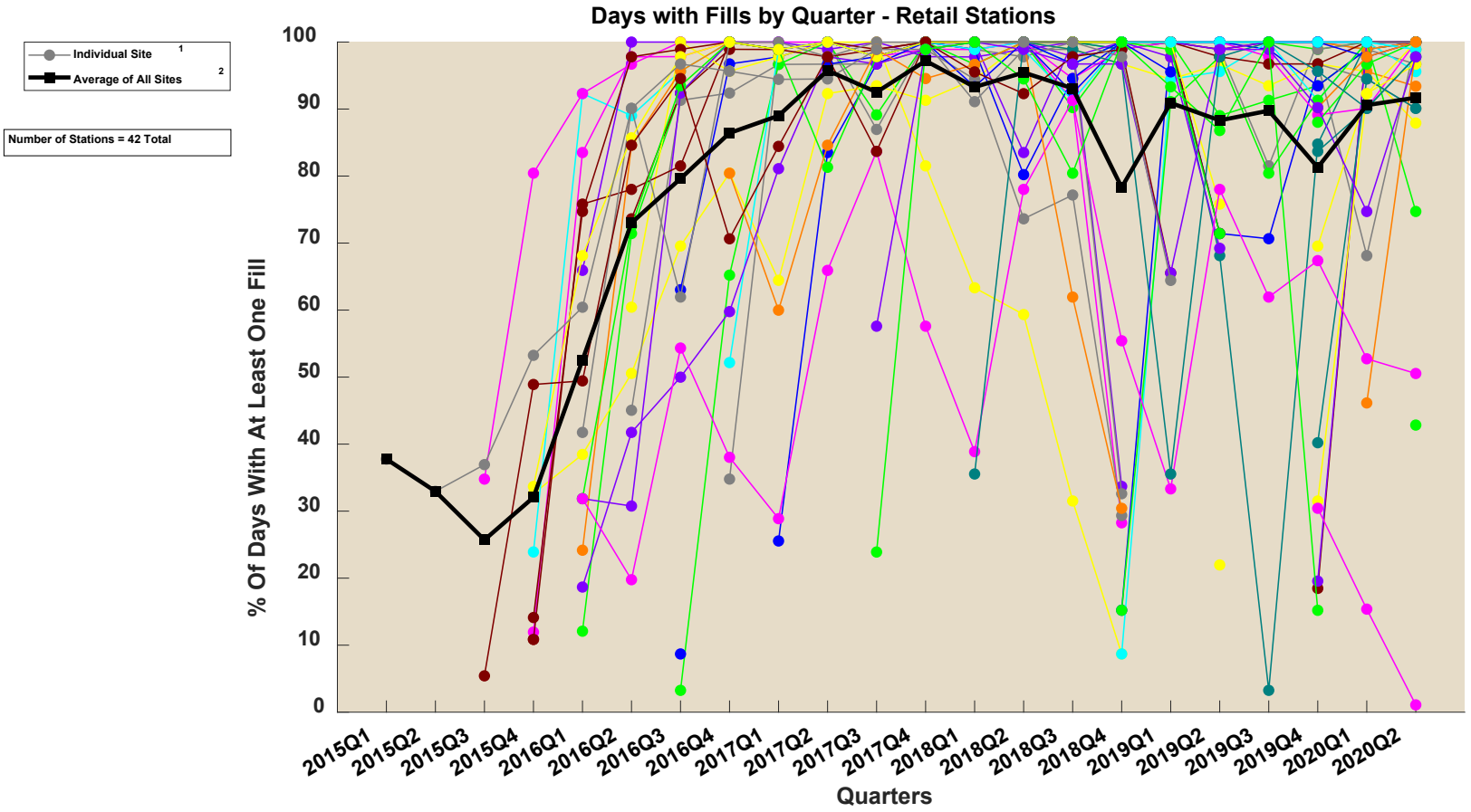


[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station was offline or missing data. Each station is represented by a unique color.

[2] Average quarterly amount only considers quarters when at least one fill occurred.

NREL cdpRETAIL_infr_45
Created: Dec-02-20 1:32 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-46
Days with Fills by Quarter

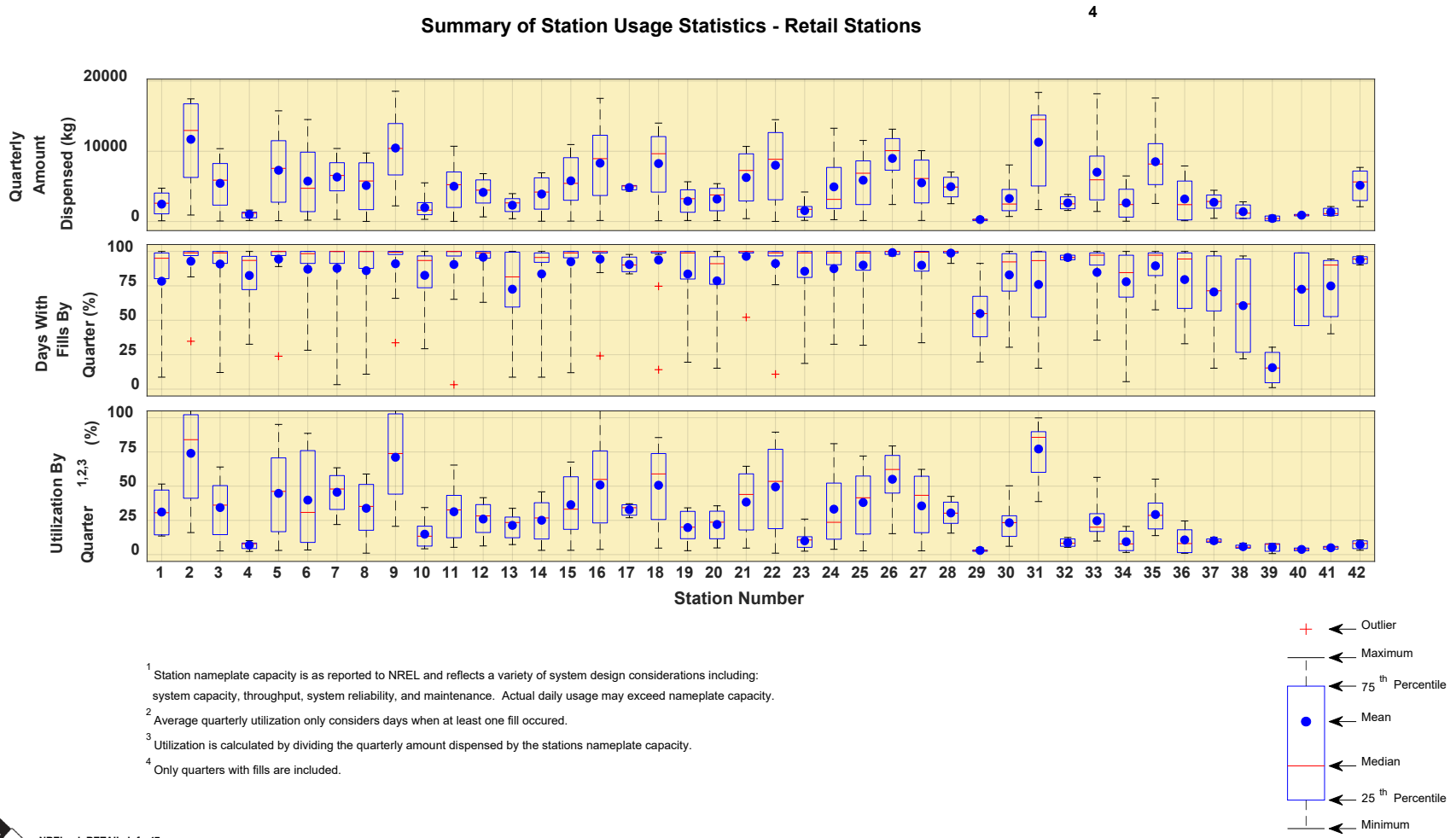


[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station had no fills or was missing data. Each station is represented by a unique color.

[2] The average percent of days with fills only considers quarters in which at least one fill occurred. Stations with no filling in a quarter are excluded from the average for that quarter. All stations with at least one fill in a quarter are given eq ual weight when calculating the average for the quarter. days

NREL cdpRETAIL_infr_46
Created: Dec-10-20 2:33 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-47
Summary of Station Usage Statistics



[1] Station nameplate capacity is as reported to NREL and reflects a variety of system design considerations including: system capacity, throughput, system reliability, and maintenance. Actual daily usage may exceed nameplate capacity.

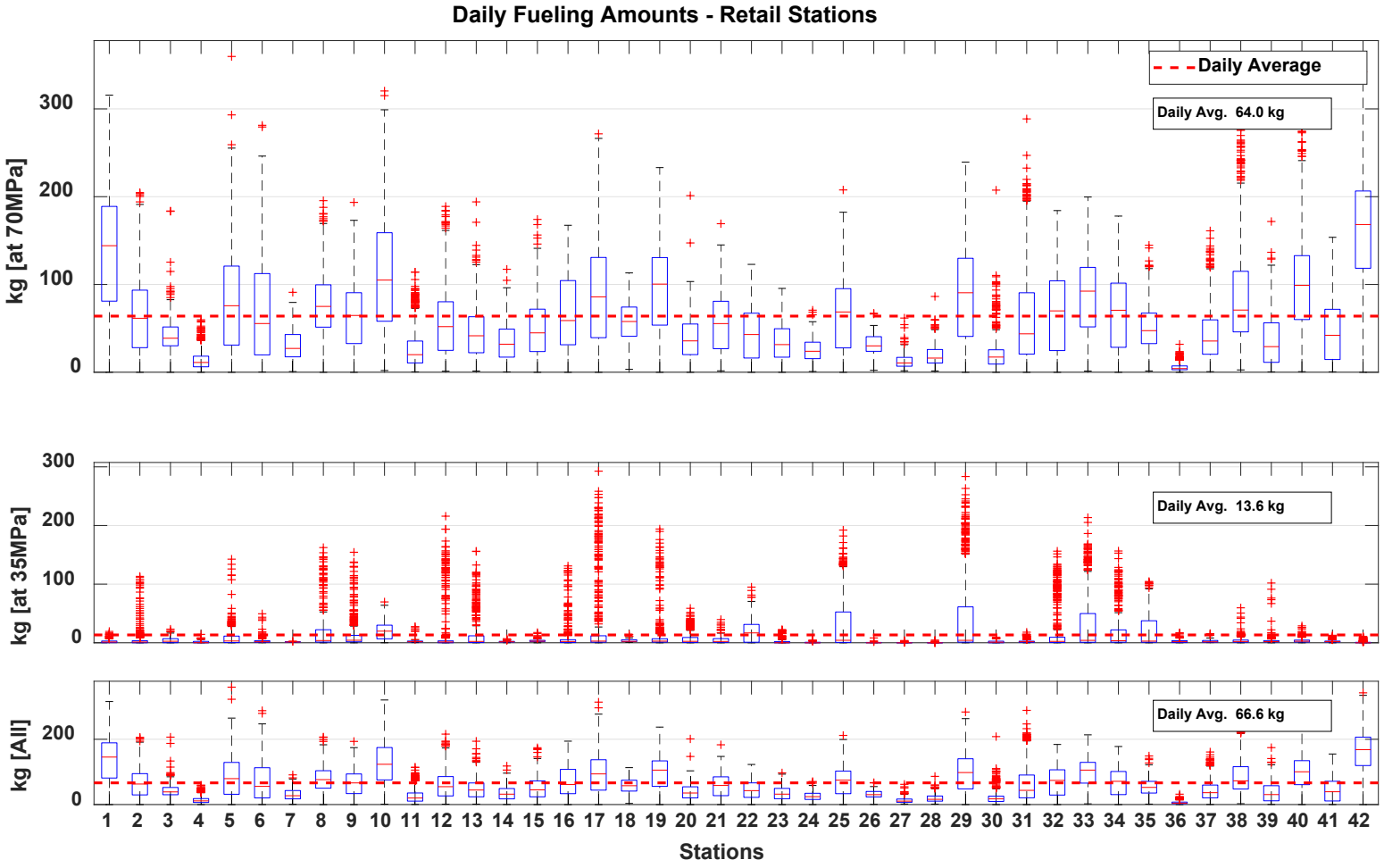
[2] Average quarterly utilization only considers days when at least one fill occured.

[3] Utilization is calculated by dividing the quarterly amount dispensed by the stations nameplate capacity.

[4] Only quarters with fills are included.

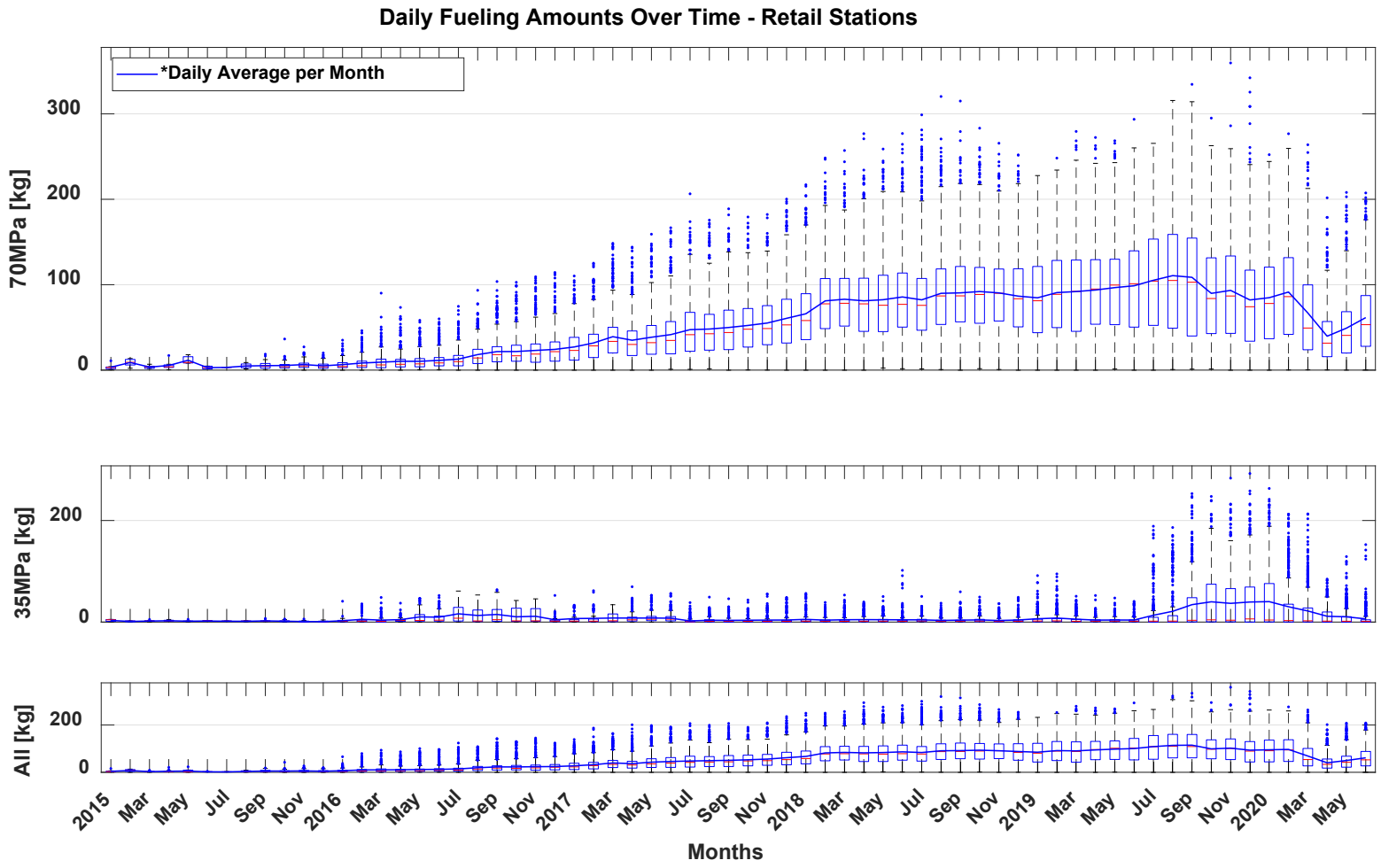
NREL cdpRETAIL_infr_47
Created: Dec-10-20 2:01 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-80
Daily Fueling Amounts by Station



NREL cdpRETAIL_infr_80
Created: Nov-13-20 6:02 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-82
Daily Fueling Amounts by Month

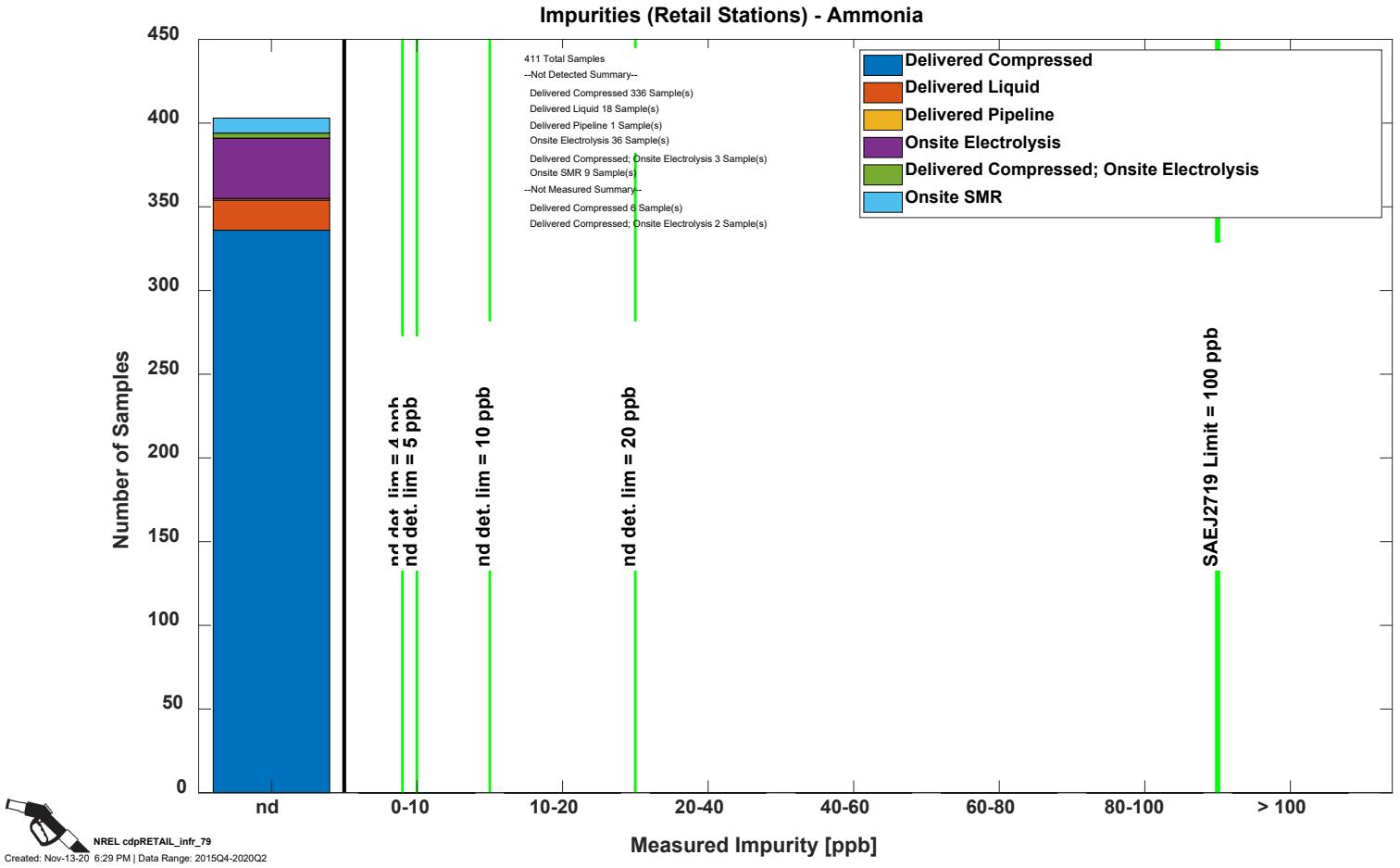


NREL cdpRETAIL_infr_82
Created: Nov-13-20 5:36 PM | Data Range: 2014Q3-2020Q2

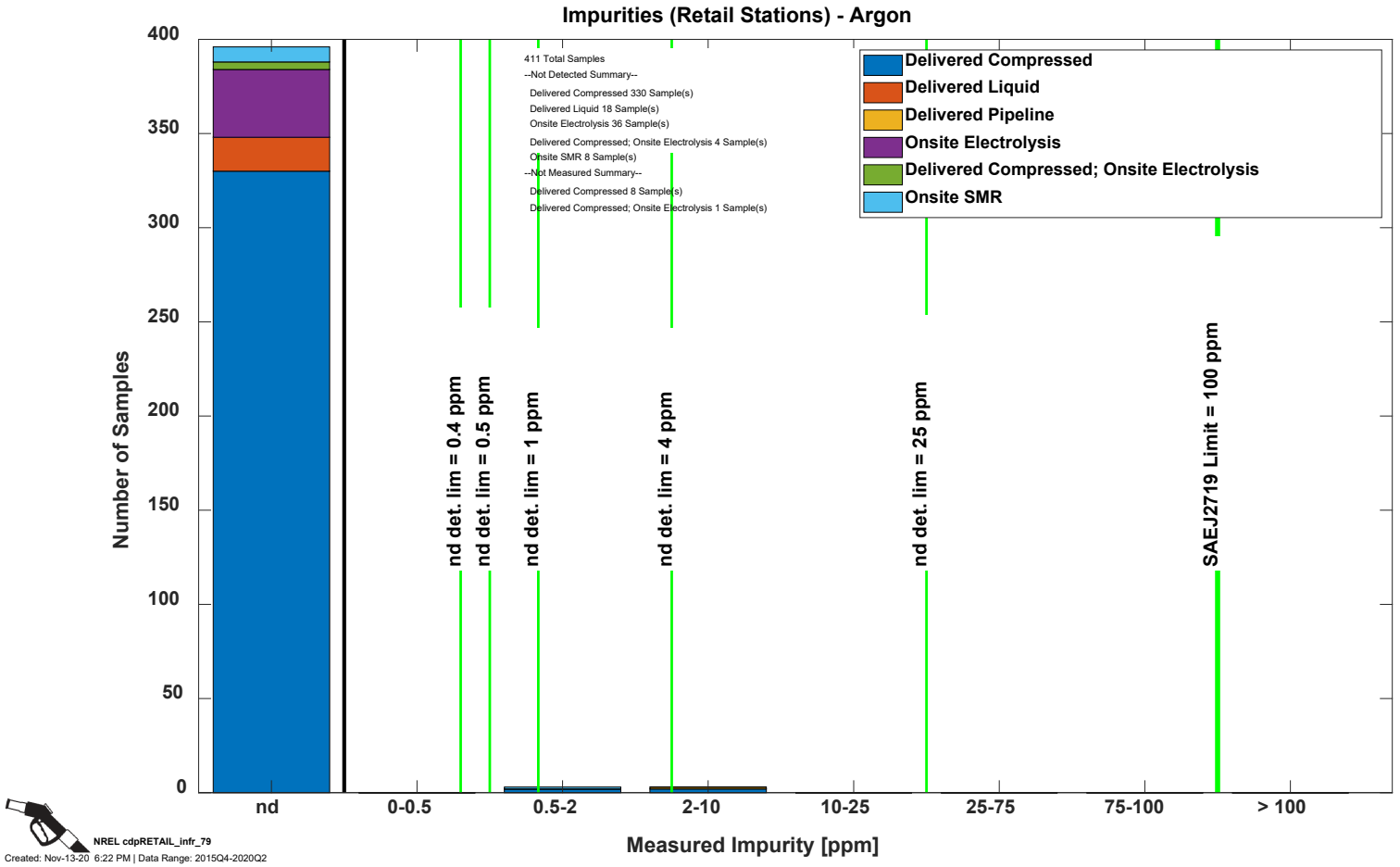
*Daily average only includes days with fills.

Hydrogen Quality

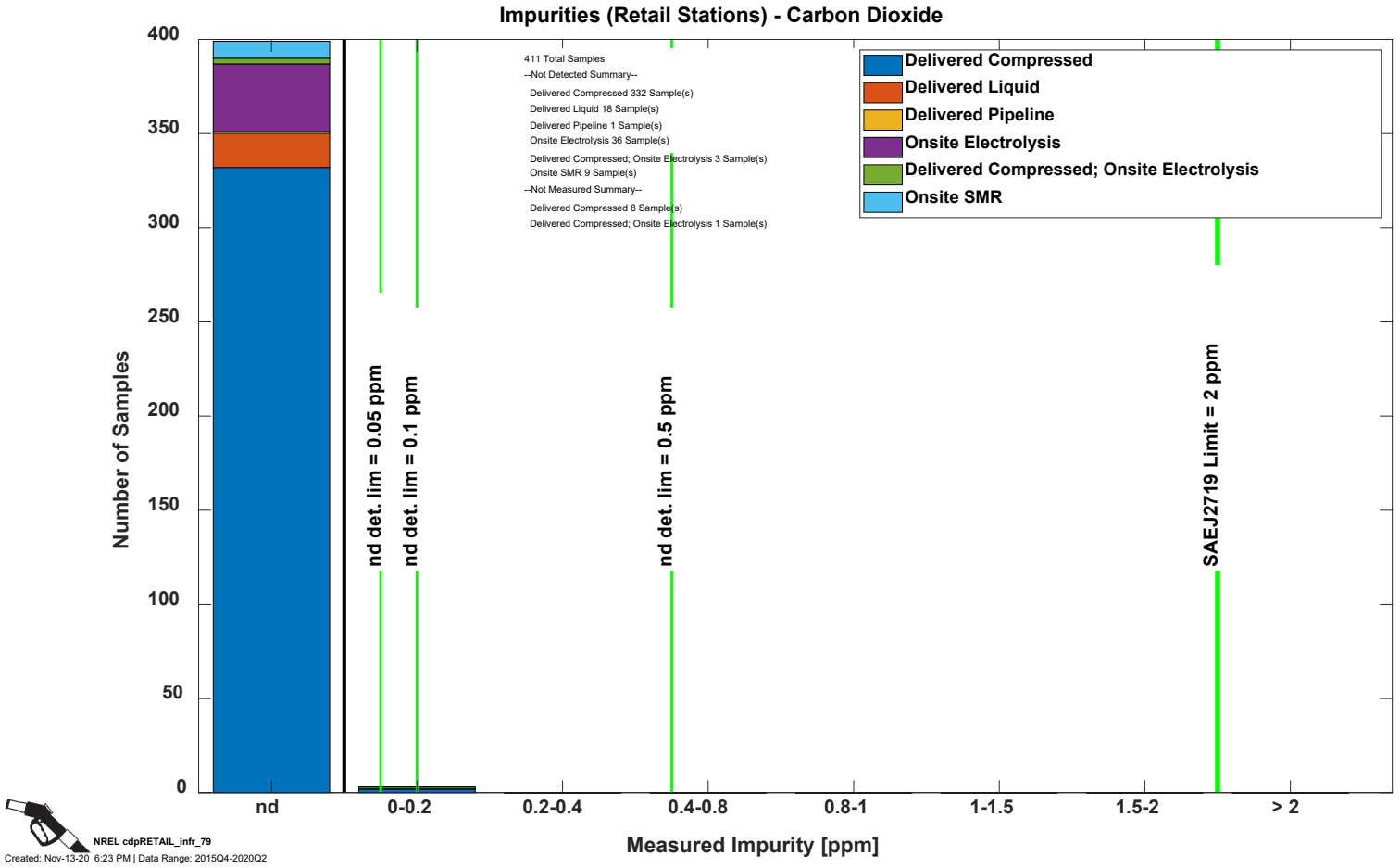
CDP-INFR-79
Impurities—Ammonia



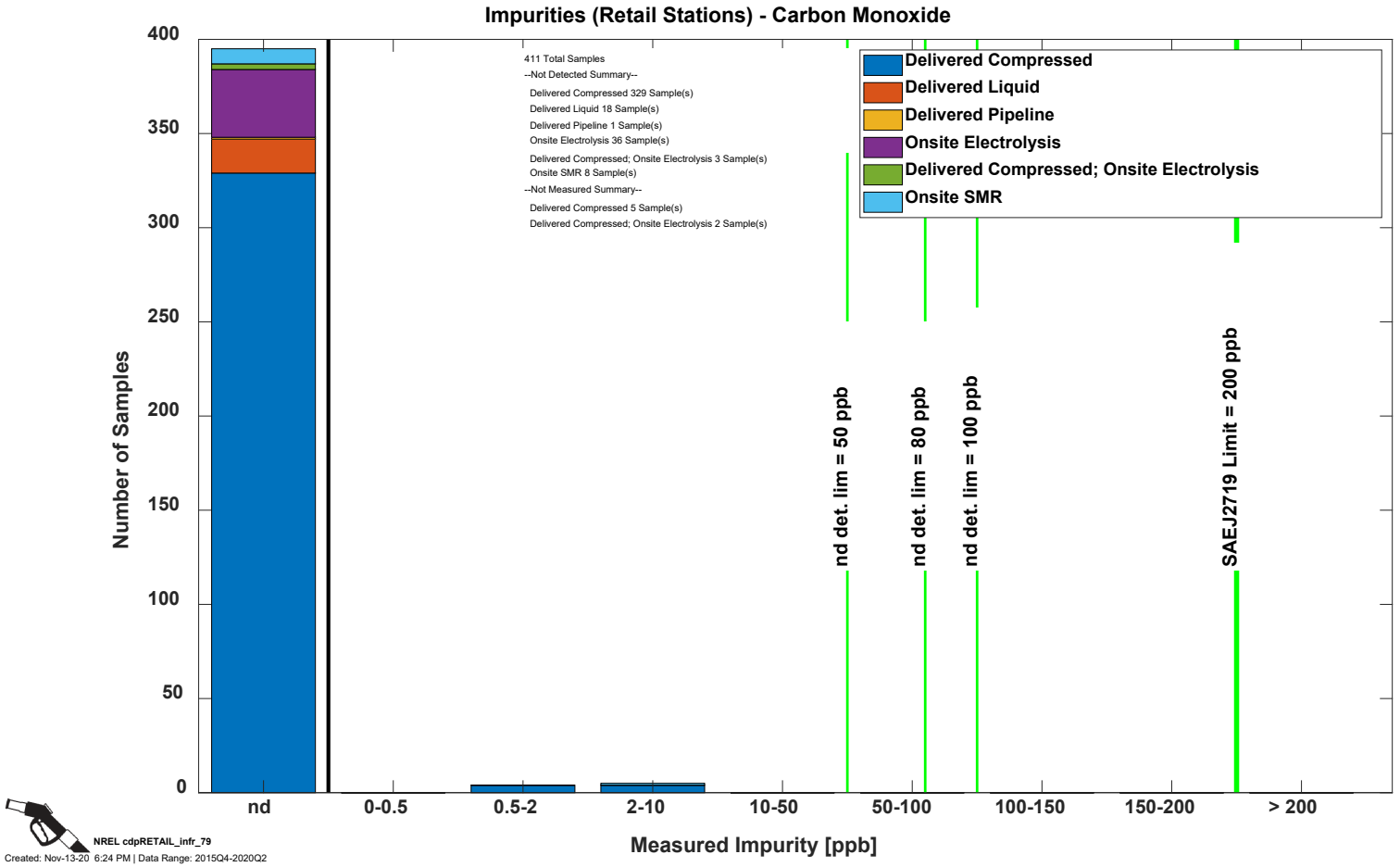
CDP-INFR-79
Impurities—Argon



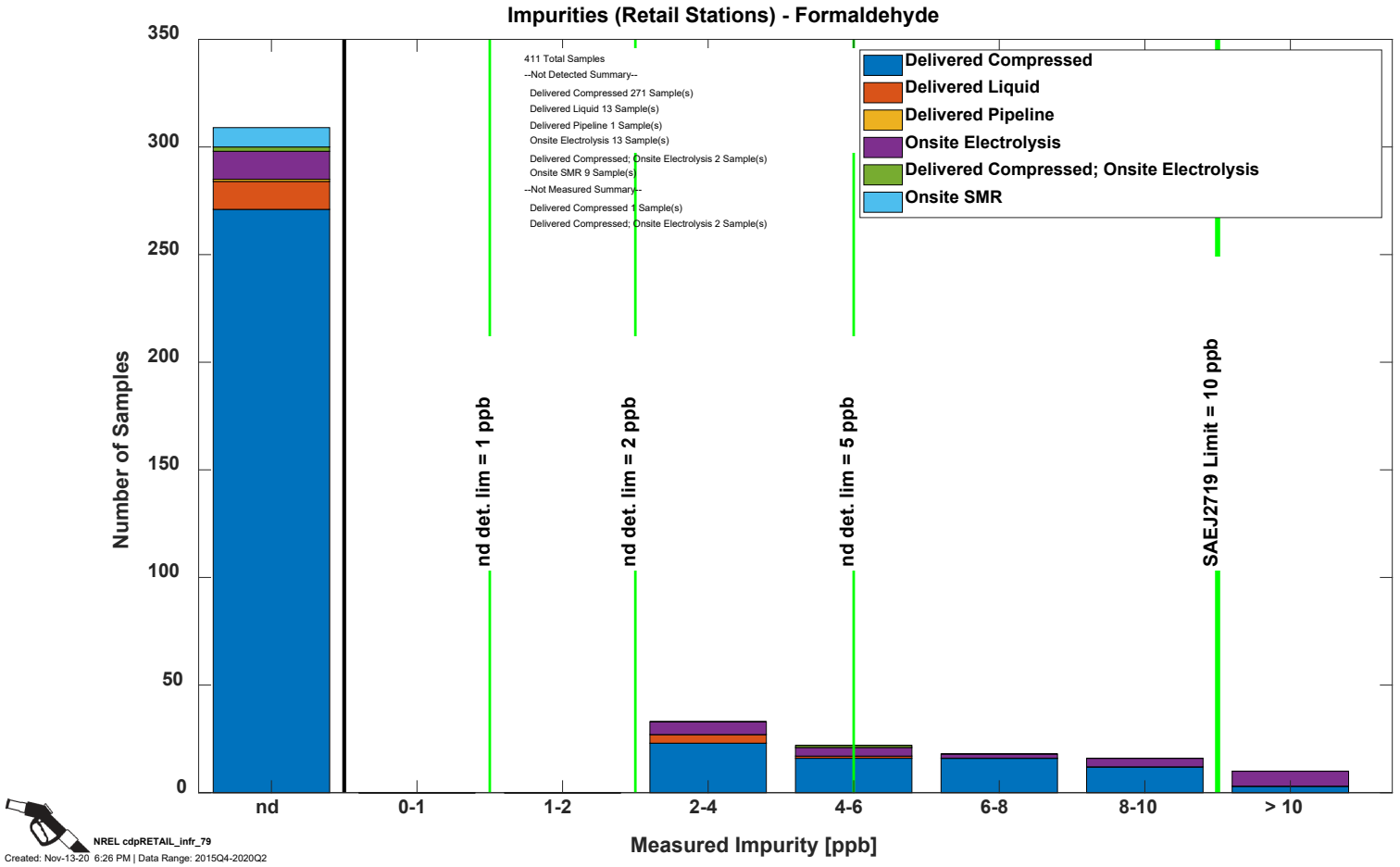
CDP-INFR-79
Impurities—Carbon Dioxide



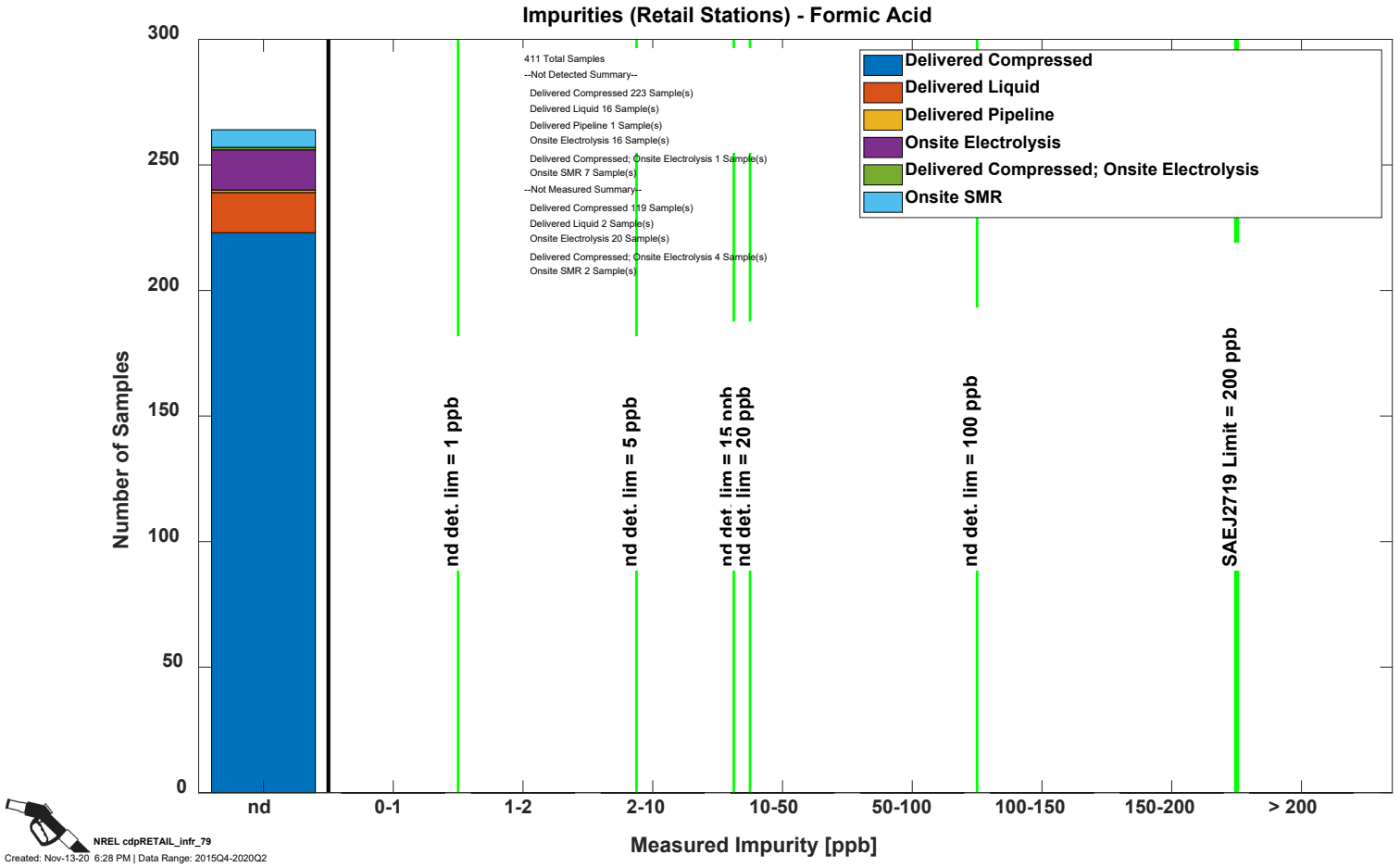
CDP-INFR-79
Impurities—Carbon Monoxide



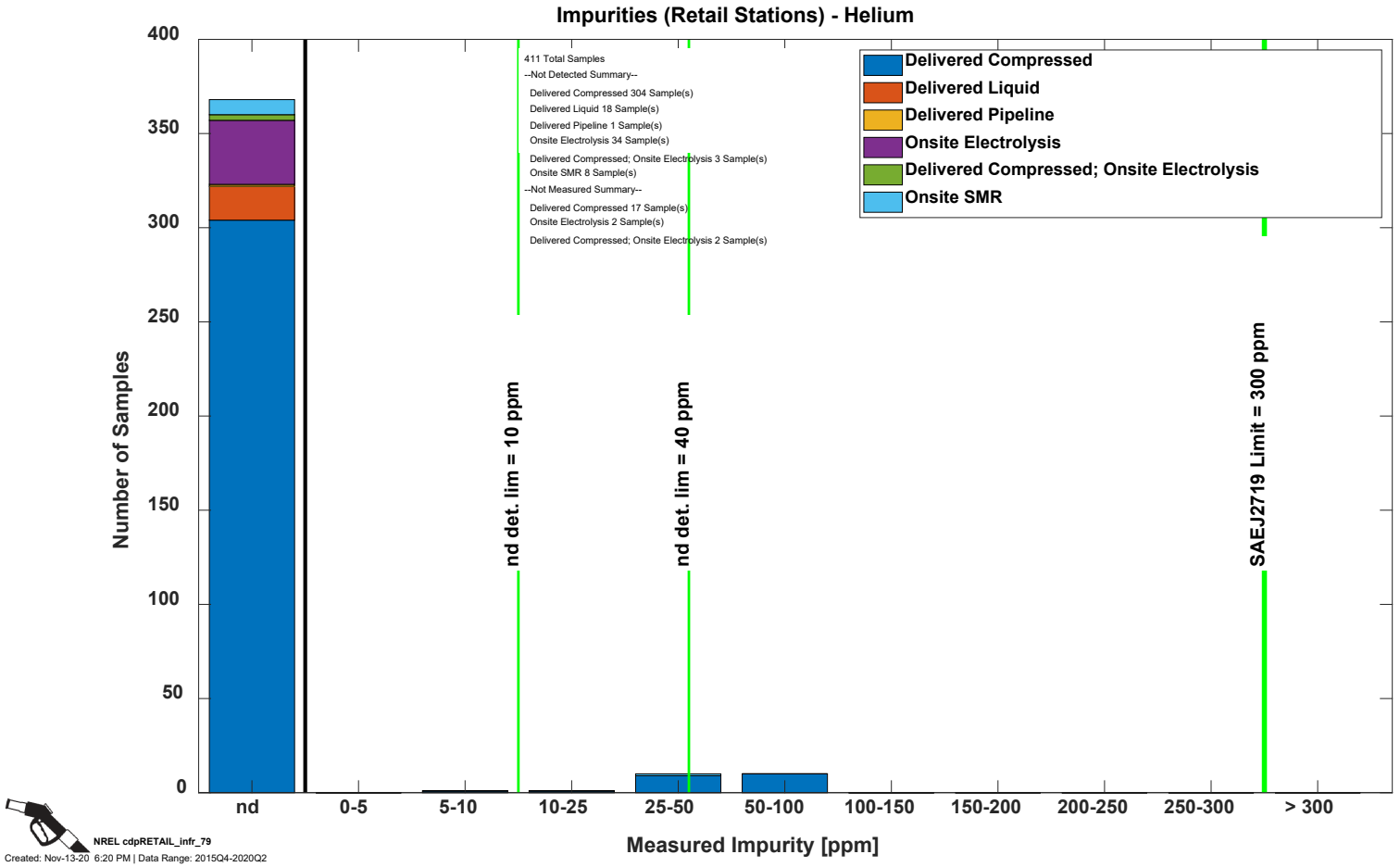
CDP-INFR-79
Impurities—Formaldehyde



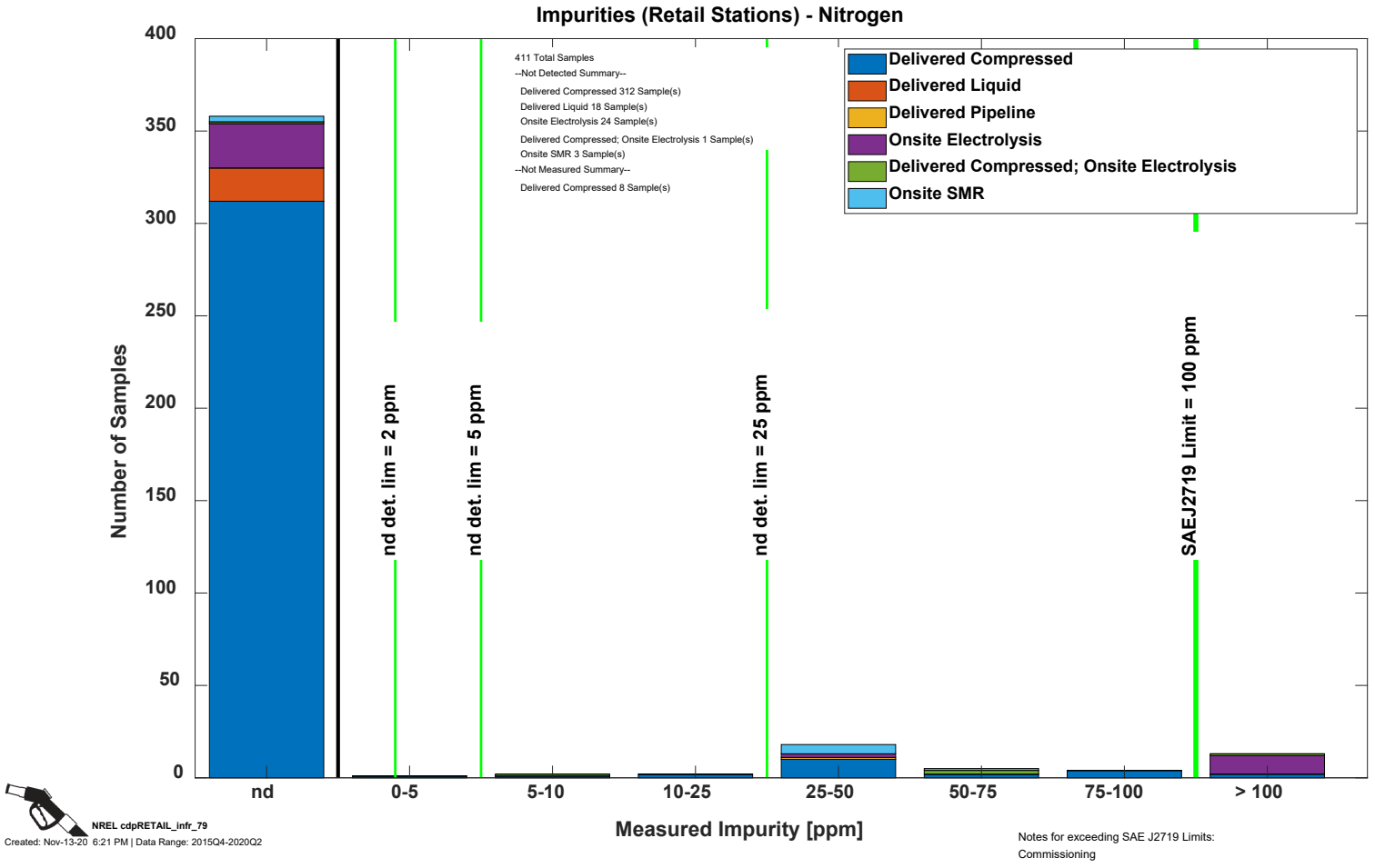
CDP-INFR-79
Impurities—Formic Acid



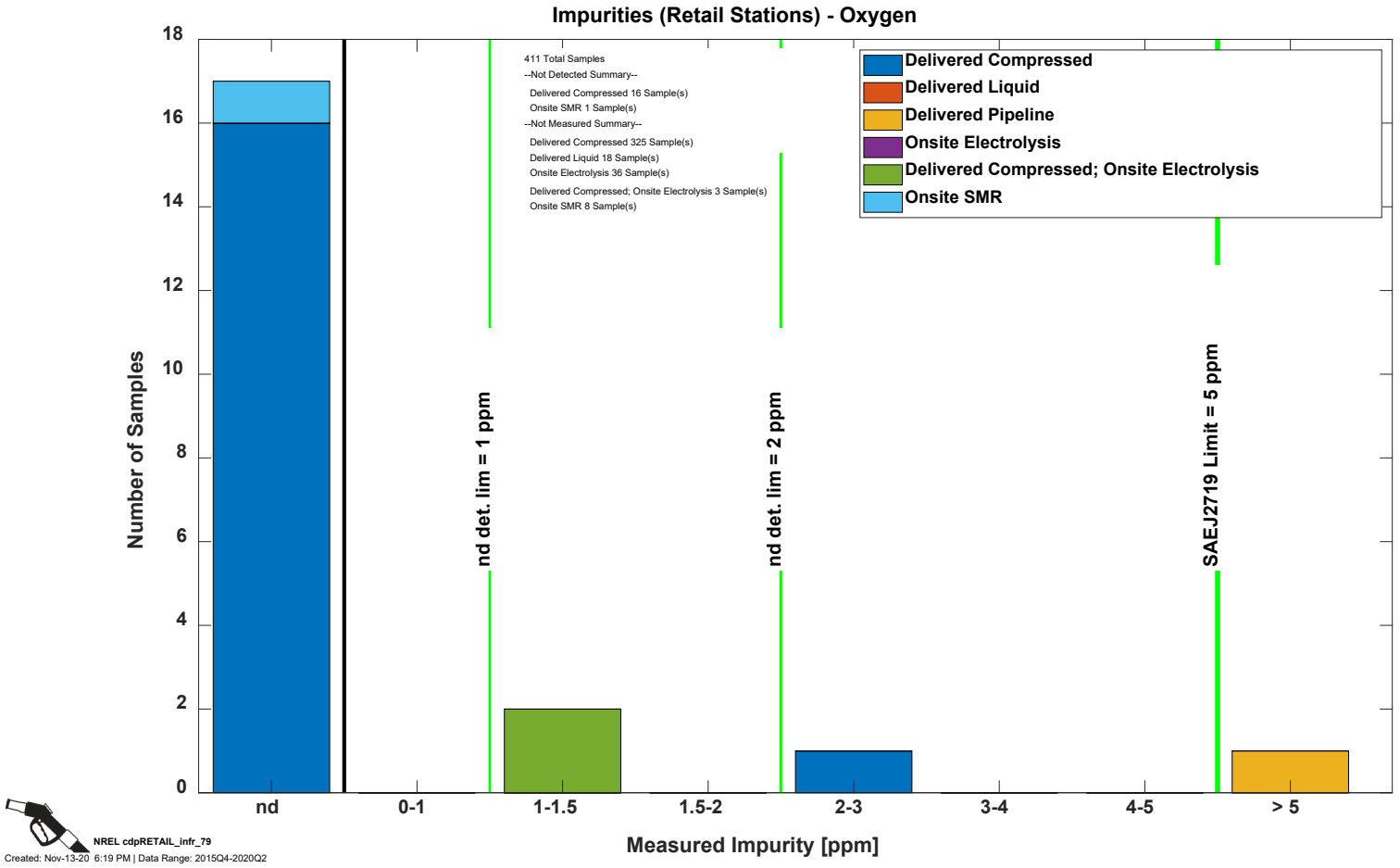
CDP-INFR-79
Impurities—Helium



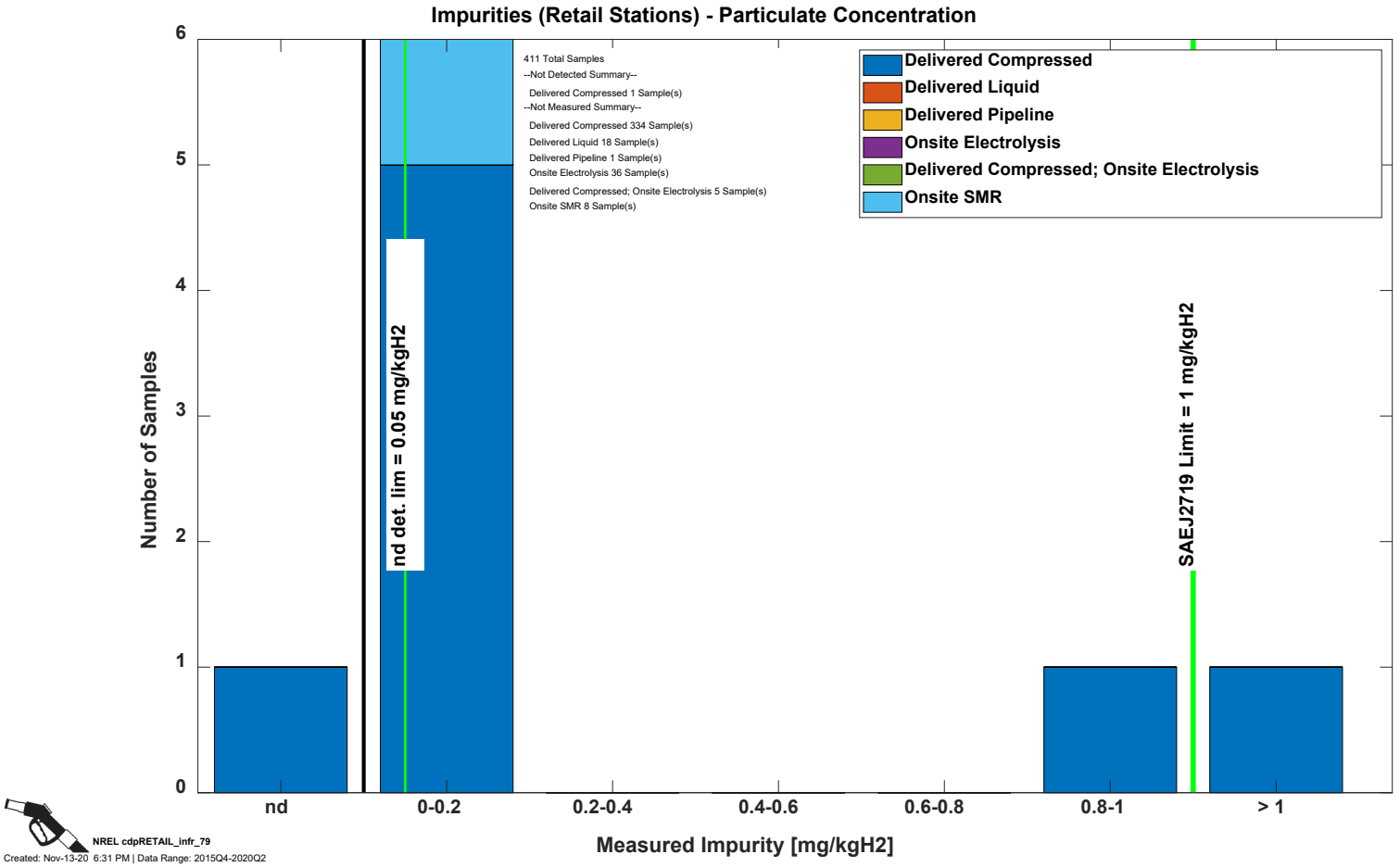
CDP-INFR-79
Impurities—Nitrogen



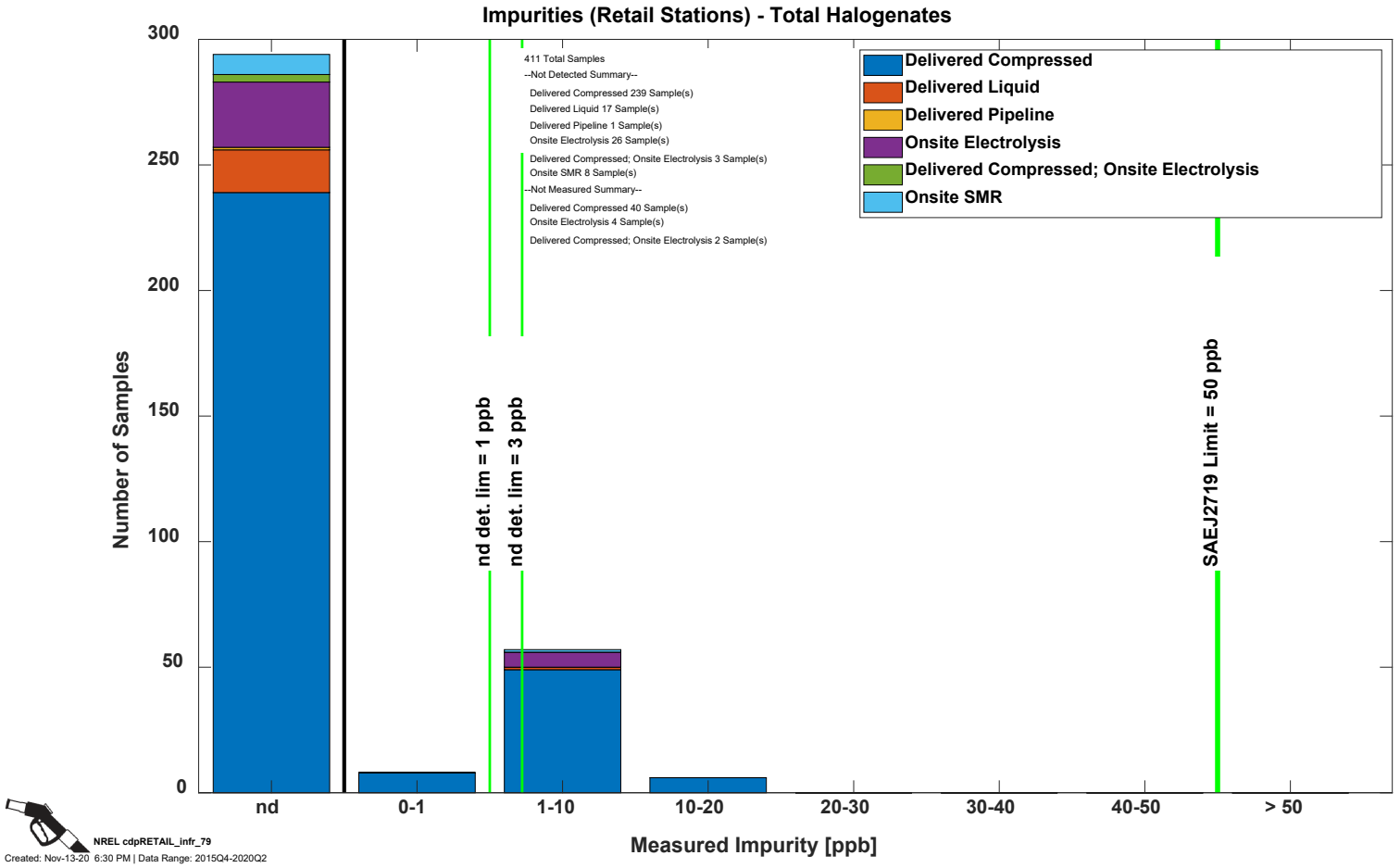
CDP-INFR-79
Impurities—Oxygen



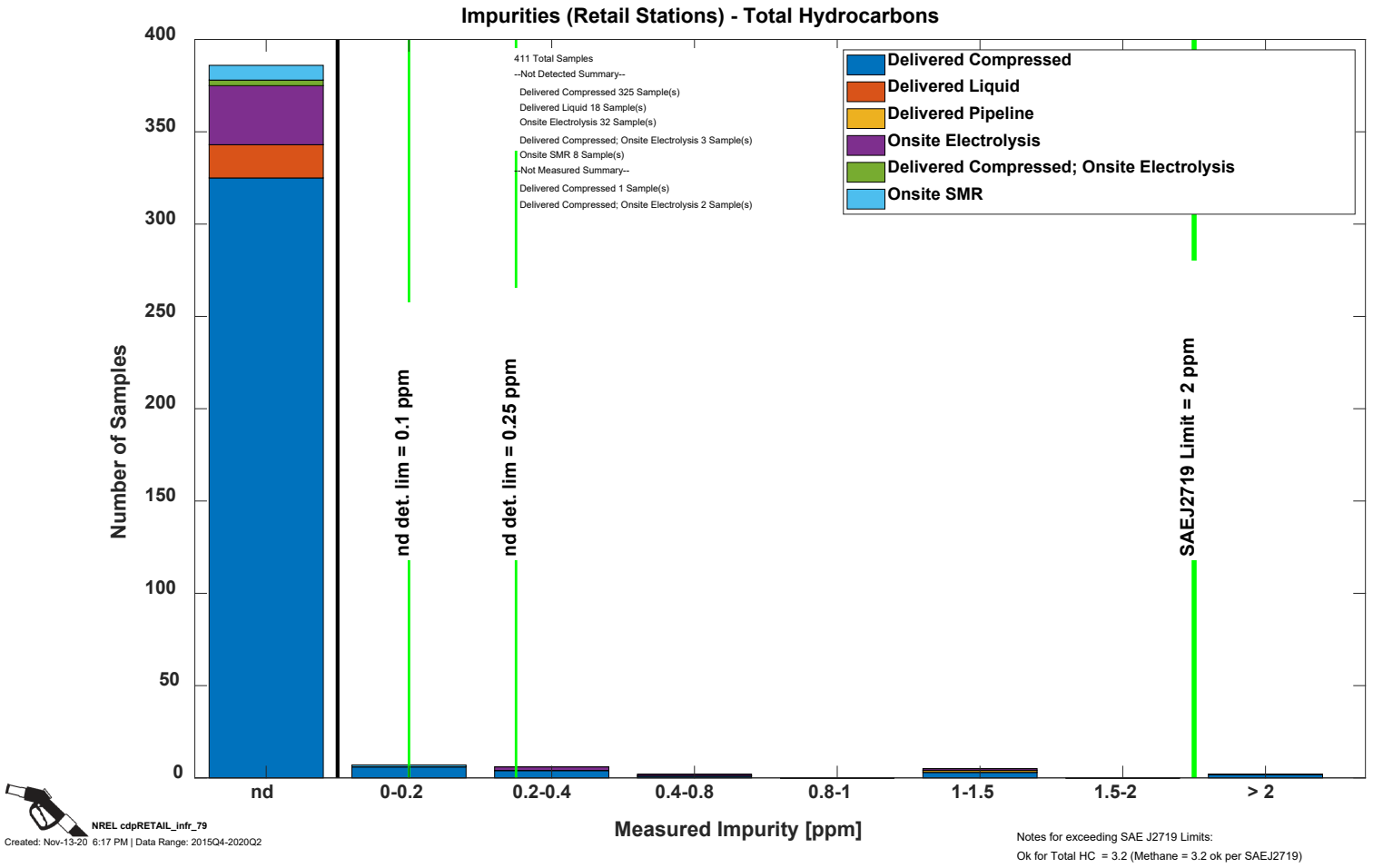
CDP-INFR-79
Impurities—Particulate Concentration



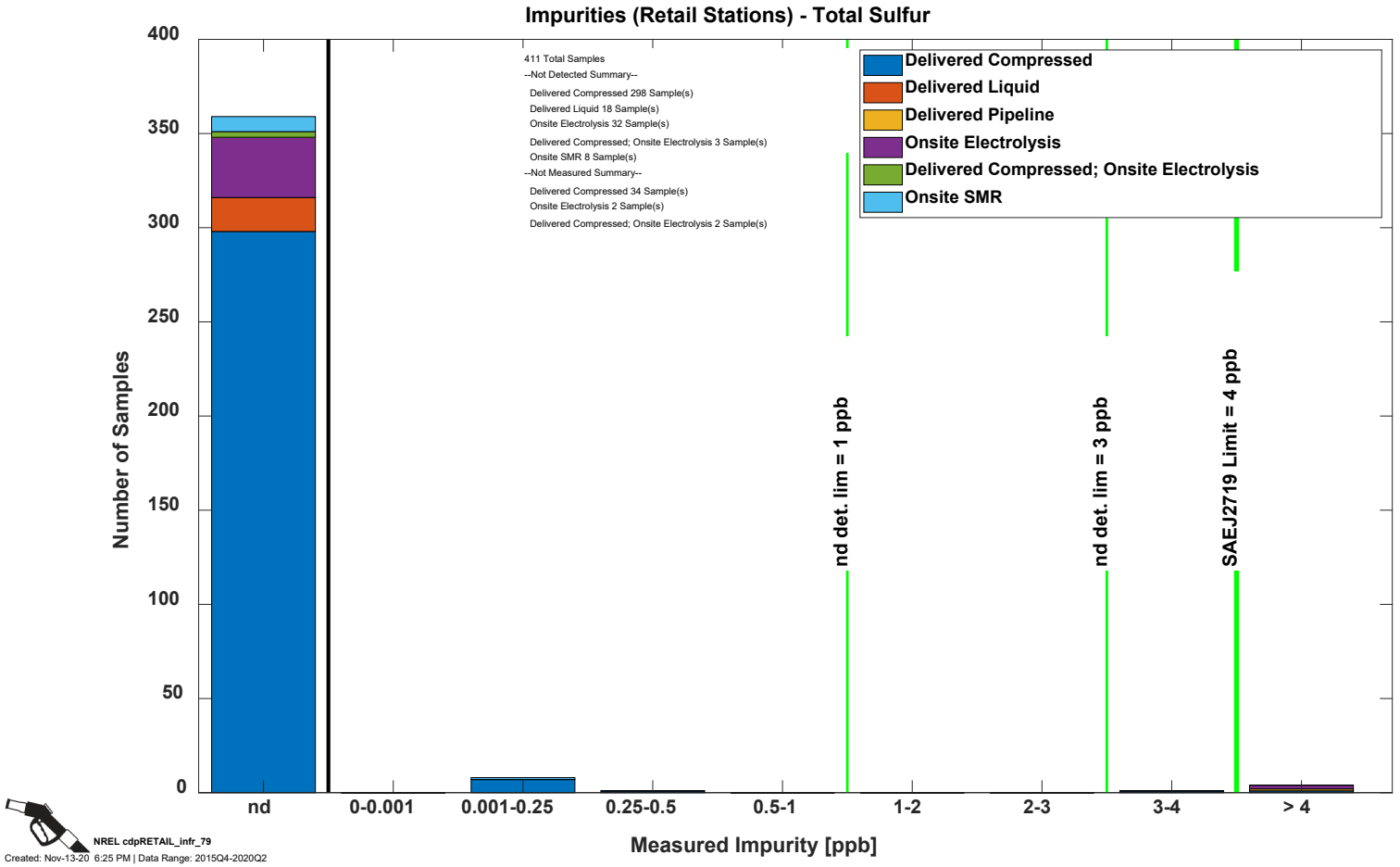
CDP-INFR-79
Impurities—Total Halogenates



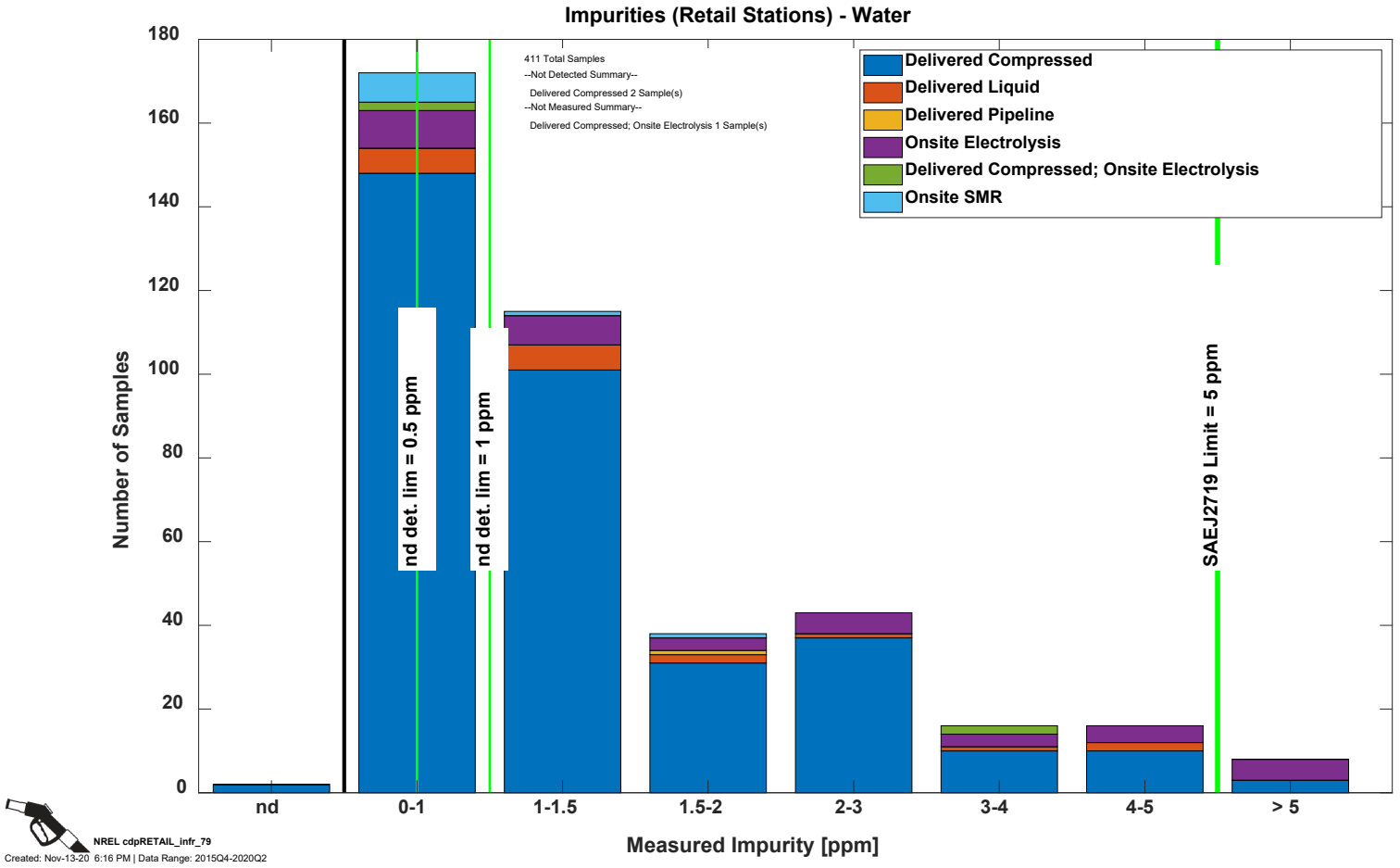
CDP-INFR-79
Impurities—Total Hydrocarbons



CDP-INFR-79
Impurities—Total Sulfur

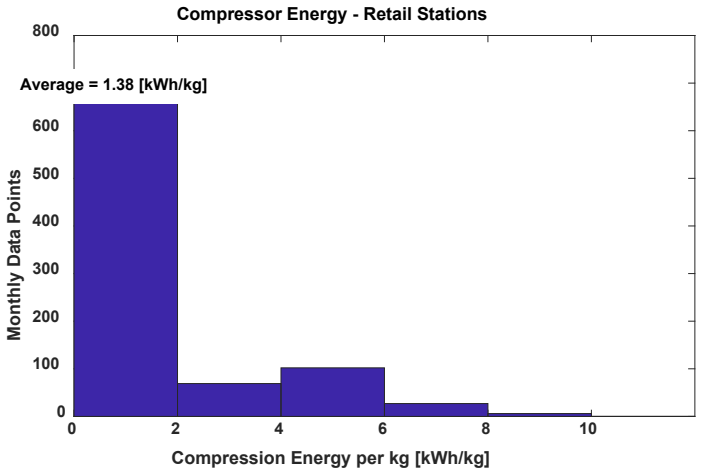


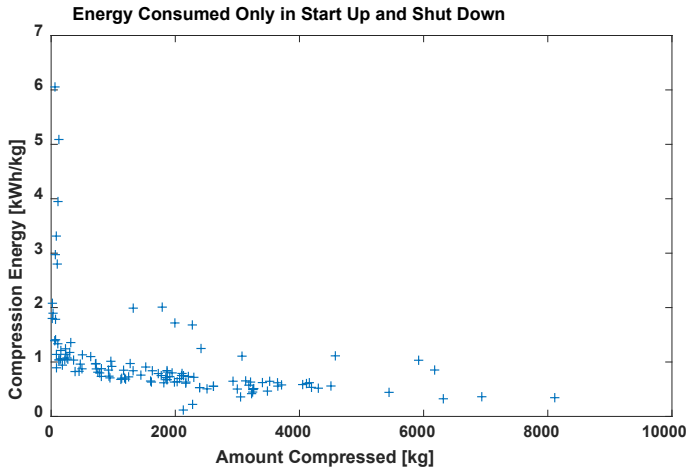
CDP-INFR-79
Impurities—Water

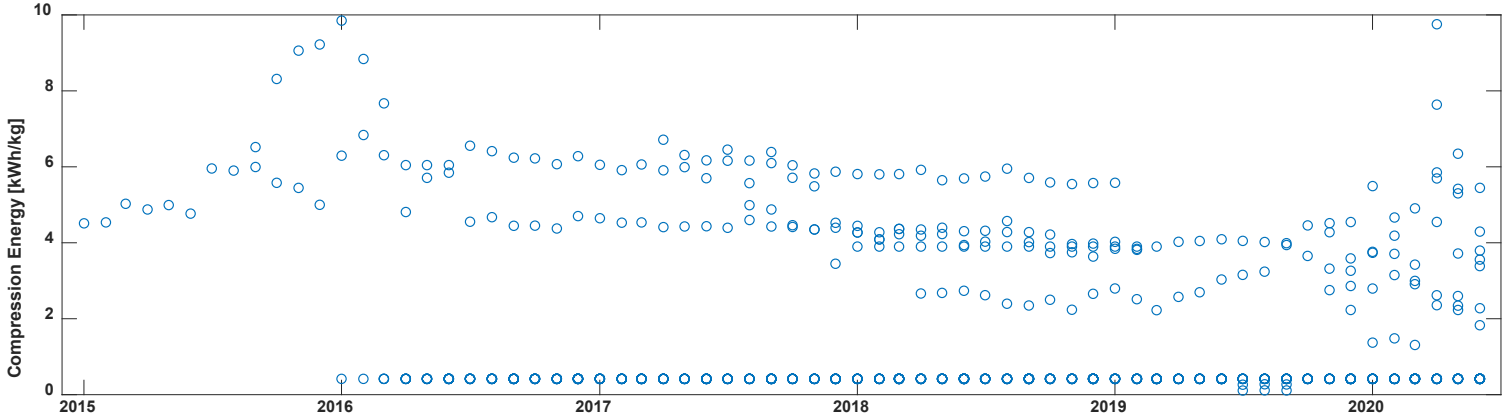


Component Energy

CDP-INFR-35
Compressor Energy

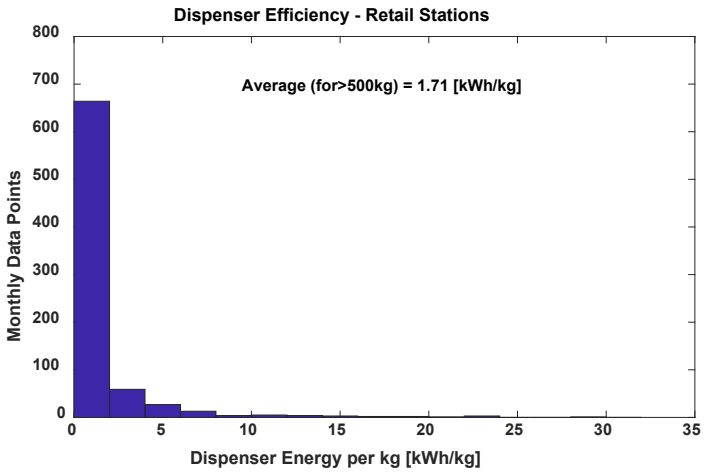


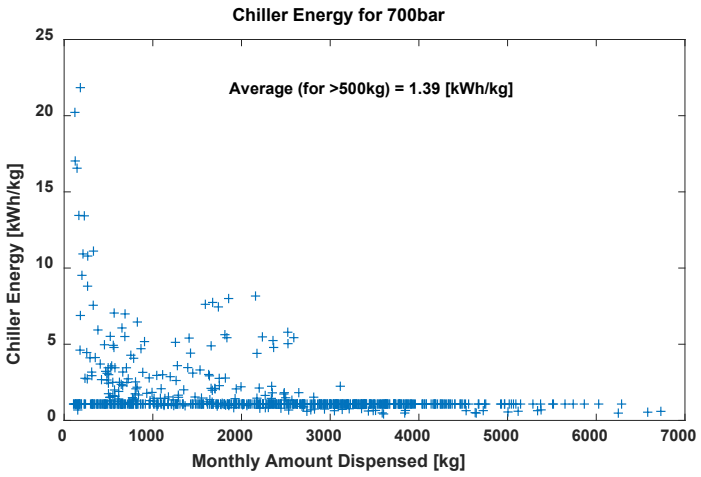


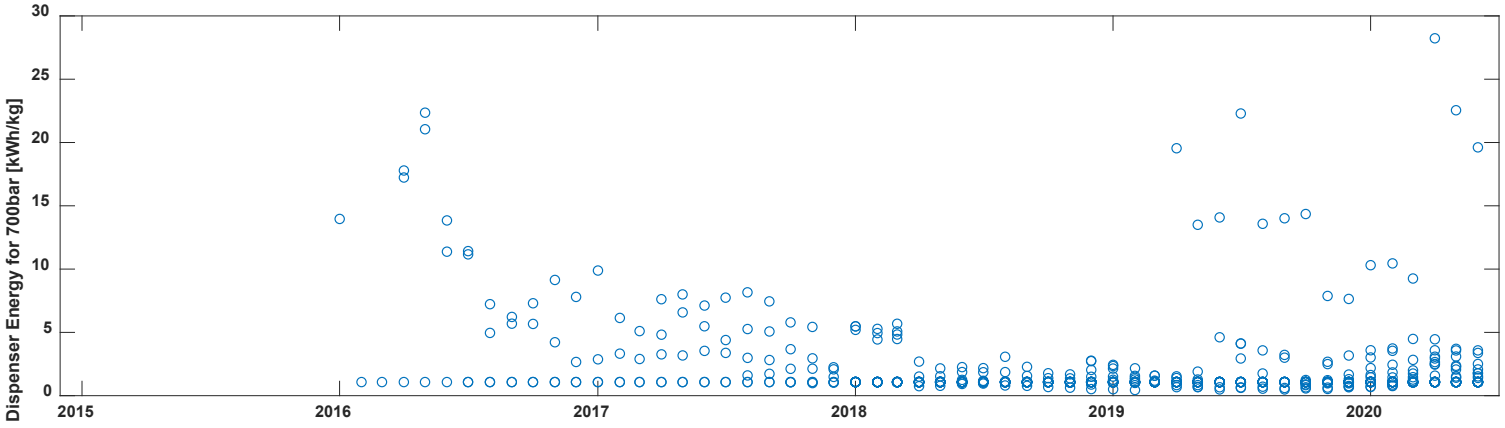


NREL cdpRETAIL_infr_35
Created: Dec-02-20 12:51 PM | Data Range: 2014Q3-2020Q2

CDP-INFR-92
Dispenser Energy

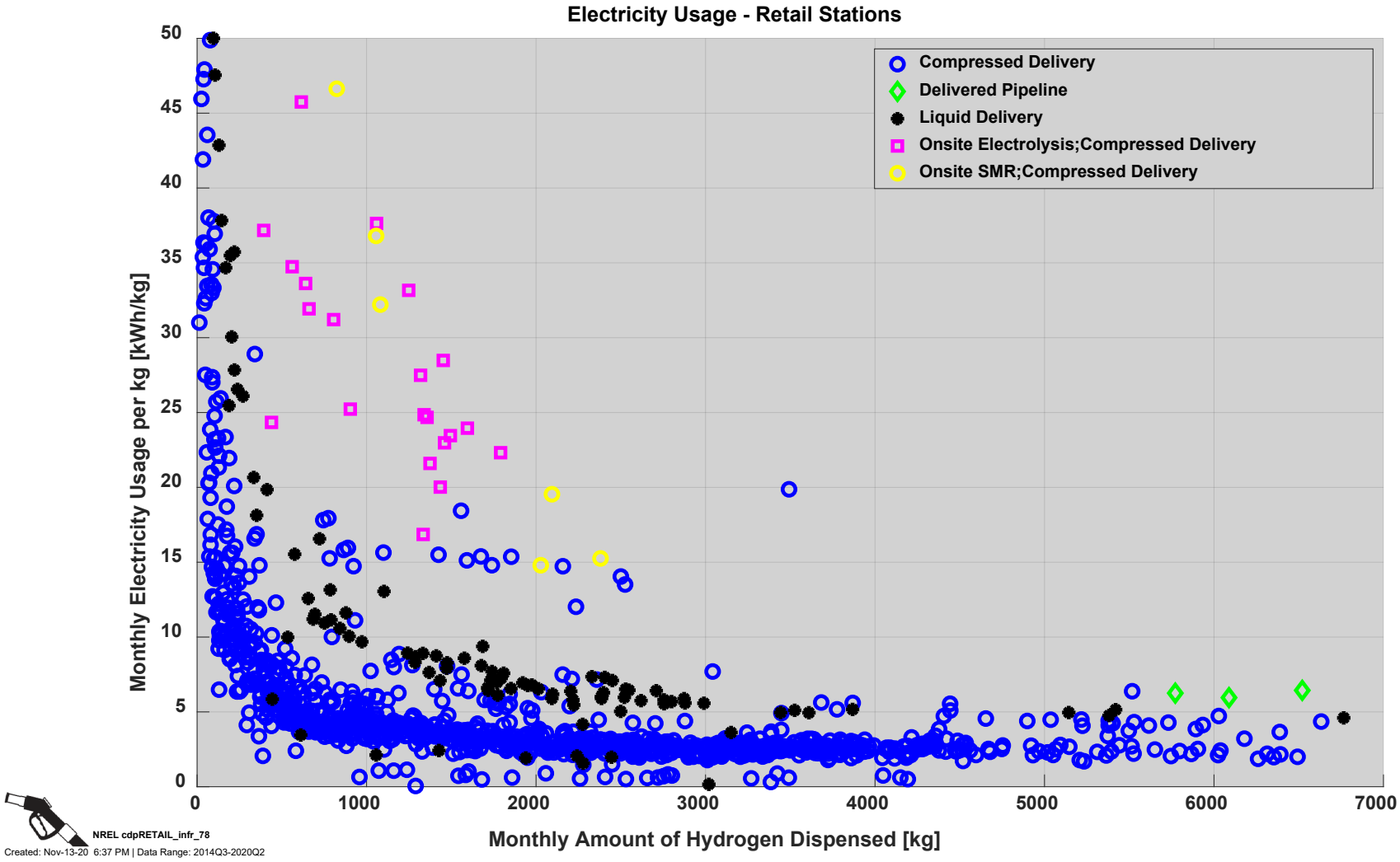




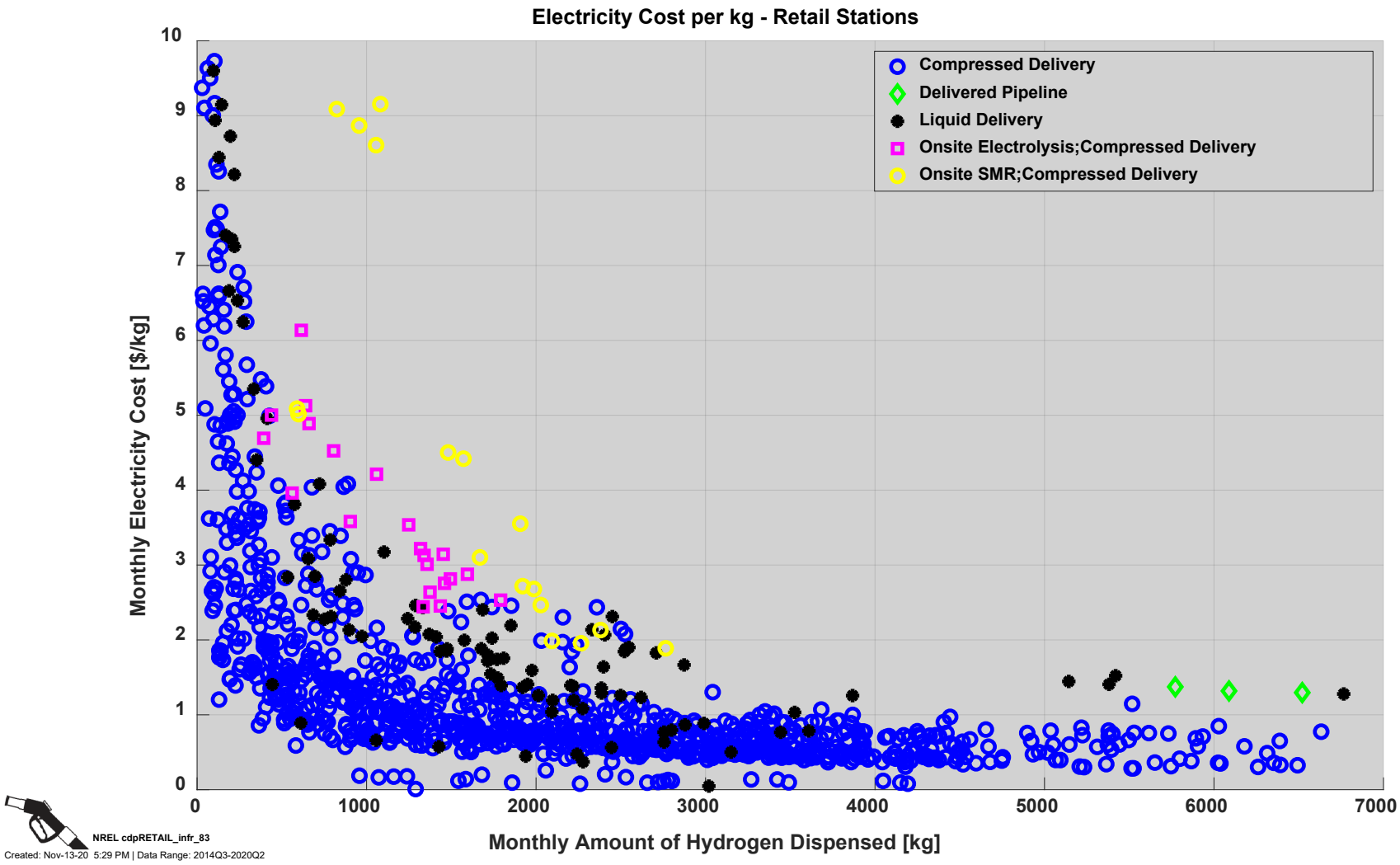


NREL cdpRETAIL_infr_92
Created: Nov-13-20 3:53 PM | Data Range: 2014Q3-2020Q2

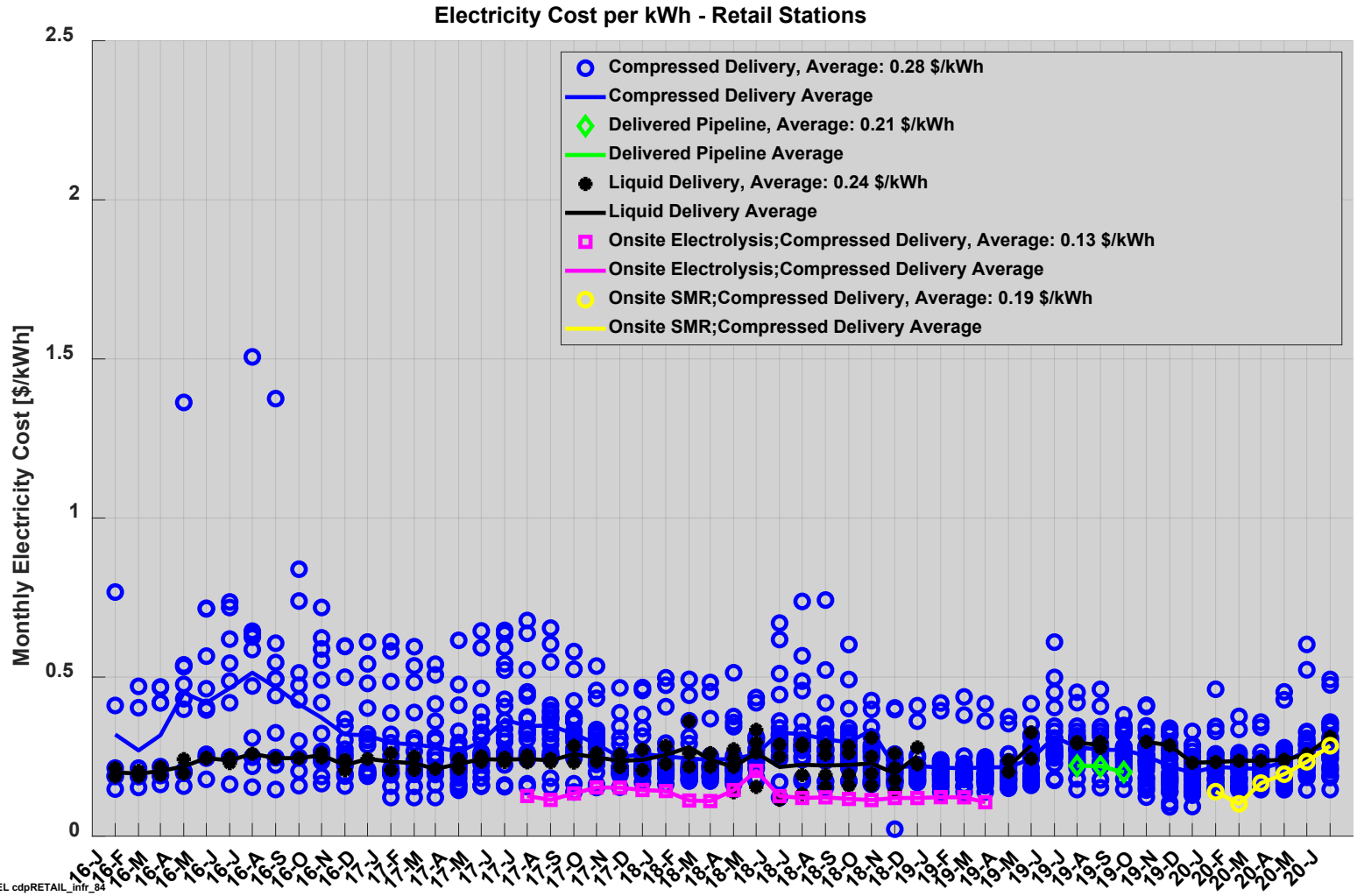
CDP-INFR-78
Station Energy per kg Dispensed



CDP-INFR-83
Station Energy Cost per kg Dispensed



CDP-INFR-84
Station Electricity Cost per kWh

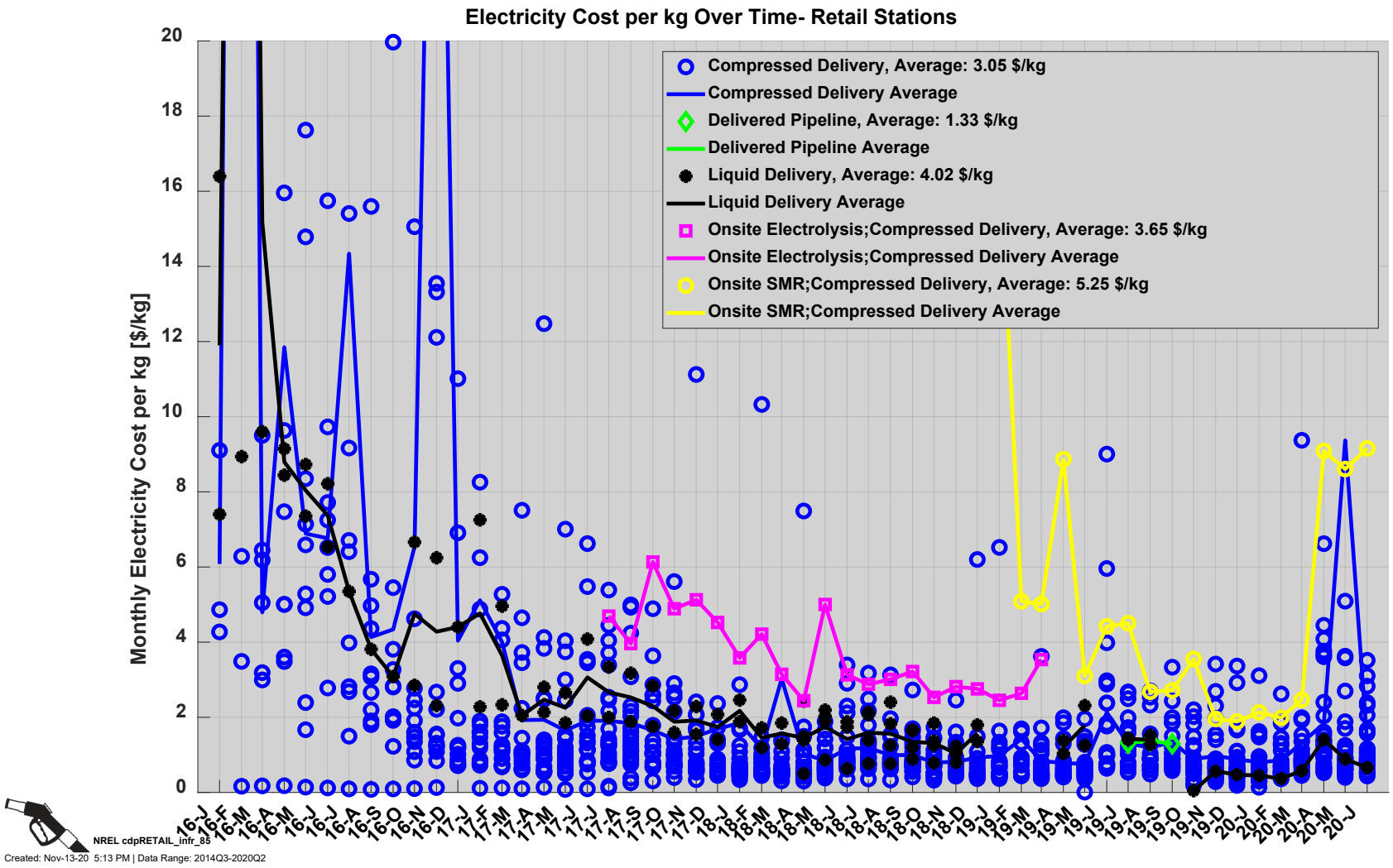


NREL cdpRETAIL_infr_84

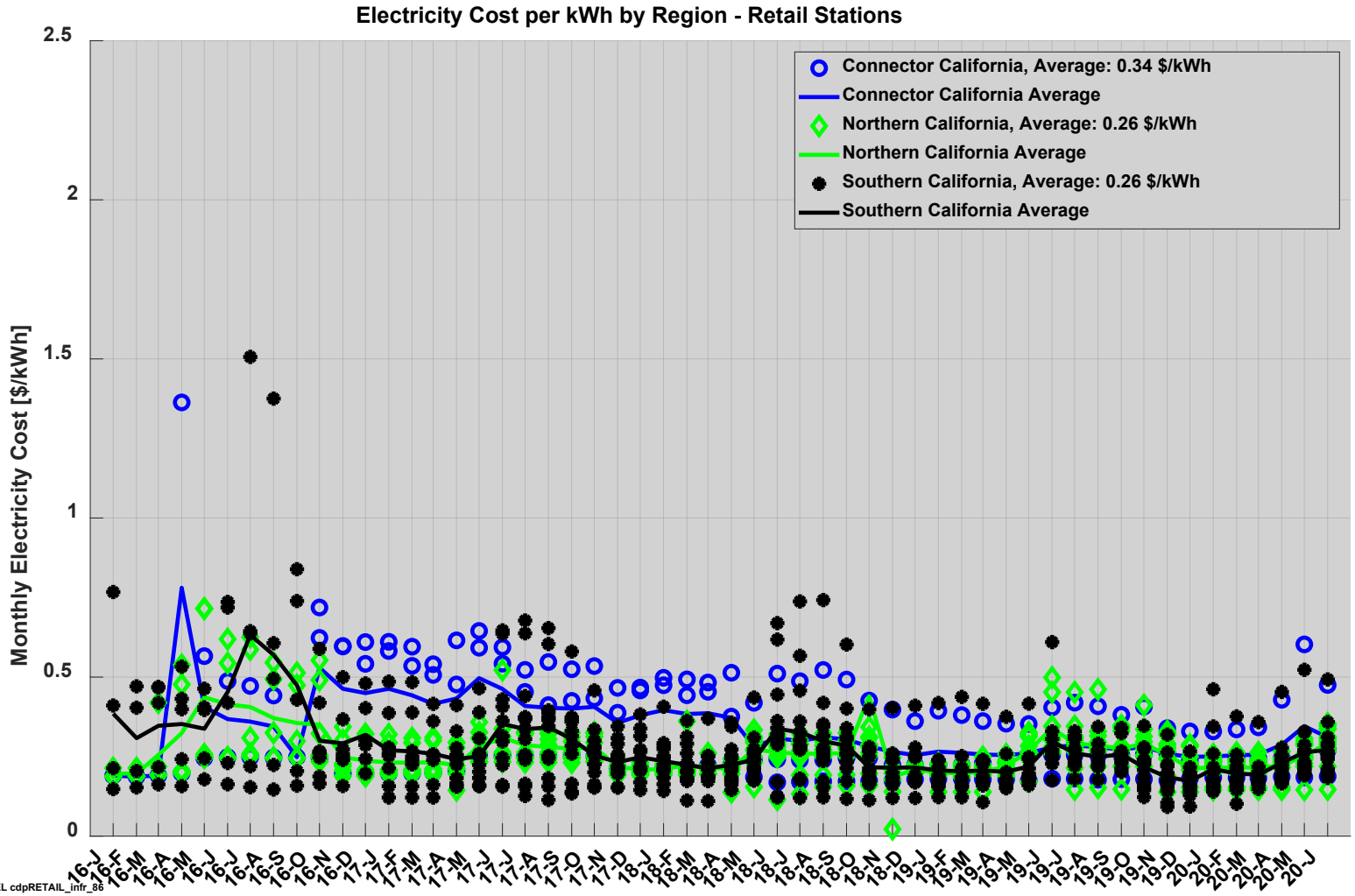
Created: Nov-13-20 5:21 PM | Data Range: 2014Q3-2020Q2

*Some data has been filtered due to station reporting errors.

CDP-INFR-85
Station Electricity Cost per kg Over Time



CDP-INFR-86
Station Electricity Cost per kWh by Region

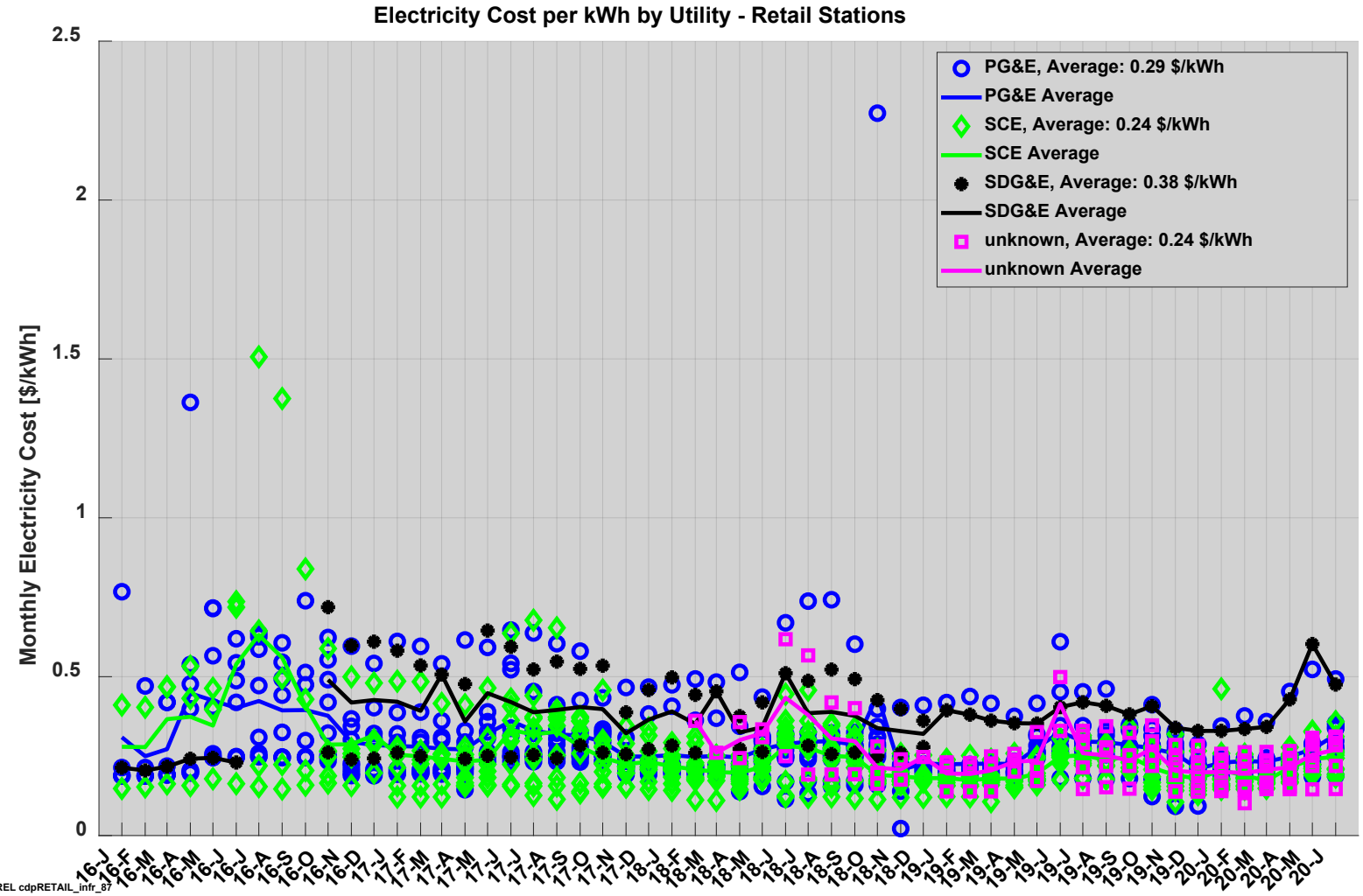


NREL cdpRETAIL_infr_86

Created: Nov-13-20 5:05 PM | Data Range: 2014Q3-2020Q2

*Some data has been filtered due to station reporting errors.

CDP-INFR-87
Station Electricity Cost per kWh by Utility



NREL cdpRETAIL_infr_87

Created: Nov-13-20 4:56 PM | Data Range: 2014Q3-2020Q2

*Some data has been filtered due to station reporting errors.

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NREL/PR-5400-79141

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