Next Generation Hydrogen Station Composite Data Products: Retail Stations

Data through Quarter 3 of 2019

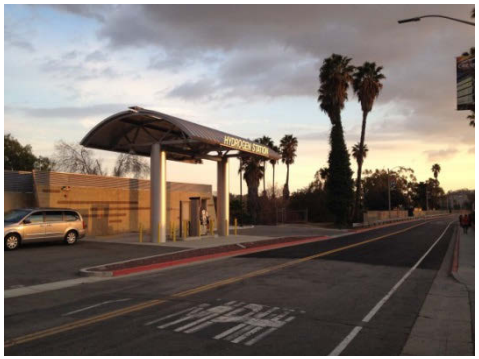
Genevieve Saur, Spencer Gilleon, and Sam Sprik

April 2020

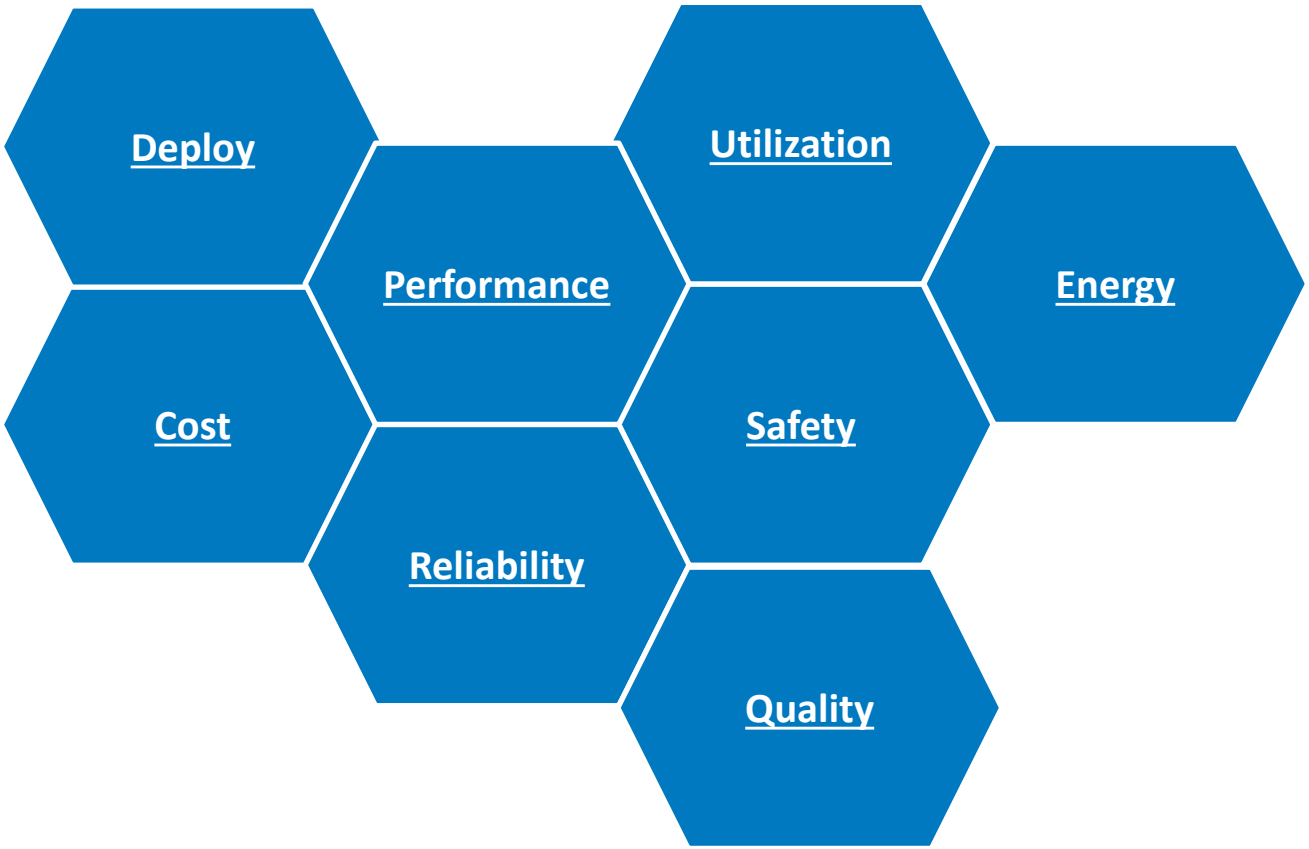
Hydrogen Station Project Partners

INFRASTRUCTURE

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

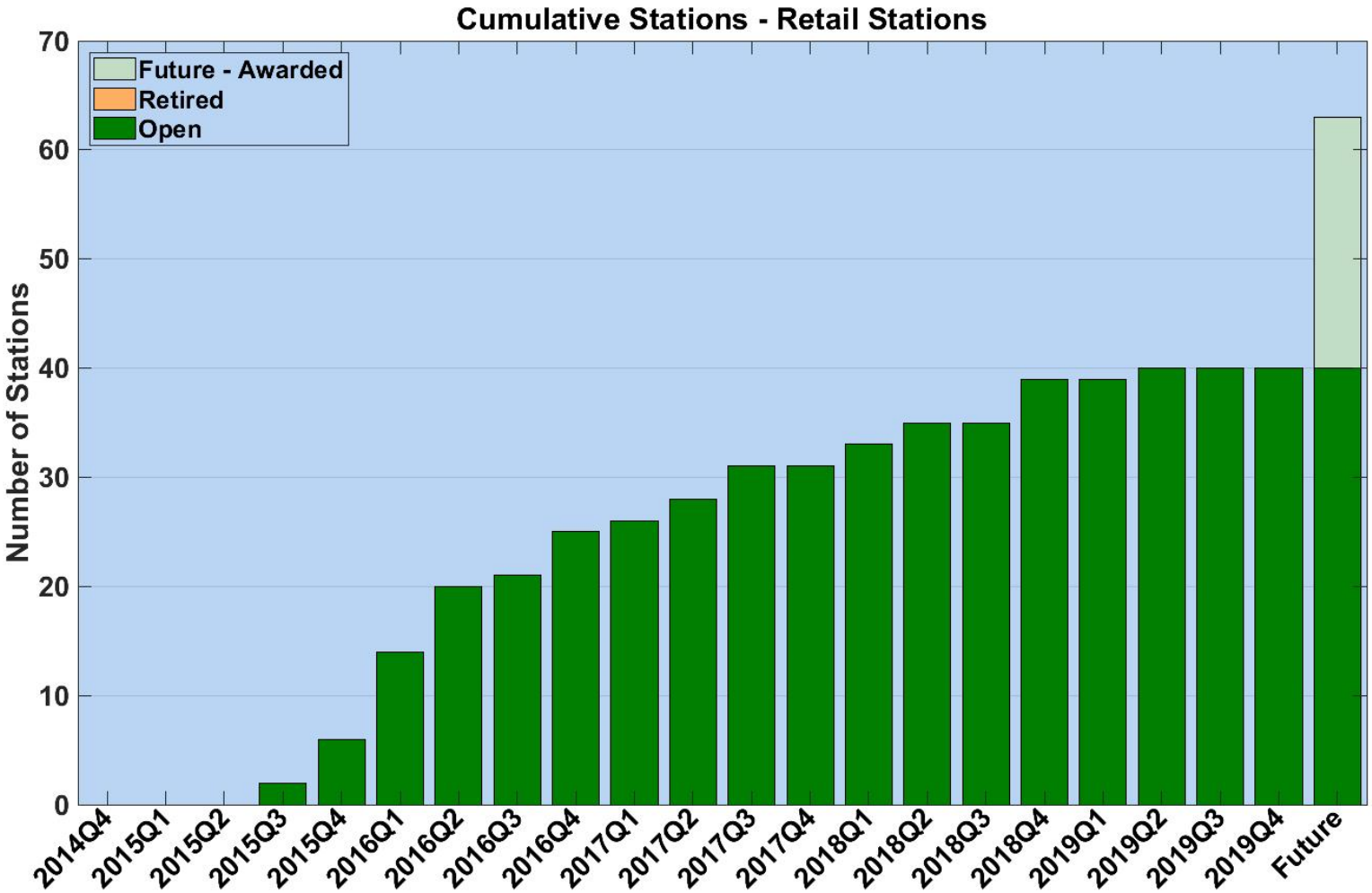


Analysis Categories



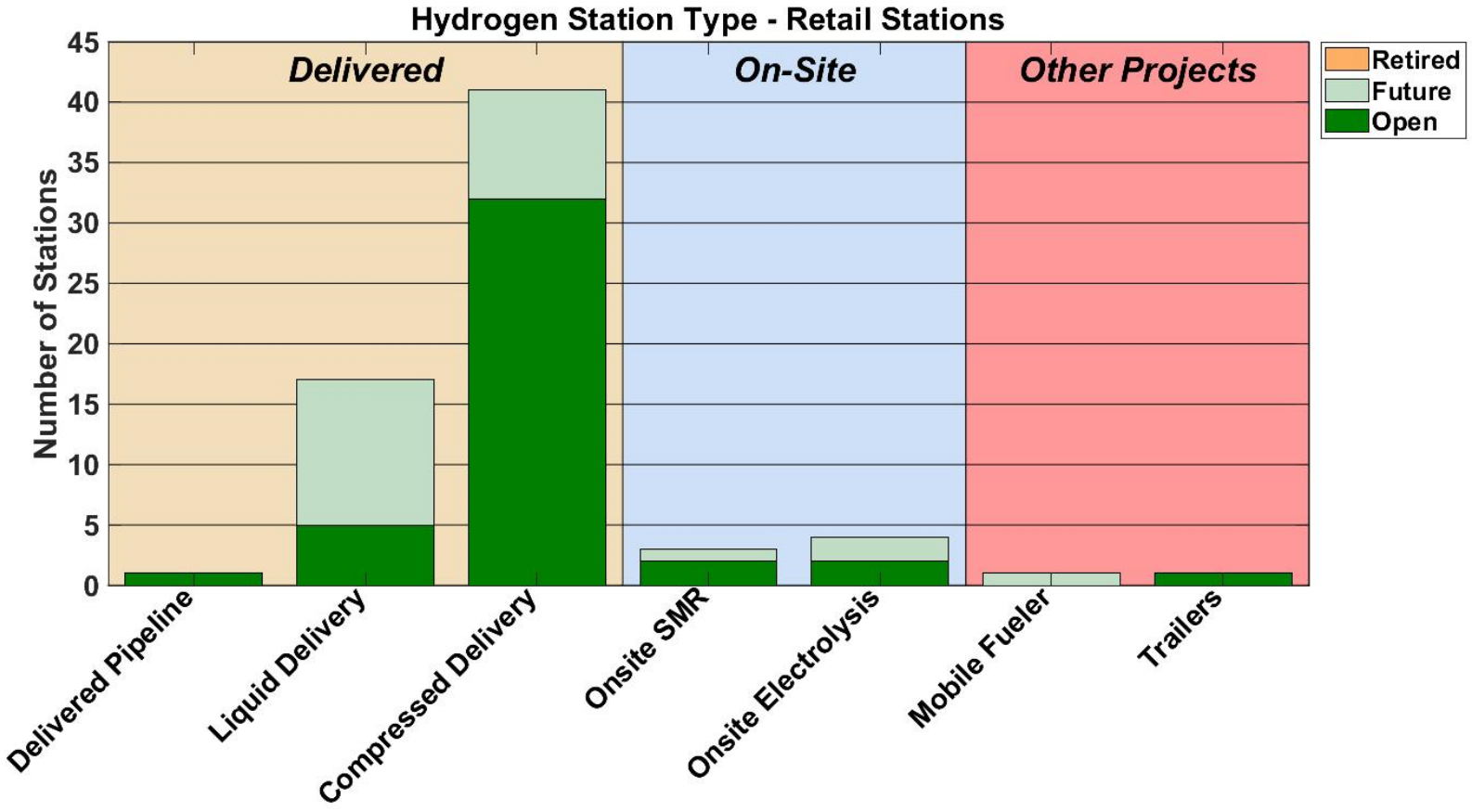
Deployment

CDP-INFR-10
Cumulative Number of Stations



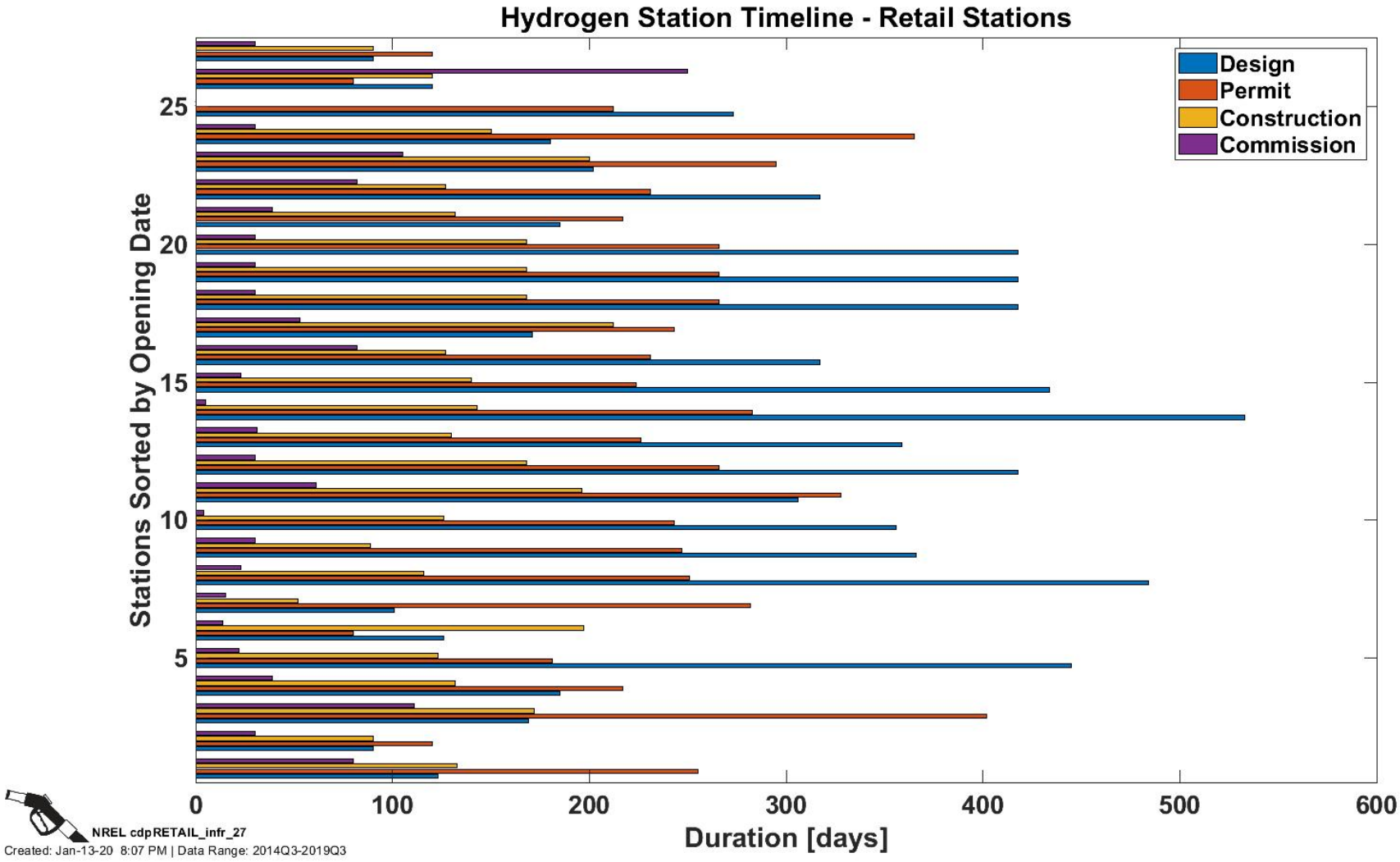
NREL cdpRETAIL_infr_10
Created: Jan-13-20 5:56 PM | Data Range: 2011Q1-2019Q3

CDP-INFR-11
Hydrogen Stations by Type



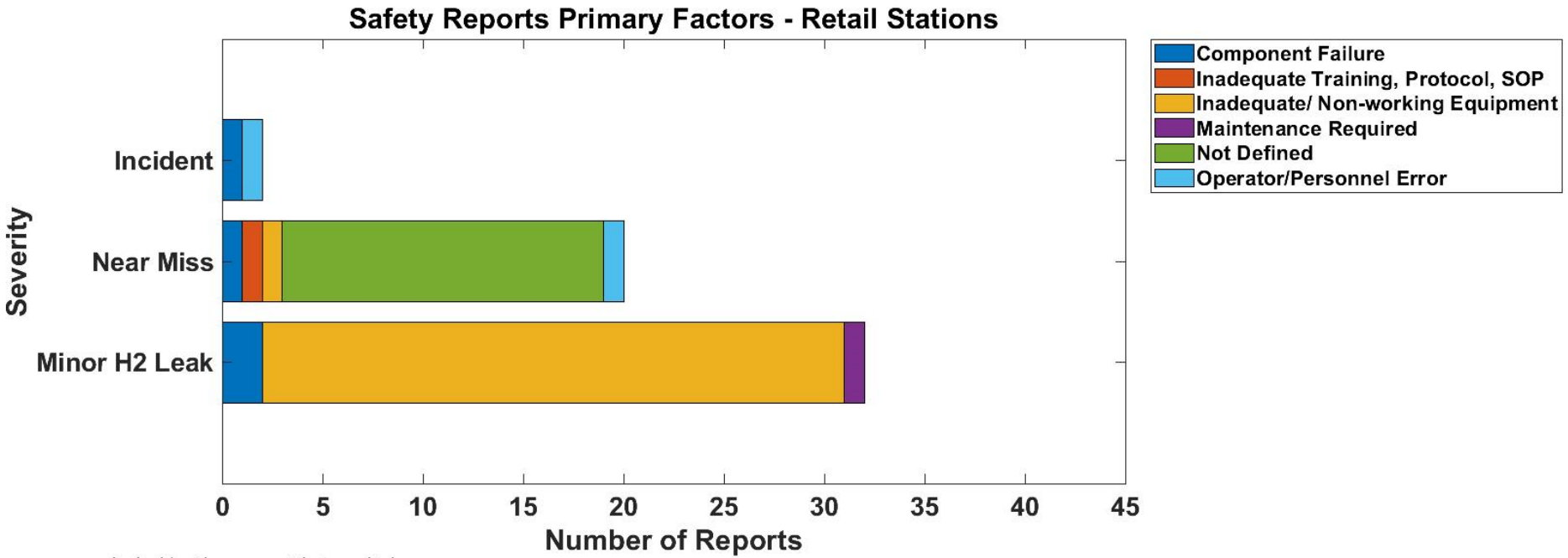
NREL cdpRETAIL_infr_11
Created: Jan-13-20 5:56 PM | Data Range: 2011Q1-2019Q3

CDP-INFR-27
Hydrogen Station Timeline



Safety

CDP-INFR-31
Safety Reports Primary Factors



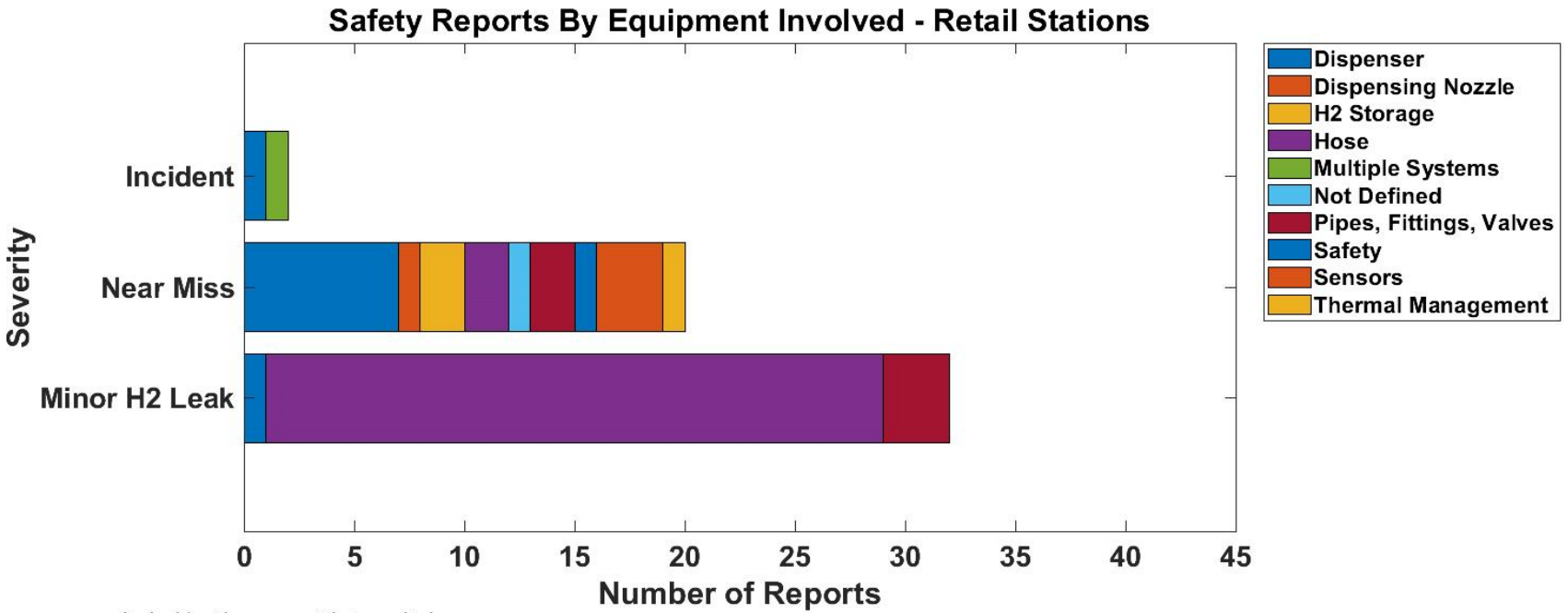
An Incident is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites
- release of any volatile, hydrogen containing 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: Jan-14-20 9:54 AM | Data Range: 2014Q3-2019Q3

CDP-INFR-32
Safety Reports by Equipment Involved



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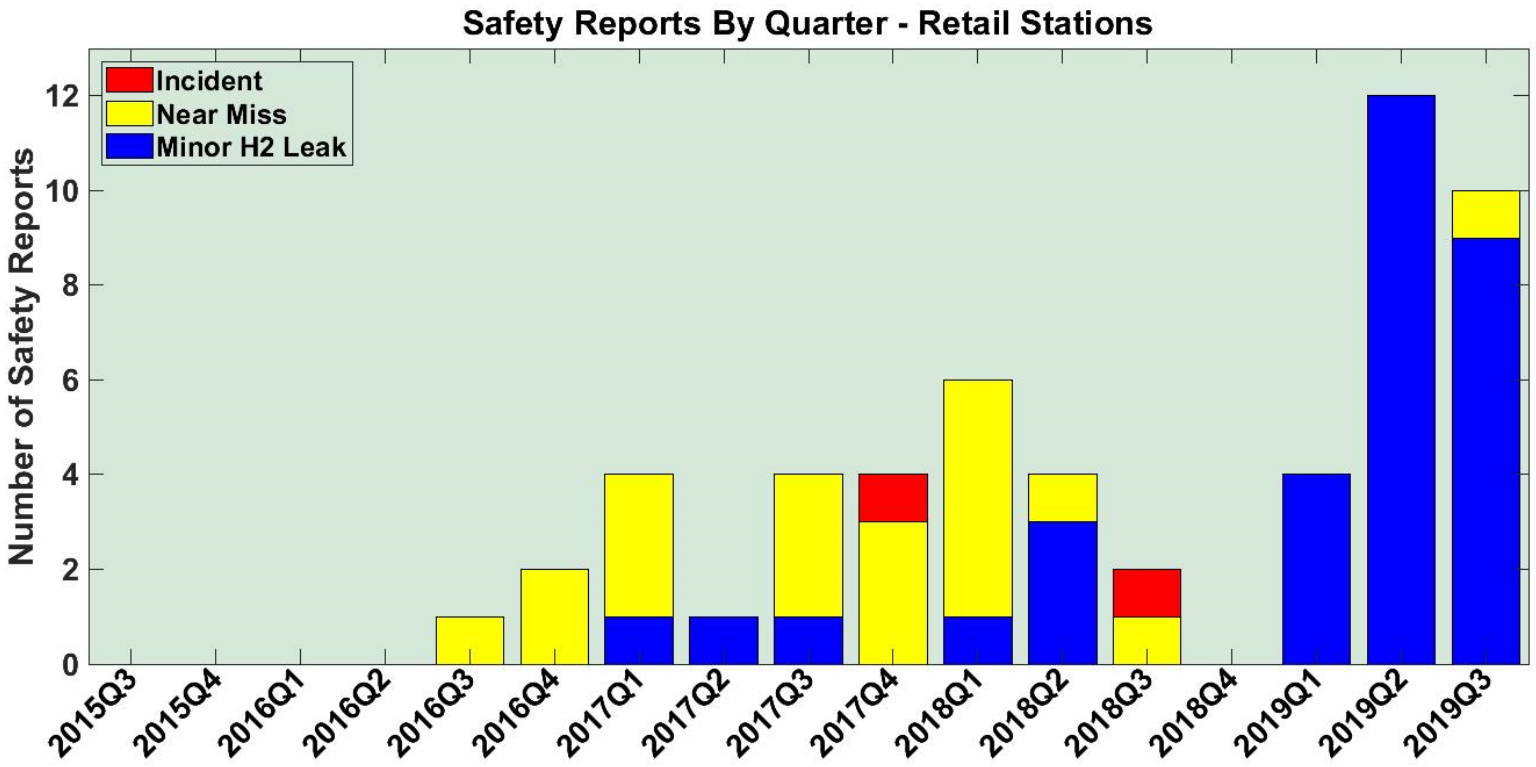
NREL cdpRETAIL_infr_32
Created: Jan-14-20 9:56 AM | Data Range: 2014Q3-2019Q3

CDP-INFR-33
Safety Reports by Quarter



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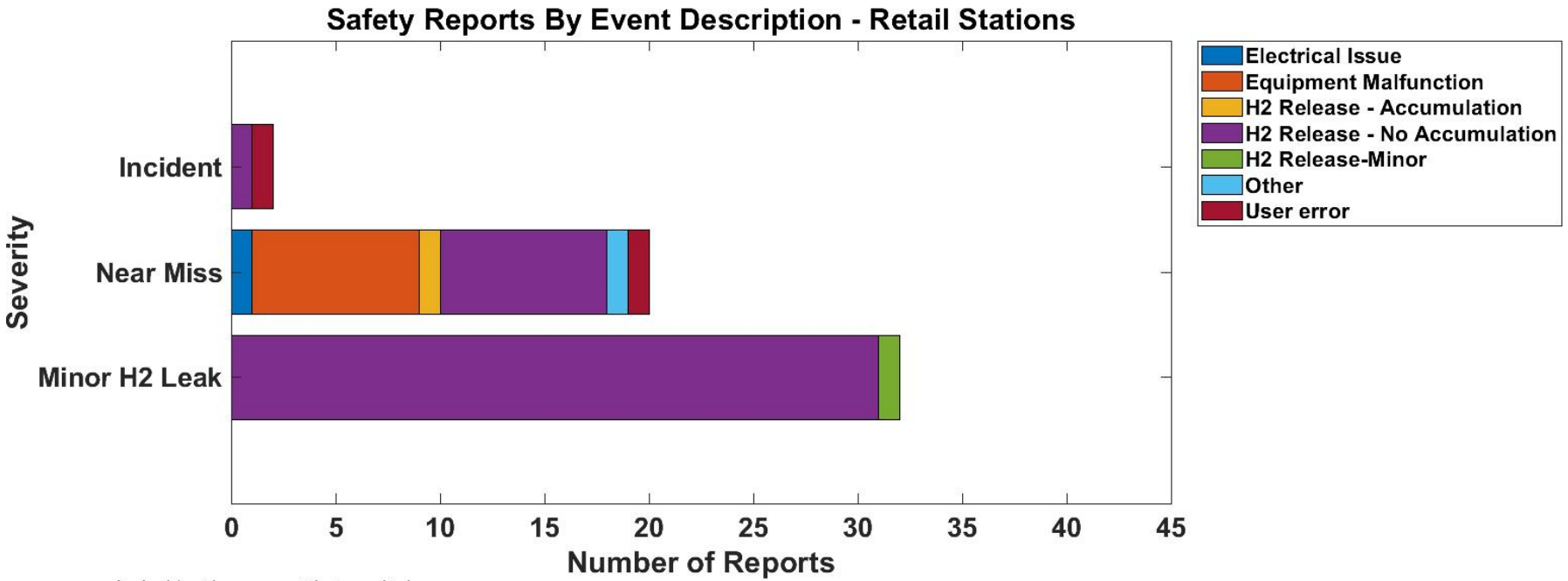
NREL cdpRETAIL_infr_33
Created: Jan-14-20 9:58 AM | Data Range: 2014Q3-2019Q3

CDP-INFR-34
Safety Reports by Event Description



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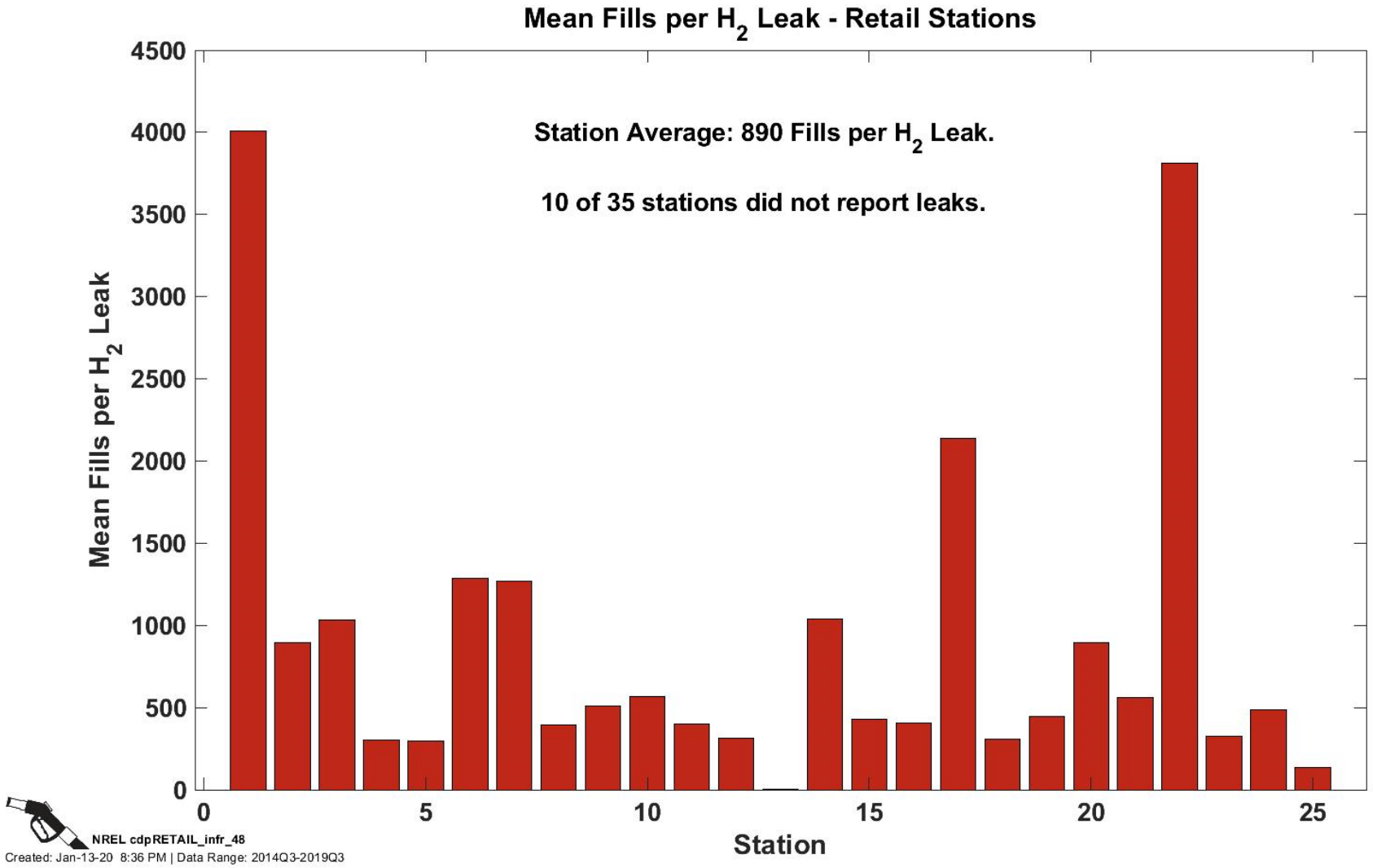
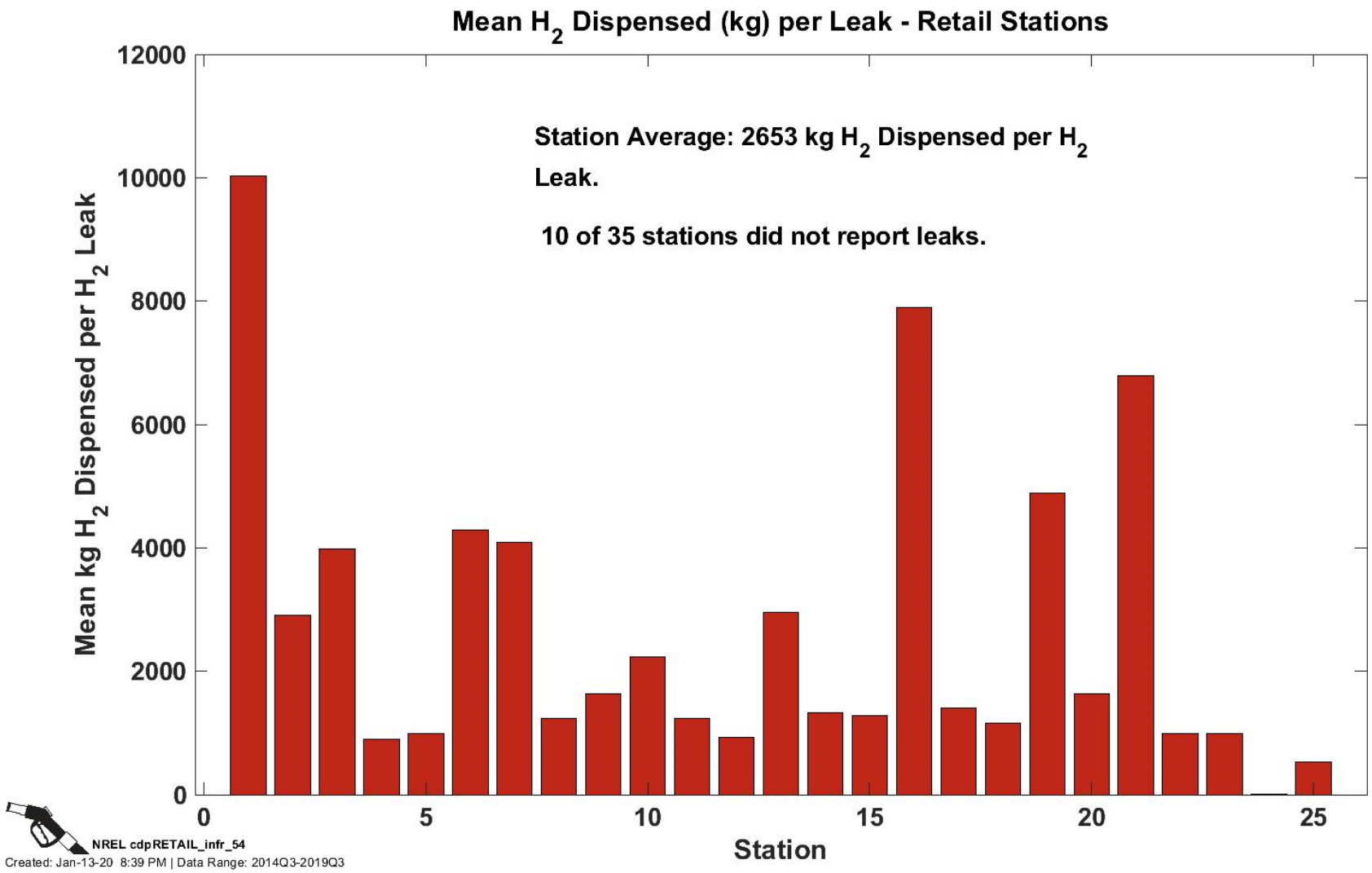
NREL cdpRETAIL_infr_34
Created: Jan-14-20 9:59 AM | Data Range: 2014Q3-2019Q3

CDP-INFR-48
Mean Fills per Hydrogen Leak

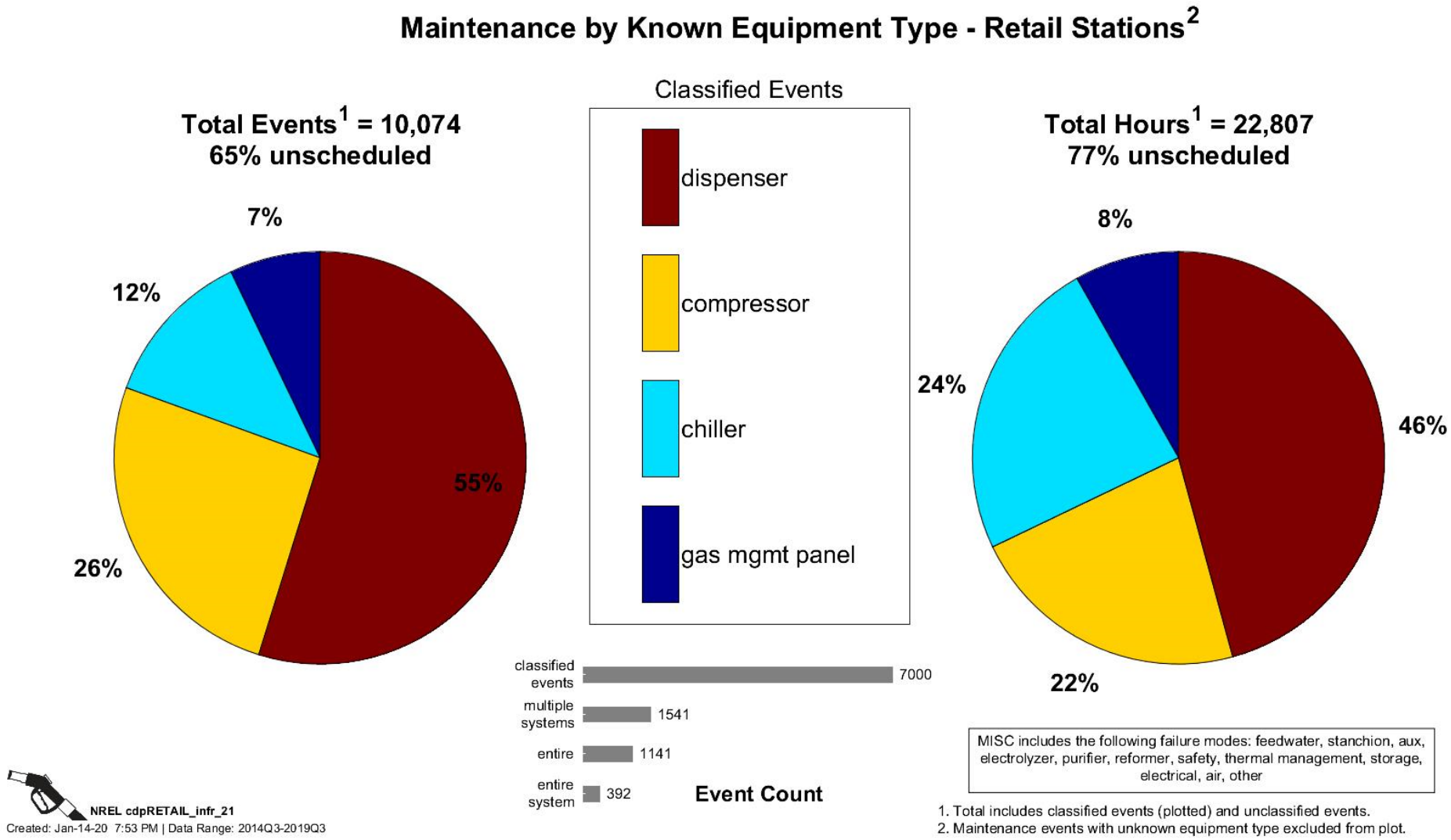


CDP-INFR-54
Mean Hydrogen Dispensed per Hydrogen Leak

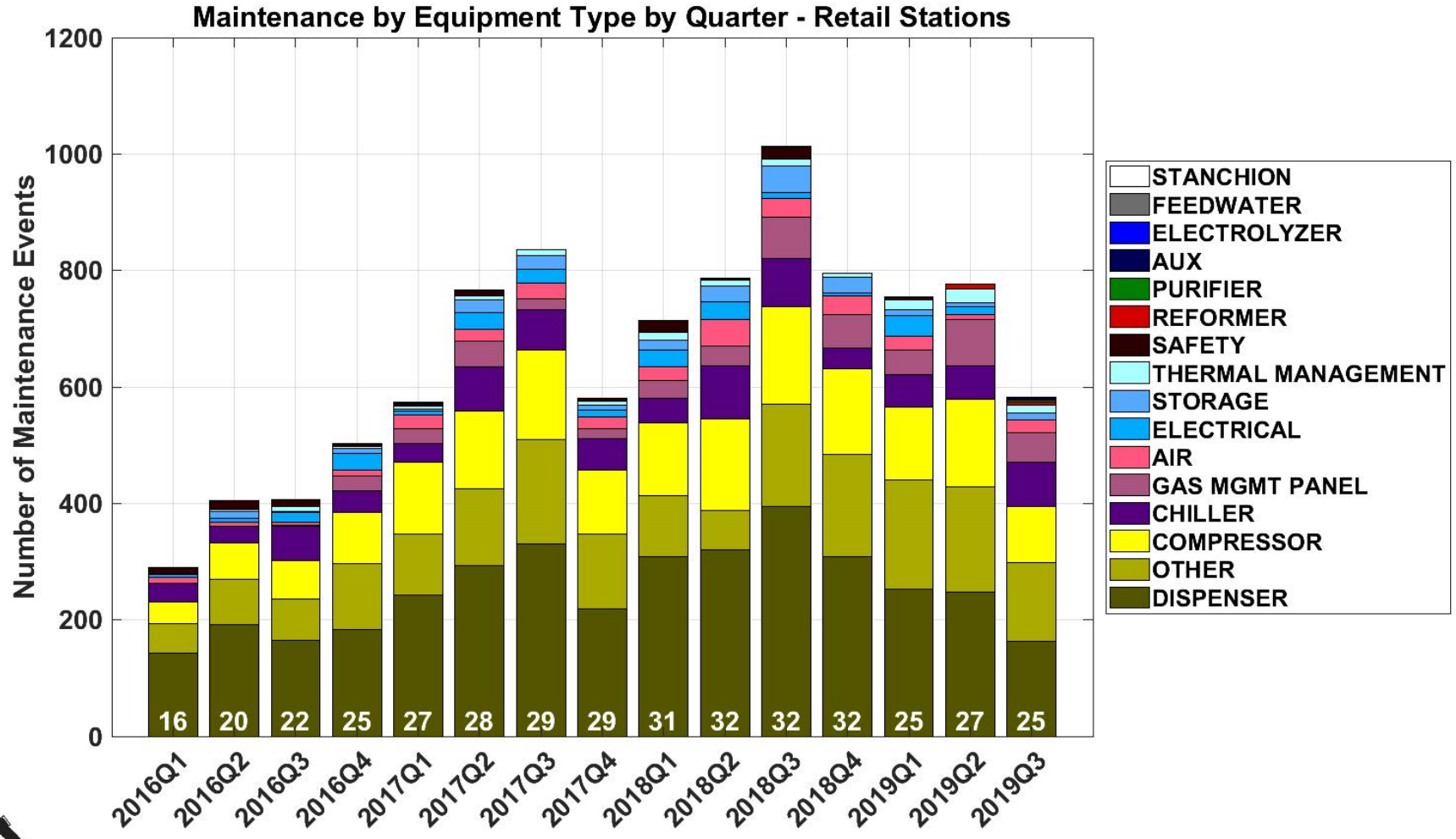


Maintenance and Reliability

CDP-INFR-21
Maintenance by Known Equipment Type



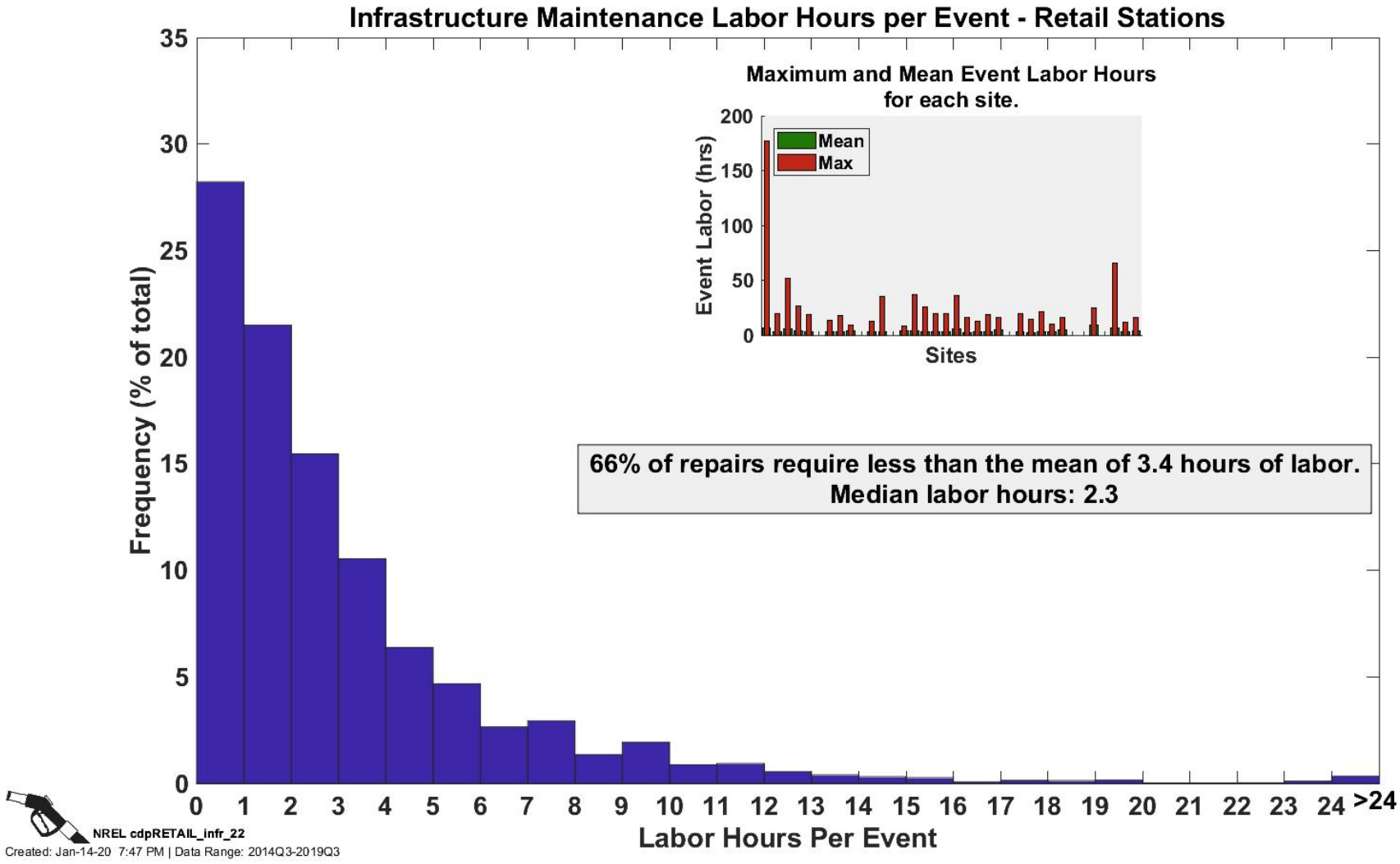
CDP-INFR-94
Maintenance by Equipment Type by Quarter



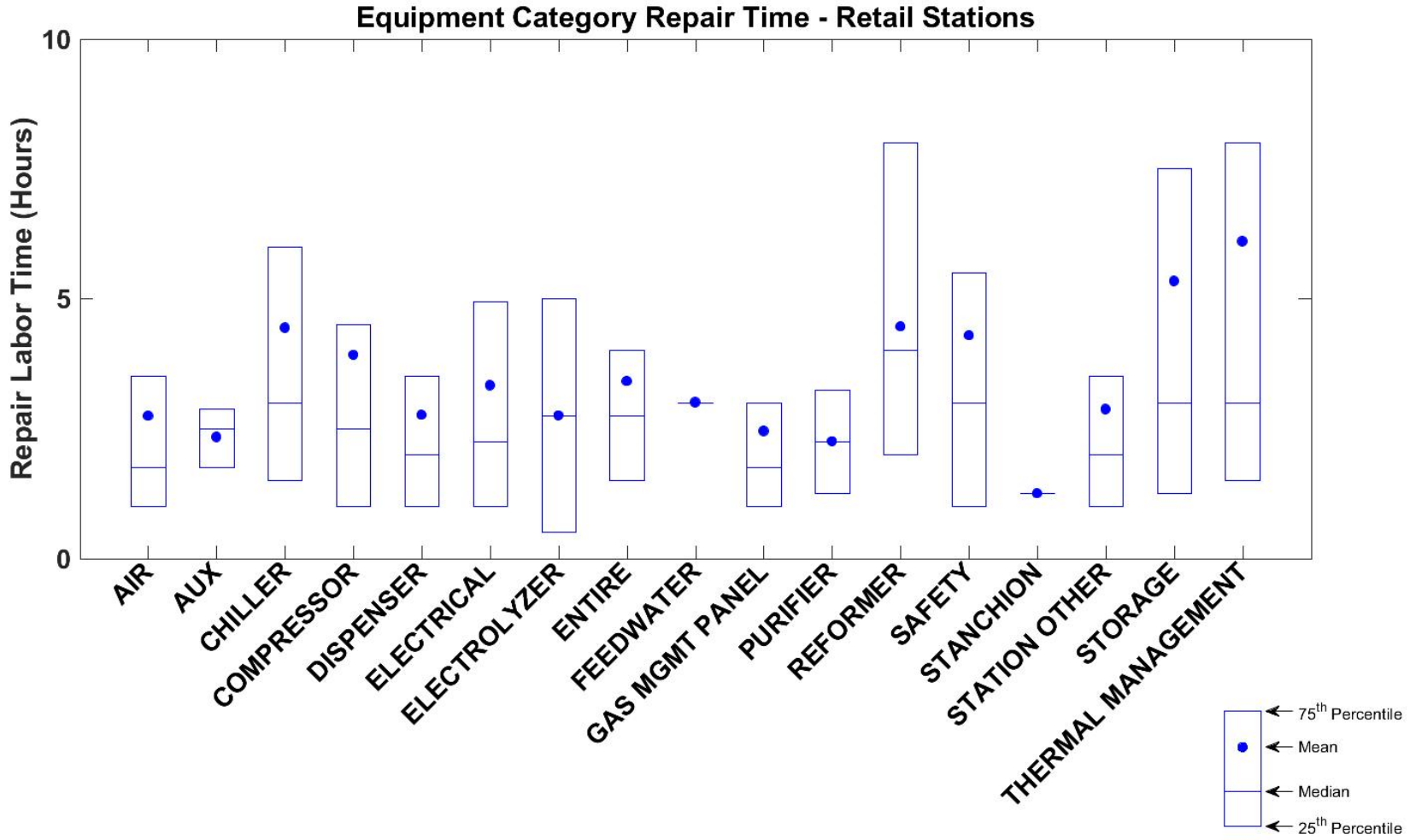
NREL cdpRETAIL_infr_94
Created: Jan-14-20 5:25 PM | Data Range: 2014Q3-2019Q3

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

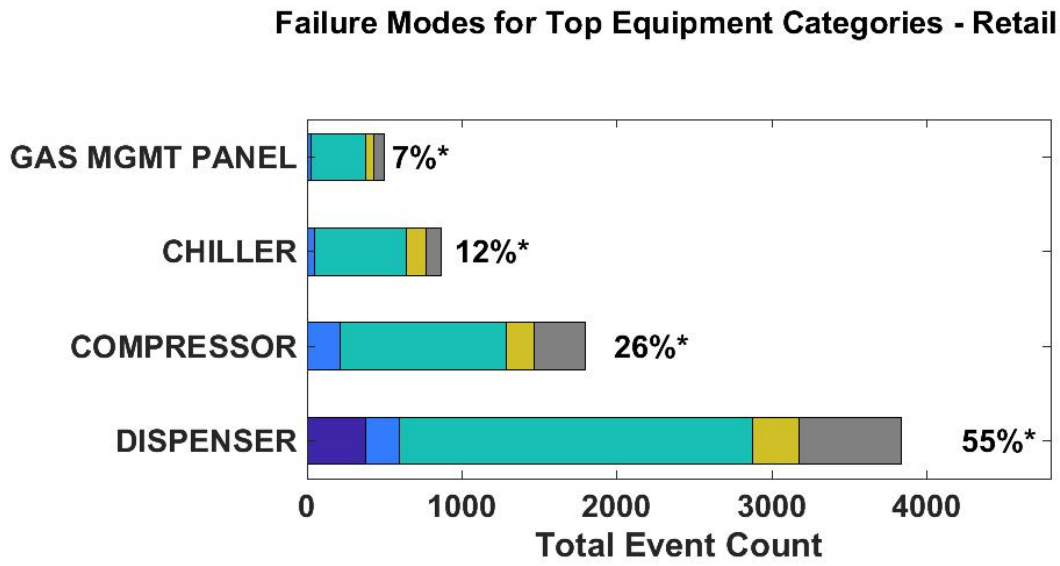


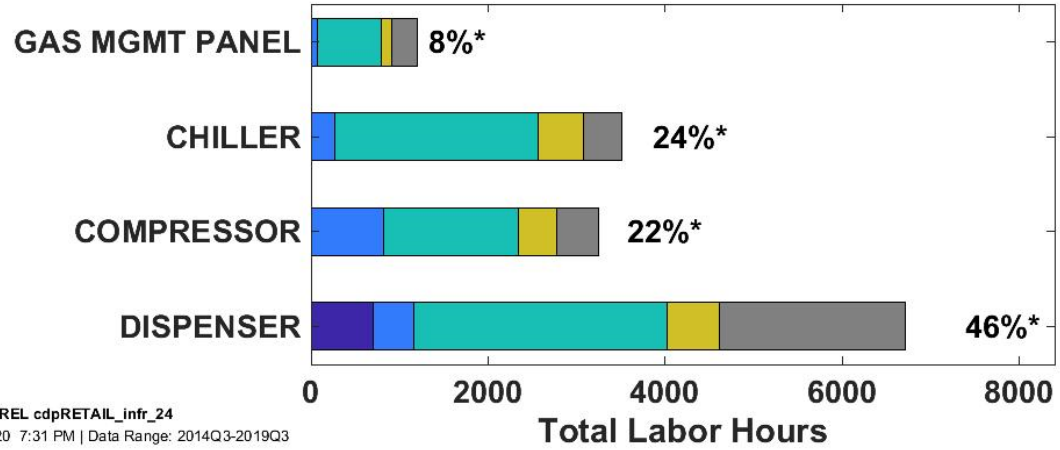
CDP-INFR-23
Equipment Category Repair Time

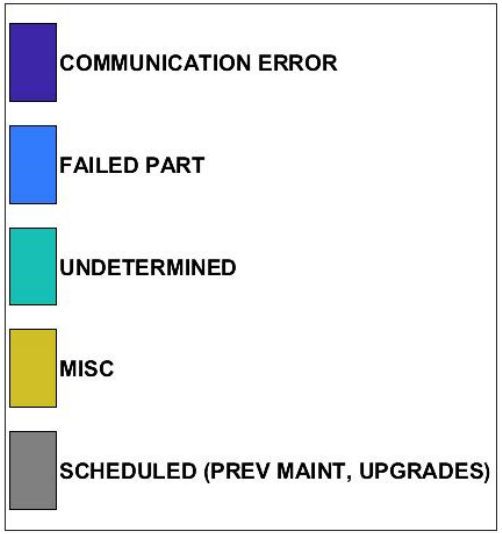


NREL cdpRETAIL_infr_23
Created: Jan-14-20 7:39 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-24
Failure Modes for Top Equipment Categories





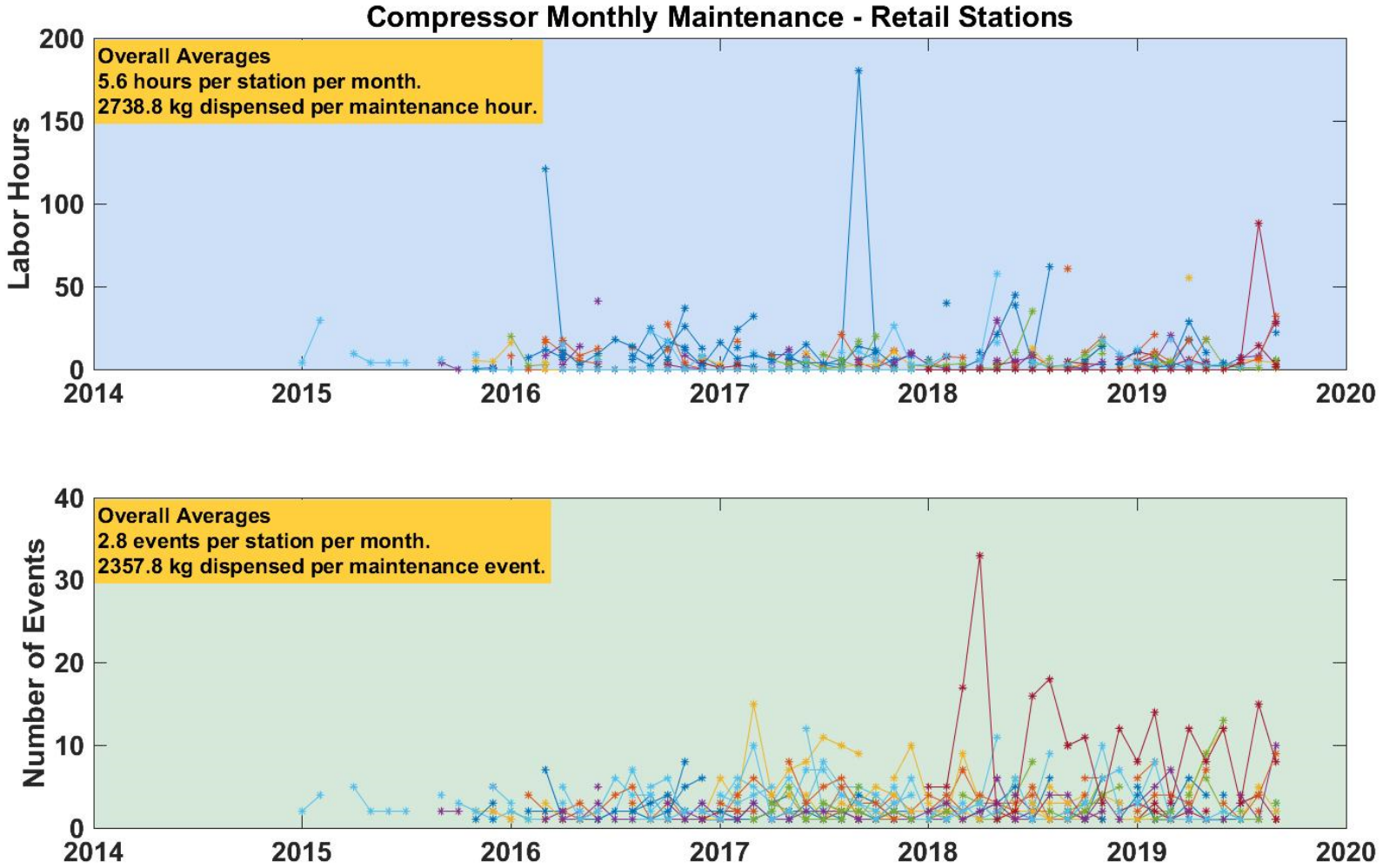


MISC includes the following failure modes: collision, communication error, contamination, debris, design flaw, electrical breaker, end of life, environmental factors, fluid temp, freezing, installation error, level low, loose electrical, loose mechanical, lost signal, maintenance error, manufacturing 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: Jan-14-20 7:31 PM | Data Range: 2014Q3-2019Q3

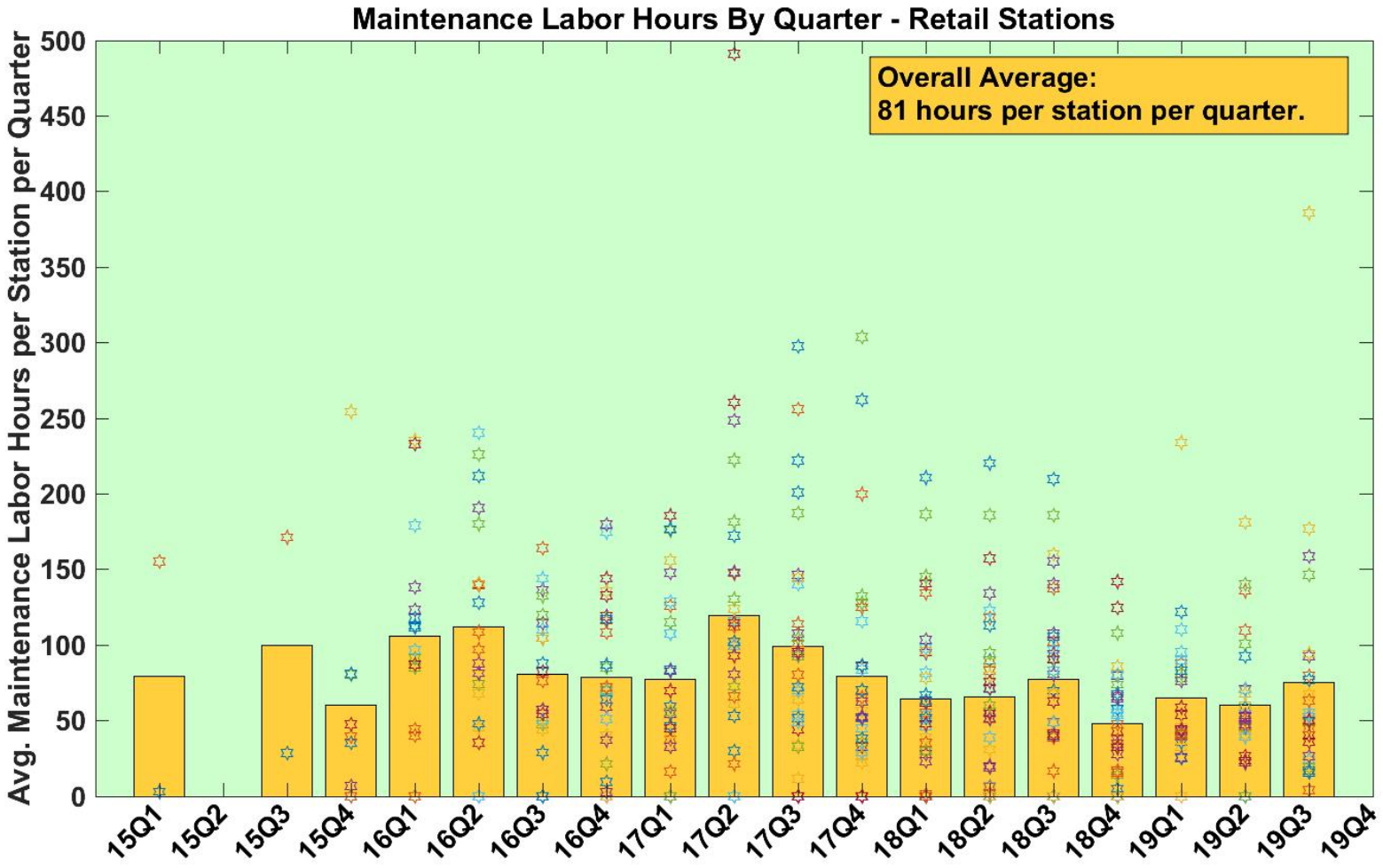
CDP-INFR-26
Compressor Monthly Maintenance



NREL cdpRETAIL_infr_26
Created: Jan-14-20 7:25 PM | Data Range: 2014Q3-2019Q3

* 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
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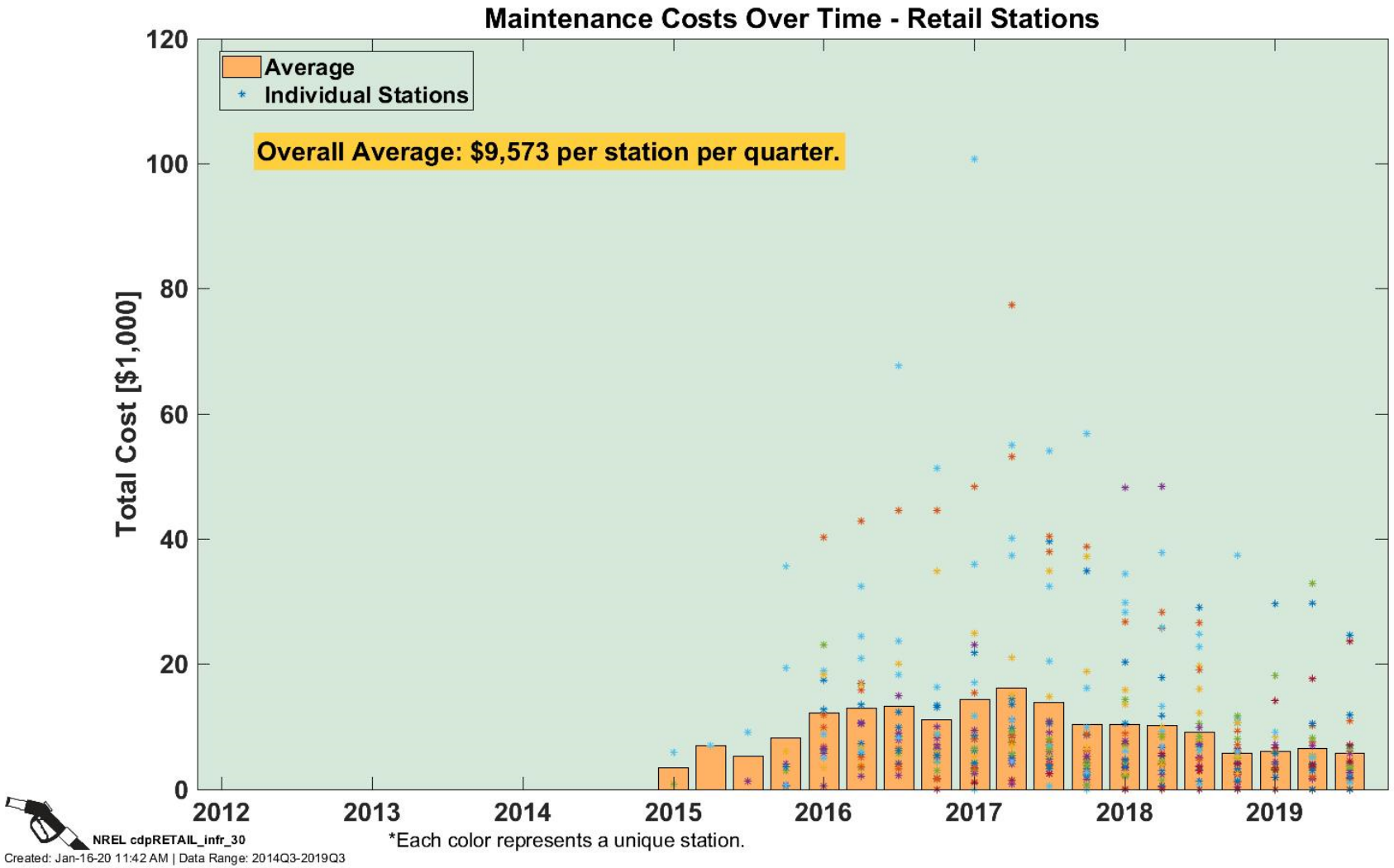
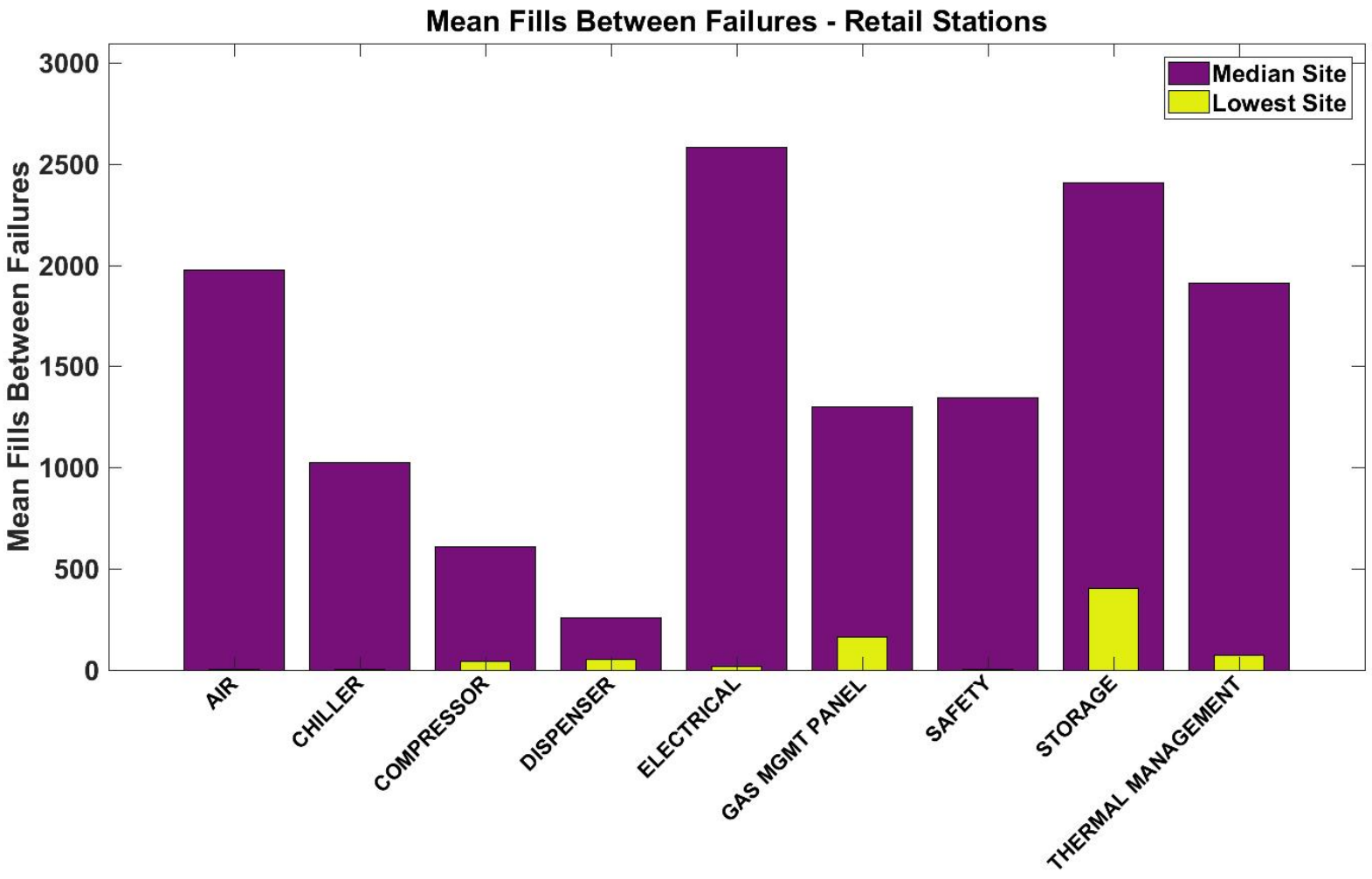
Stars represent individual station maintenance hours in a given quarter.

CDP-INFR-30
Maintenance Costs Over Time



CDP-INFR-49
Mean Fills Between Failures



NREL cdpRETAIL_infr_49
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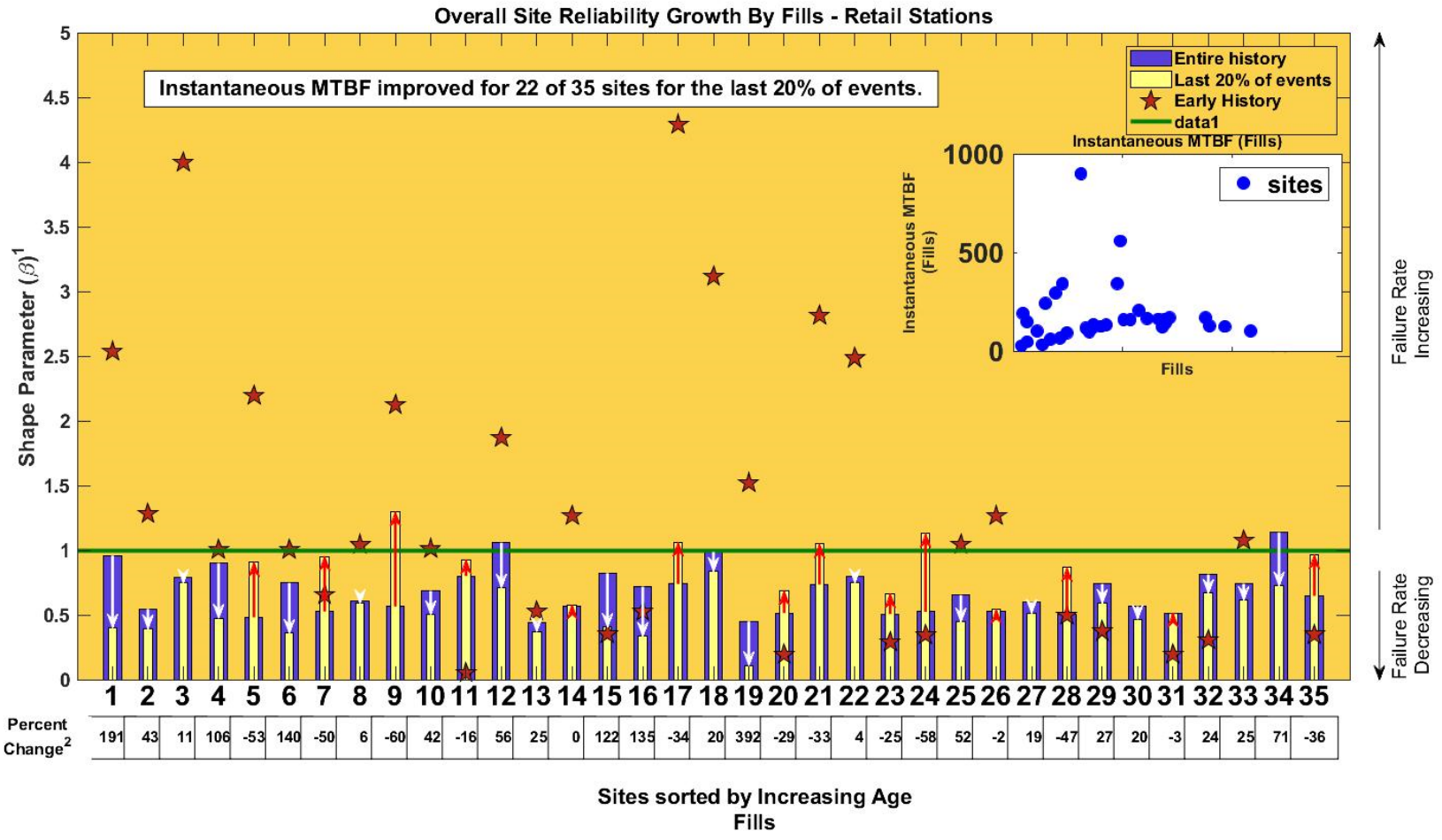
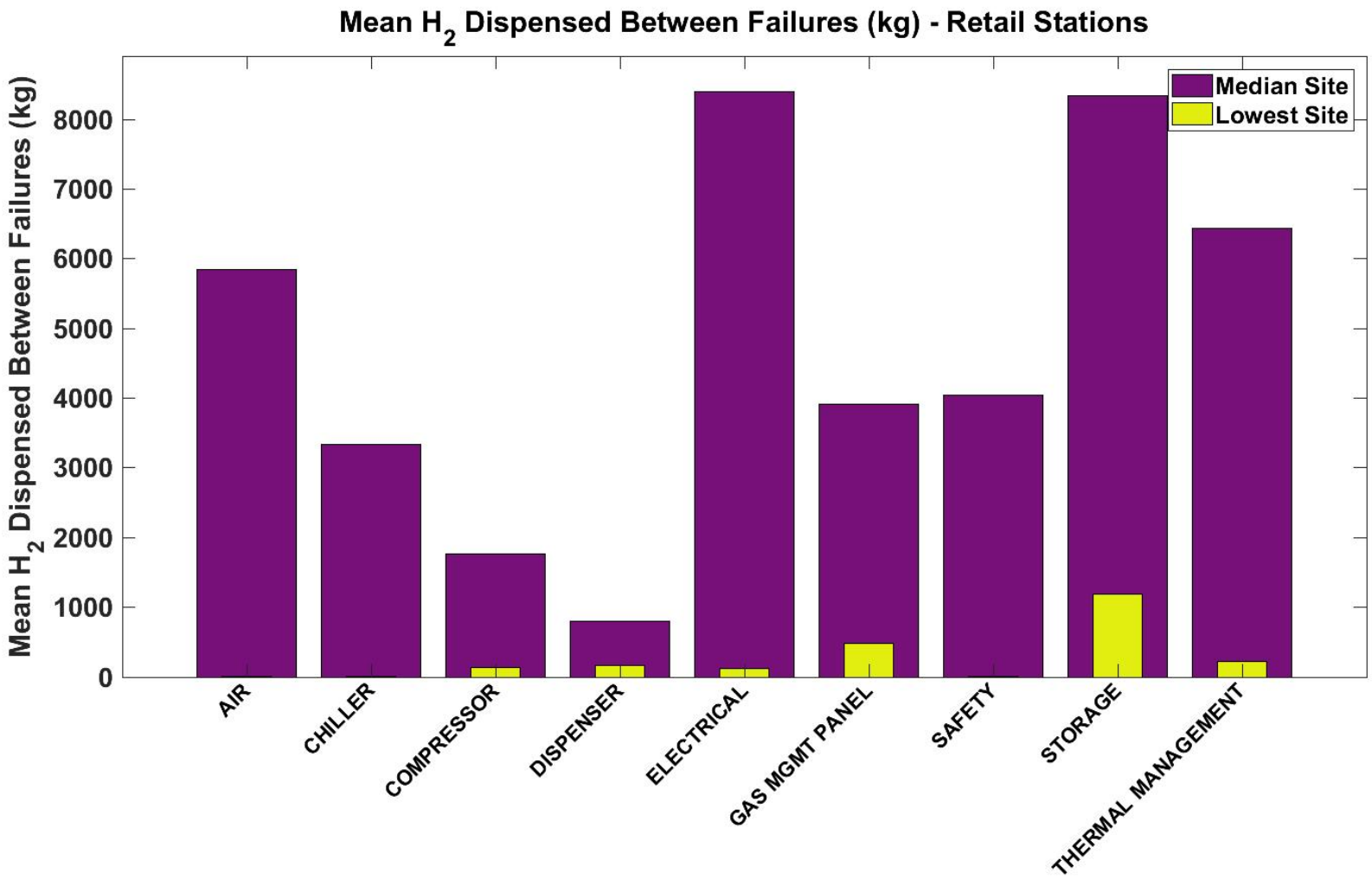
CDP-INFR-50
Reliability Growth by Fills



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

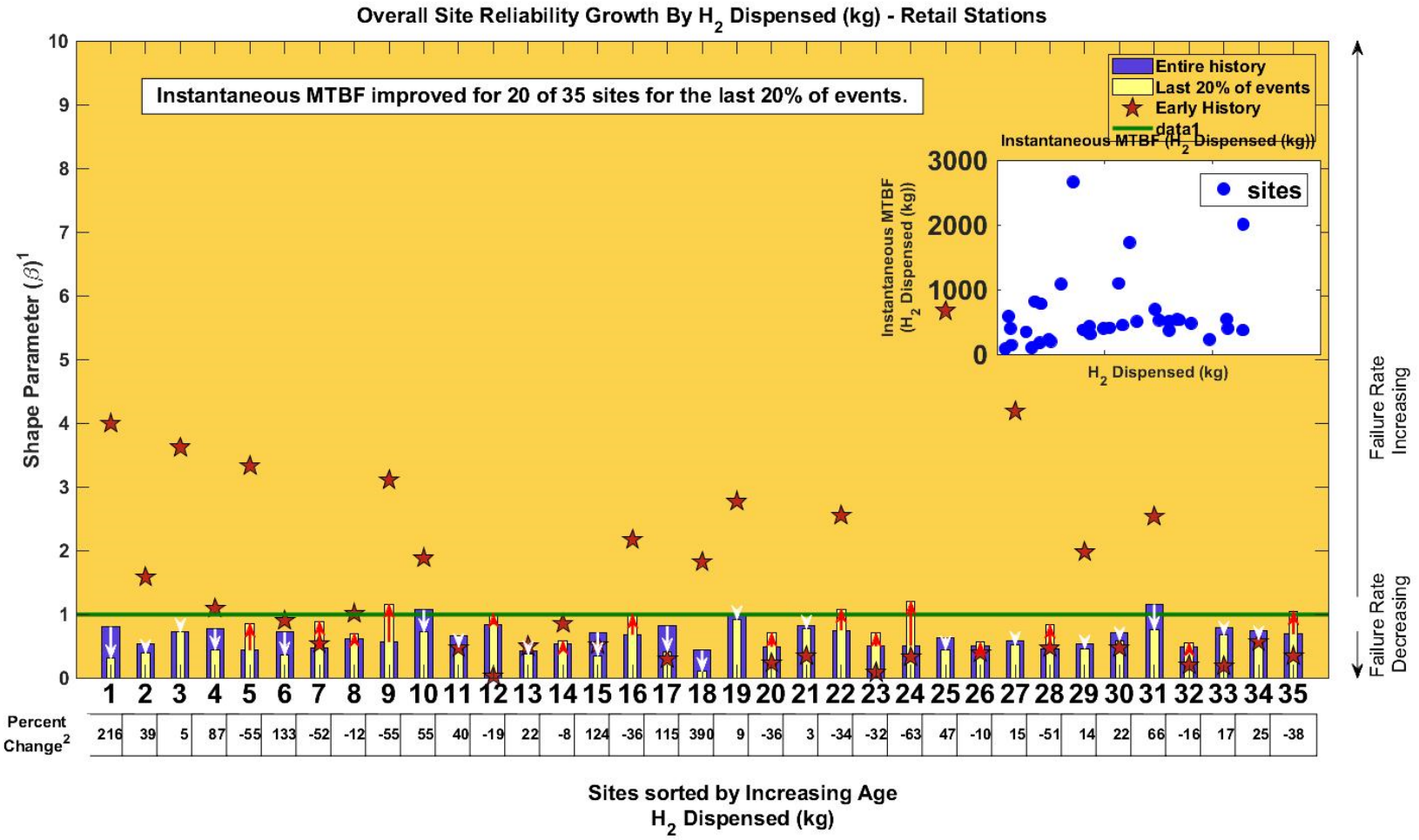
NREL cdpRETAIL_infr_50
Created: Jan-14-20 6:53 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-51
Mean Amount Dispensed Between Failures



NREL cdpRETAIL_infr_51
Created: Jan-14-20 6:46 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-52
Reliability Growth by Amount Dispensed



Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Percent Change[2]	216	39	5	87	-55	133	-52	-12	-55	55	40	-19	22	-8	124	-36	115	390	9	-36	3	-34	-32	-63	47	-10	15	-51	14	22	66	-16	17	25	-38

1. IEC 61164:2004(E)., Reliability Growth - Statistical Test and Evaluation Methods, IEC. 2004.
2. % change in instantaneous mean H_2 Dispensed (kg) between failures

NREL cdpRETAIL_infr_52
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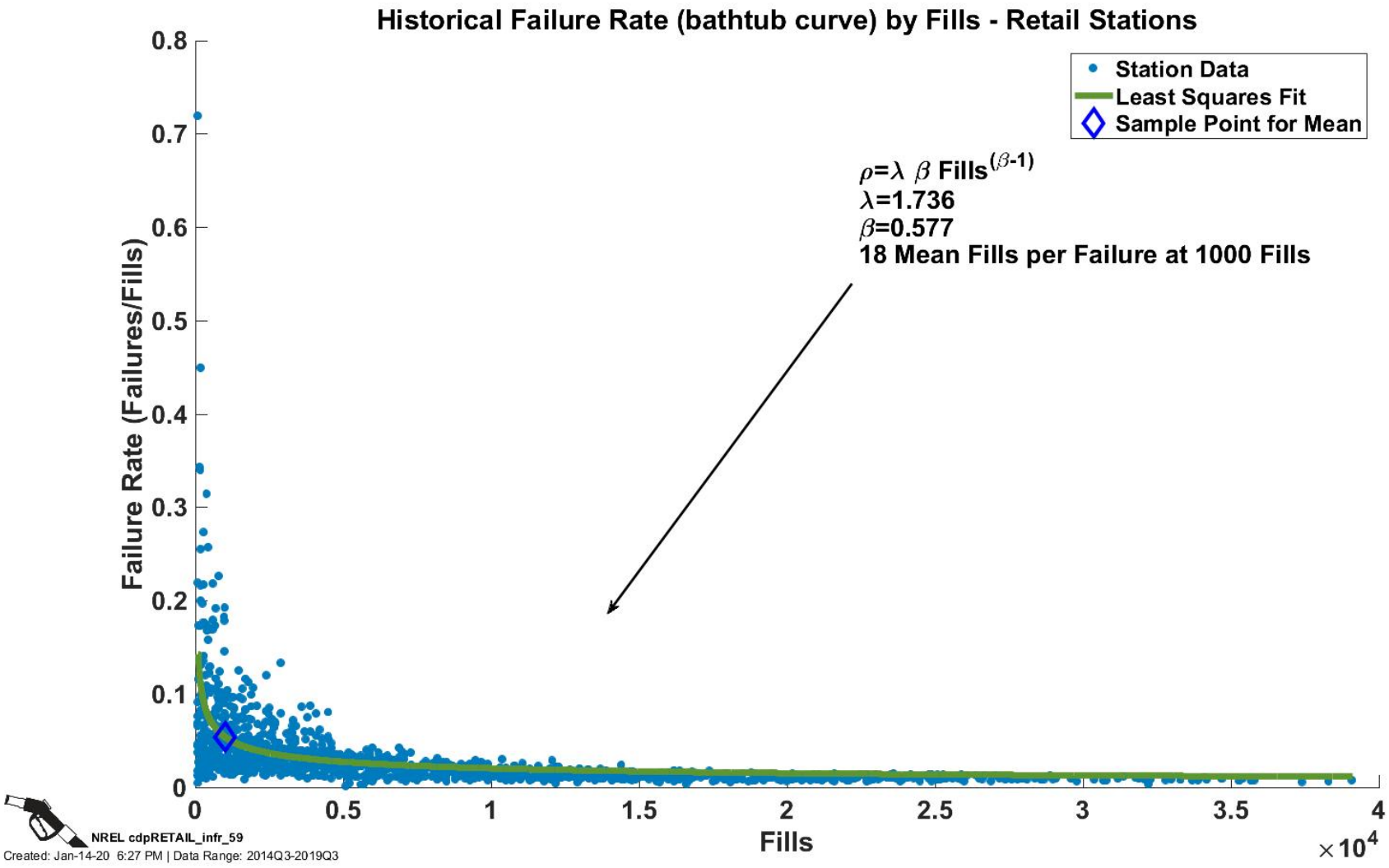
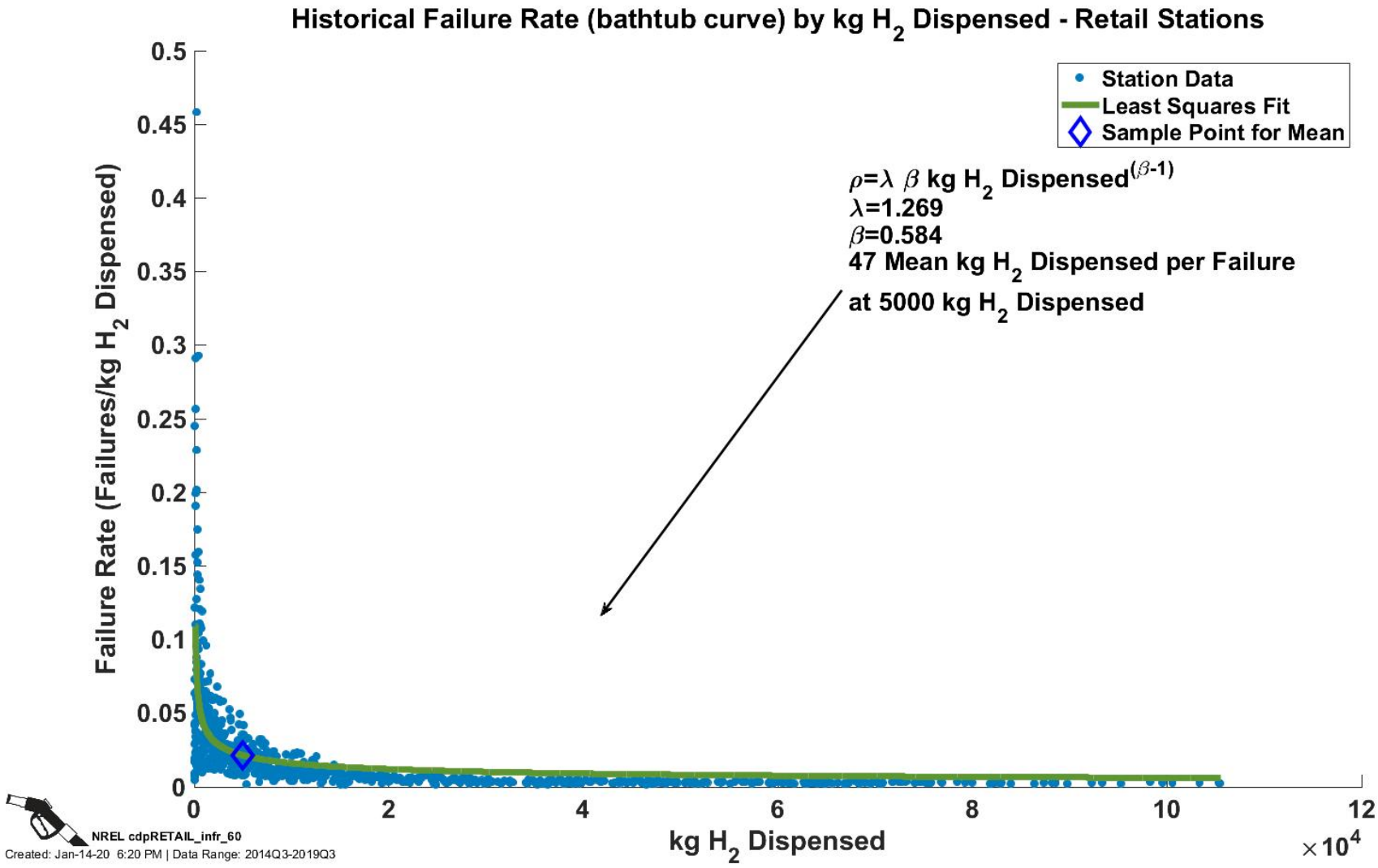
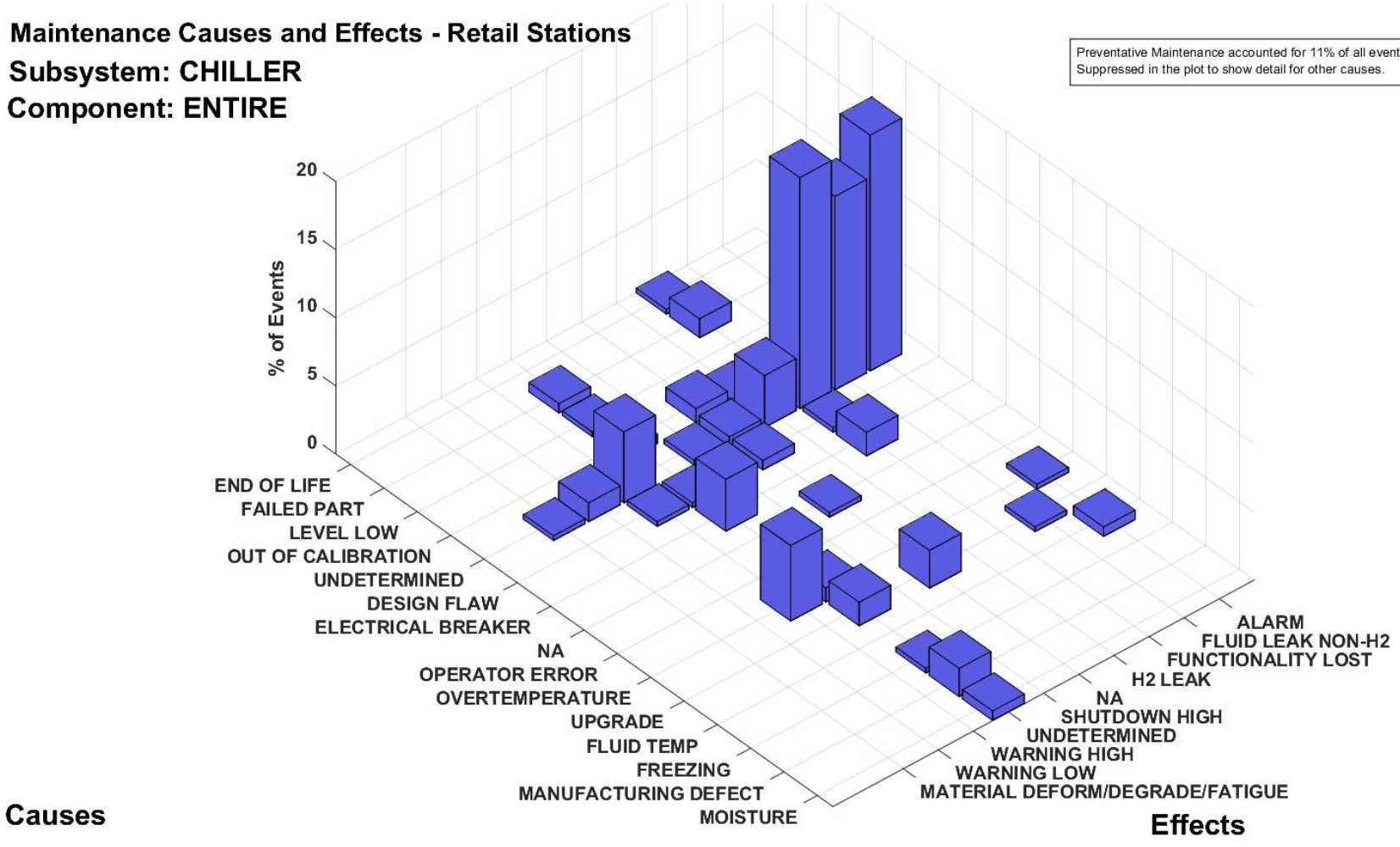
CDP-INFR-59
Historical Failure Rate by Fills



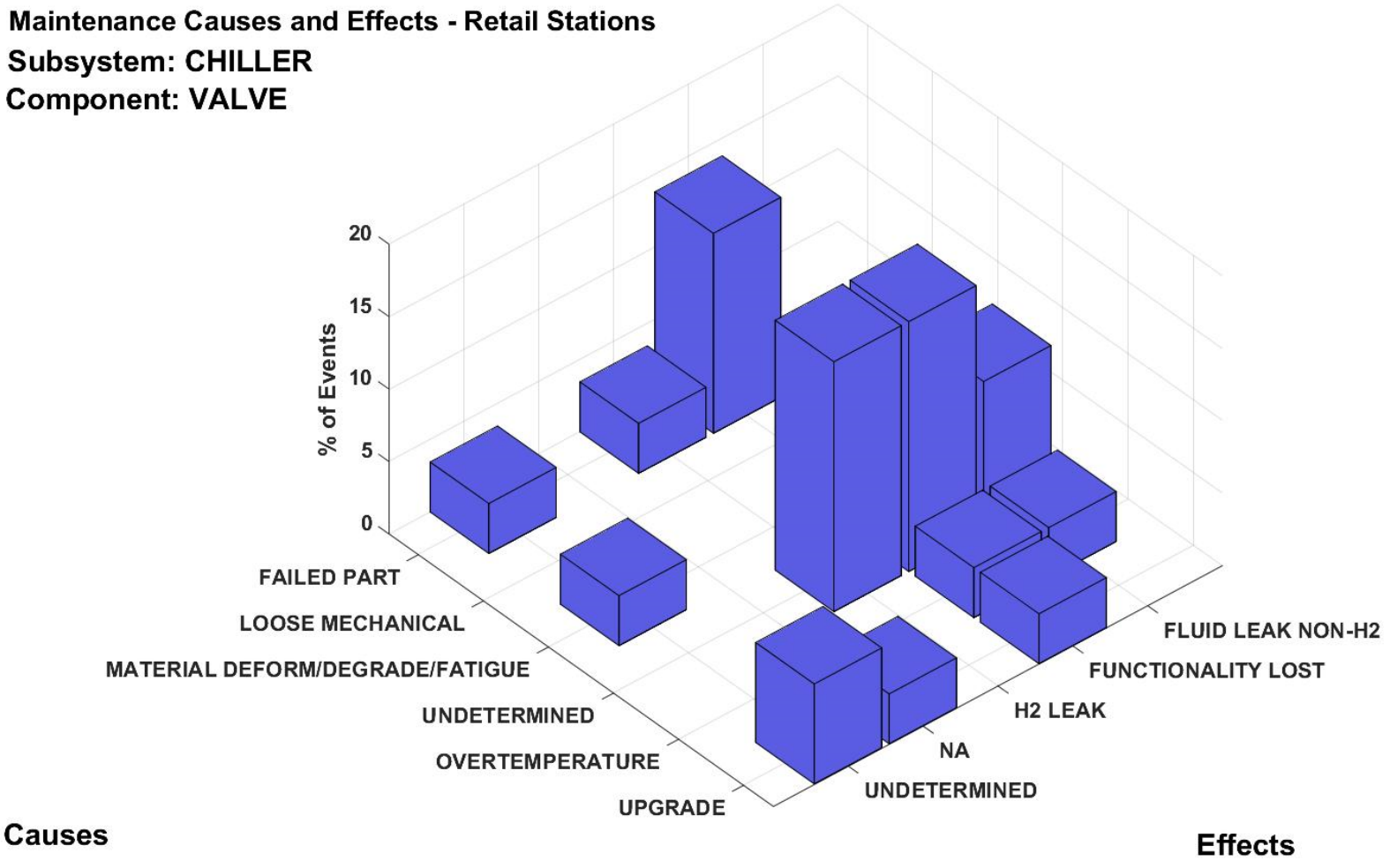
CDP-INFR-60
Historical Failure Rate by Amount Dispensed



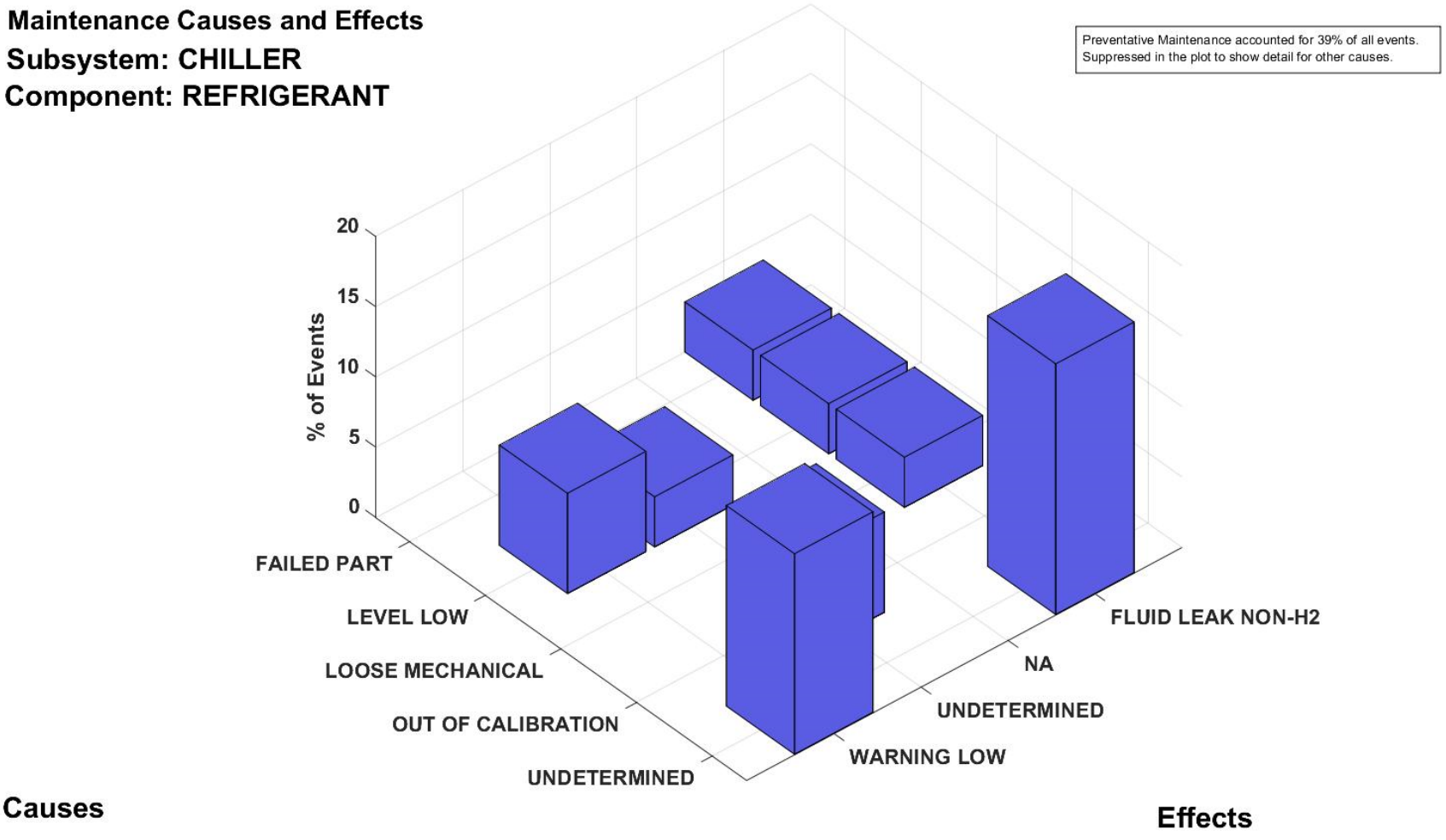
CDP-INFR-64
Maintenance Causes and Effects: Chiller (Entire)



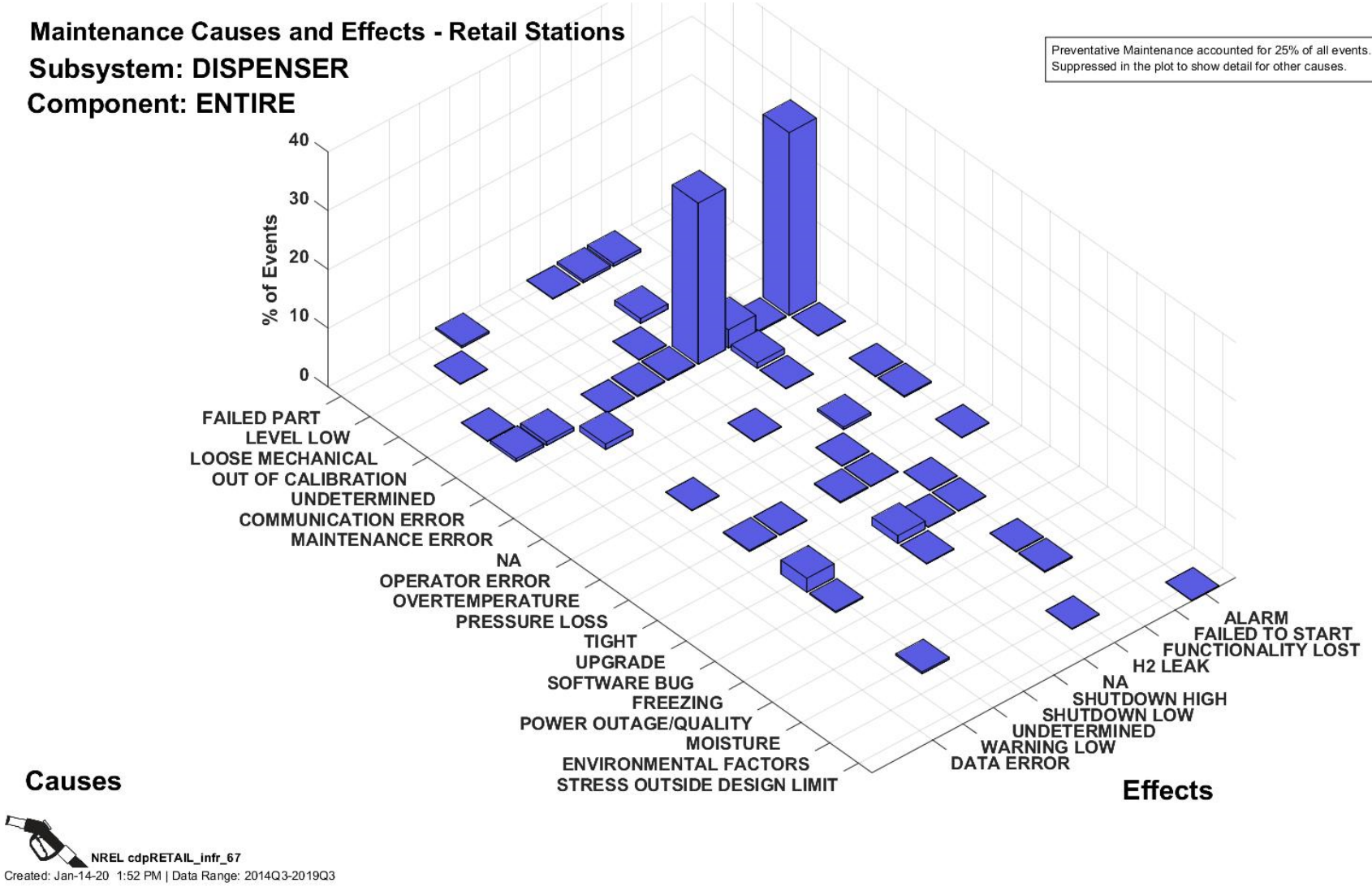
CDP-INFR-65
Maintenance Causes and Effects: Chiller (Valve)



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

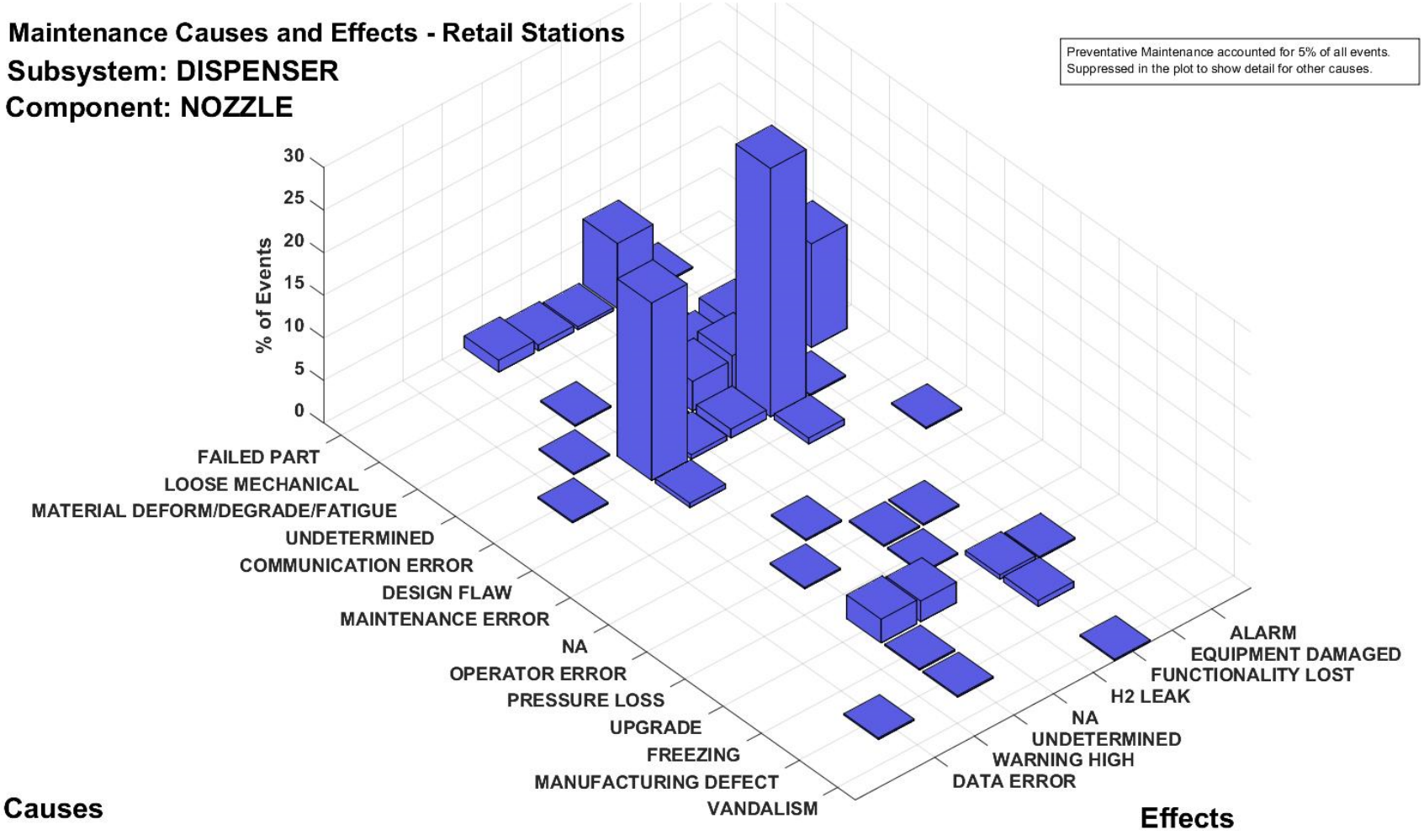


CDP-INFR-67
Maintenance Causes and Effects: Dispenser (Entire)

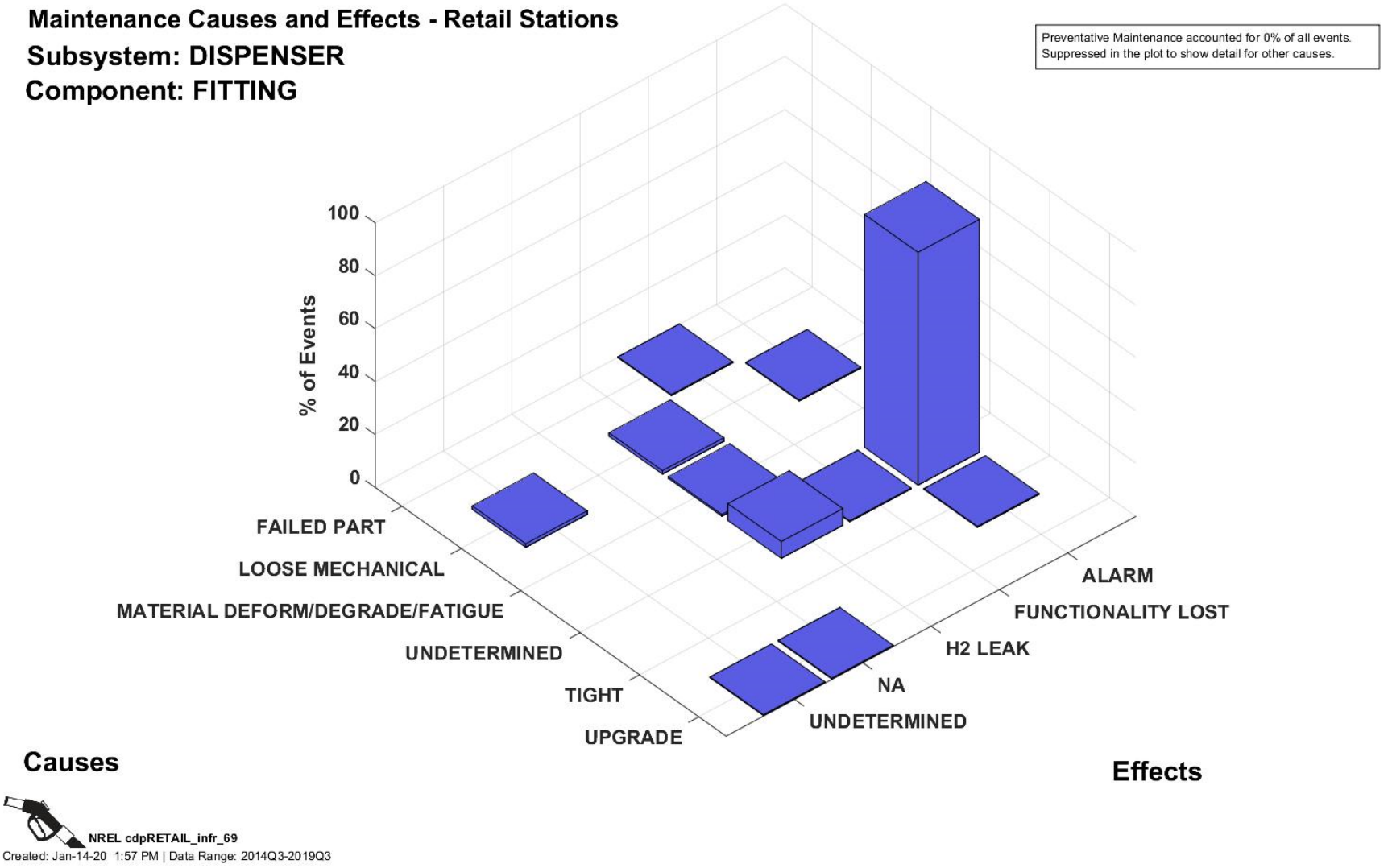


NREL cdpRETAIL_infr_67
Created: Jan-14-20 1:52 PM | Data Range: 2014Q3-2019Q3

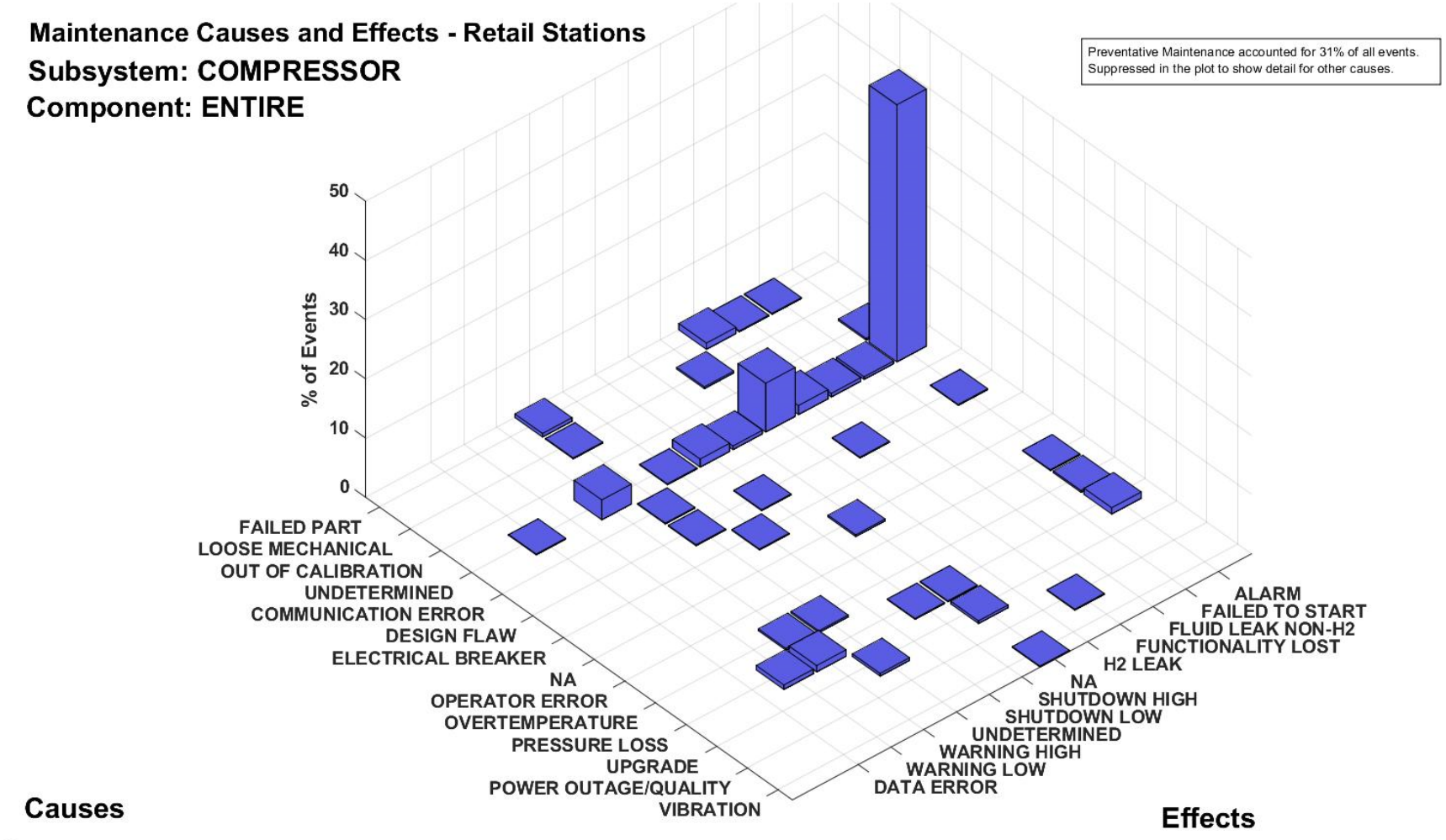
CDP-INFR-68
Maintenance Causes and Effects: Dispenser (Nozzle)



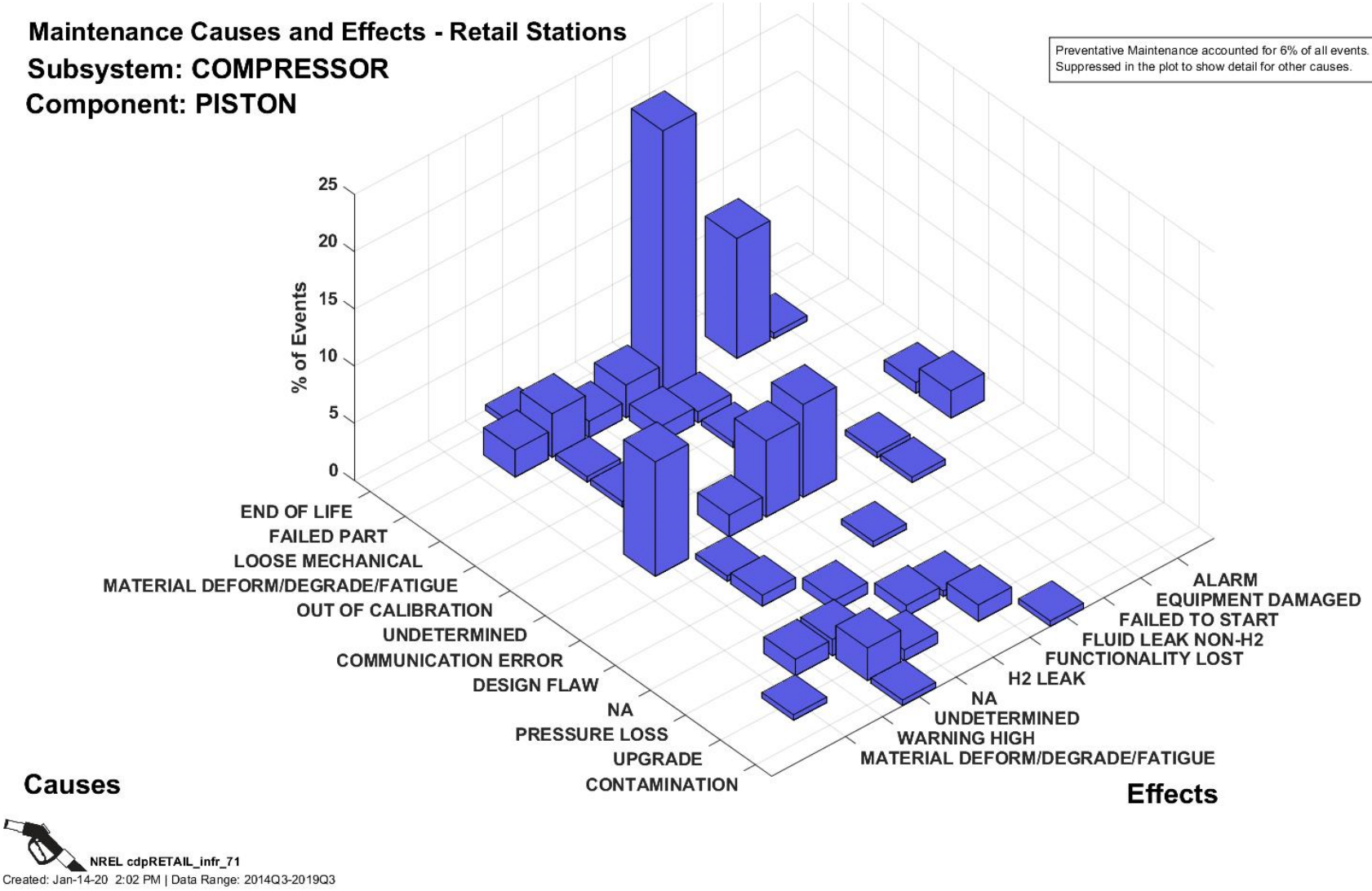
CDP-INFR-69
Maintenance Causes and Effects: Dispenser (Fitting)



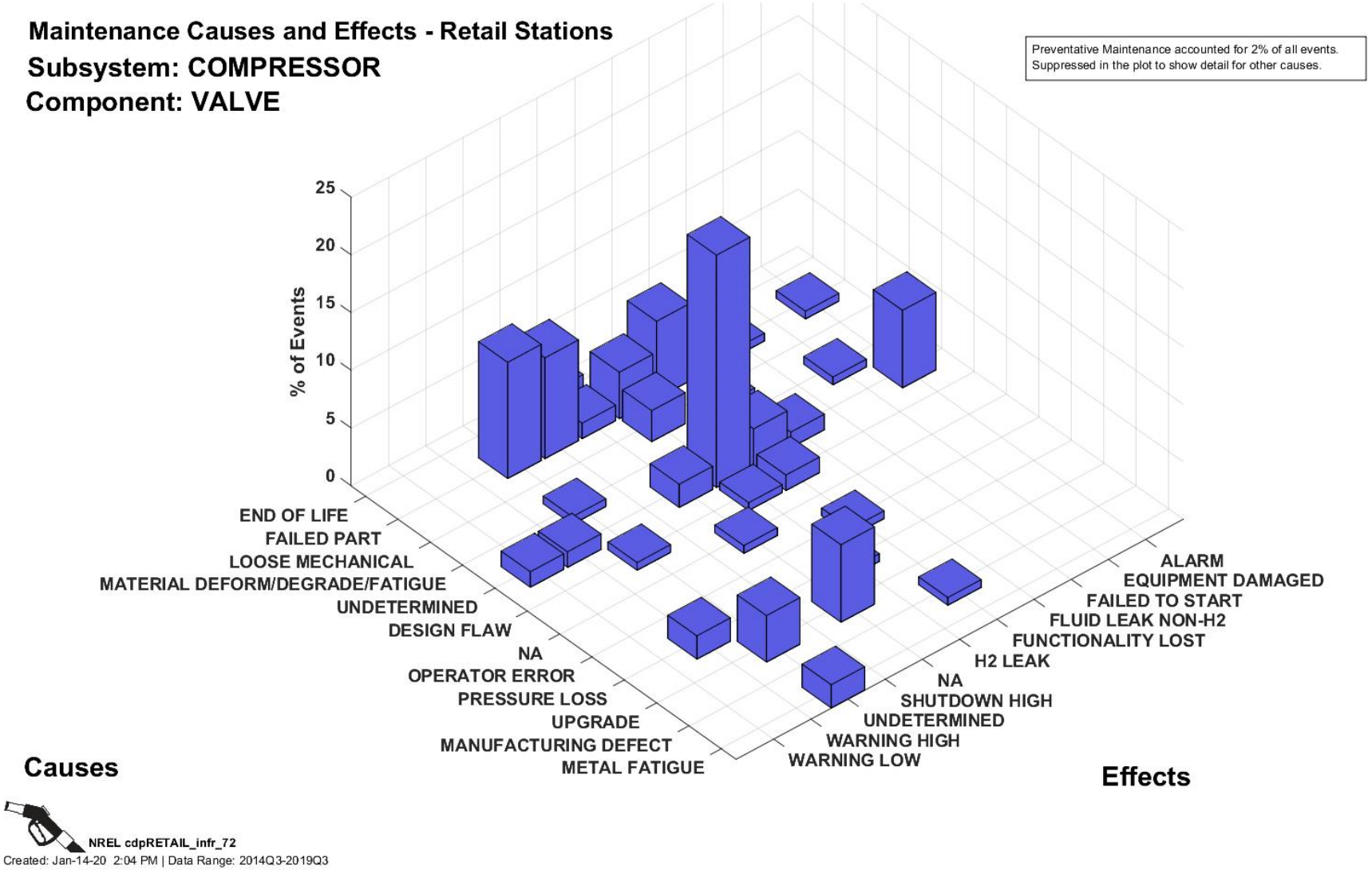
CDP-INFR-70
Maintenance Causes and Effects: Compressor (Entire)



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

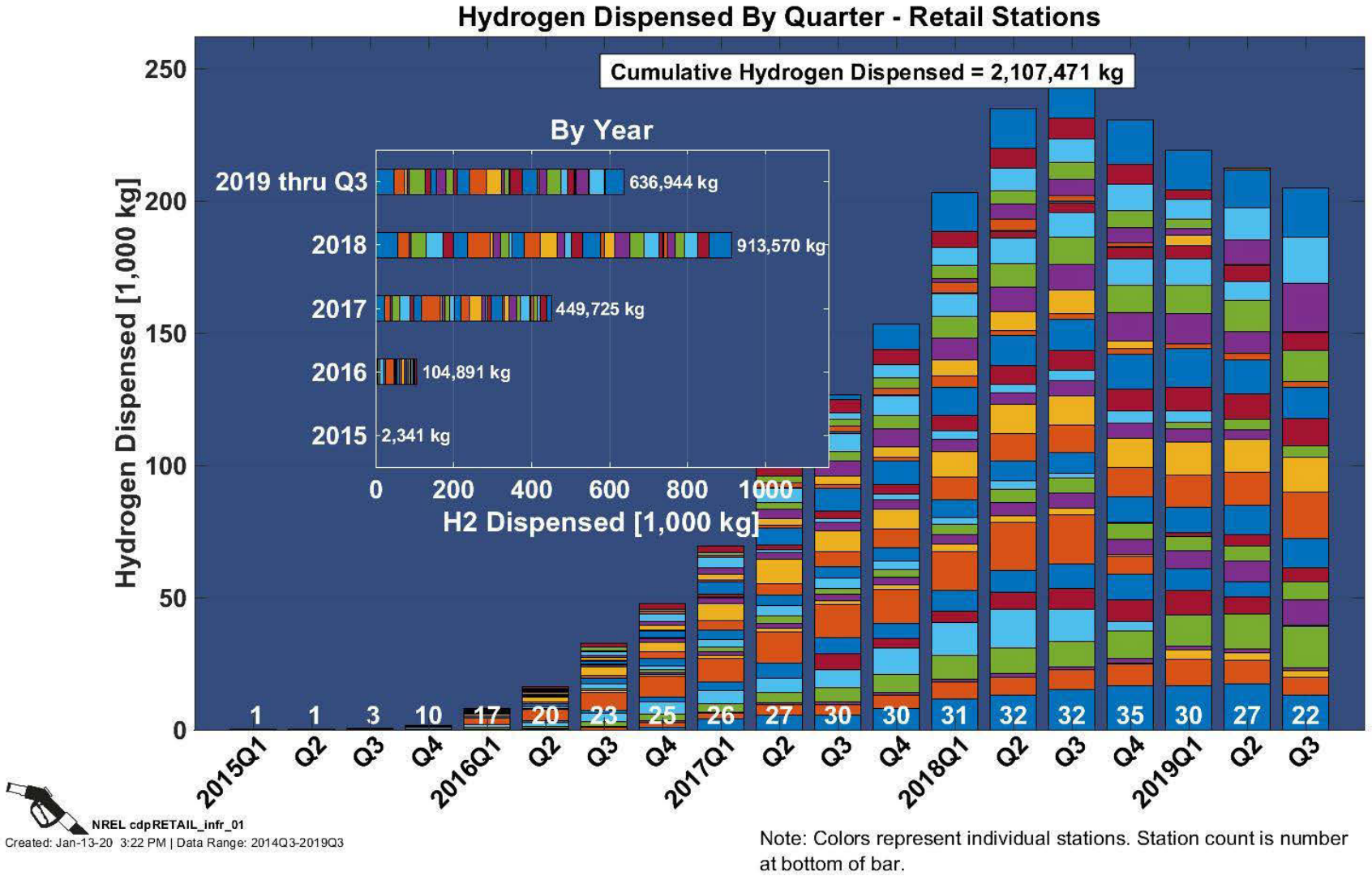


CDP-INFR-72
Maintenance Causes and Effects: Compressor (Valve)



Performance

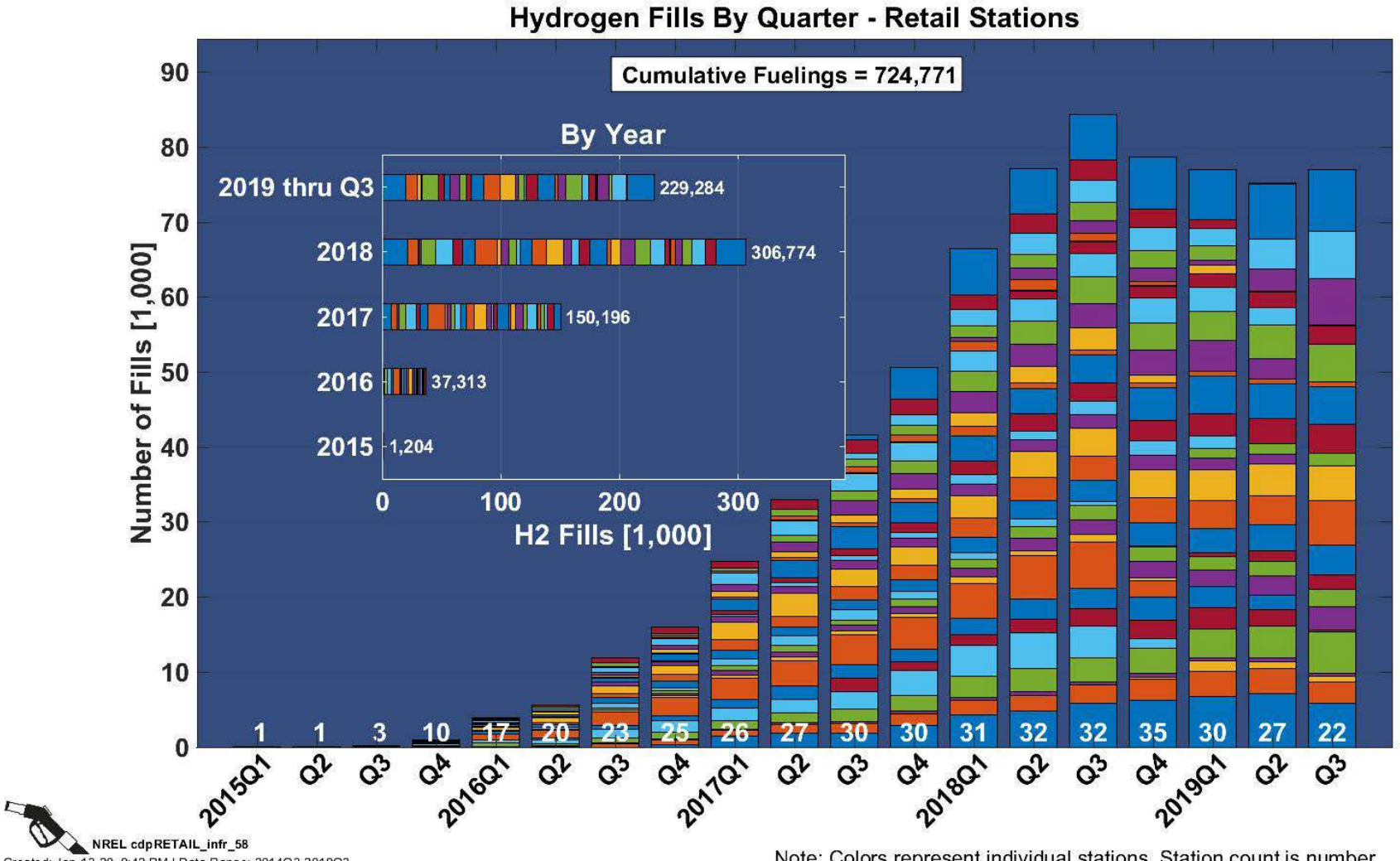
CDP-INFR-01
Hydrogen Dispensed by Quarter



NREL cdpRETAIL_infr_01
Created: Jan-13-20 3:22 PM | Data Range: 2014Q3-2019Q3

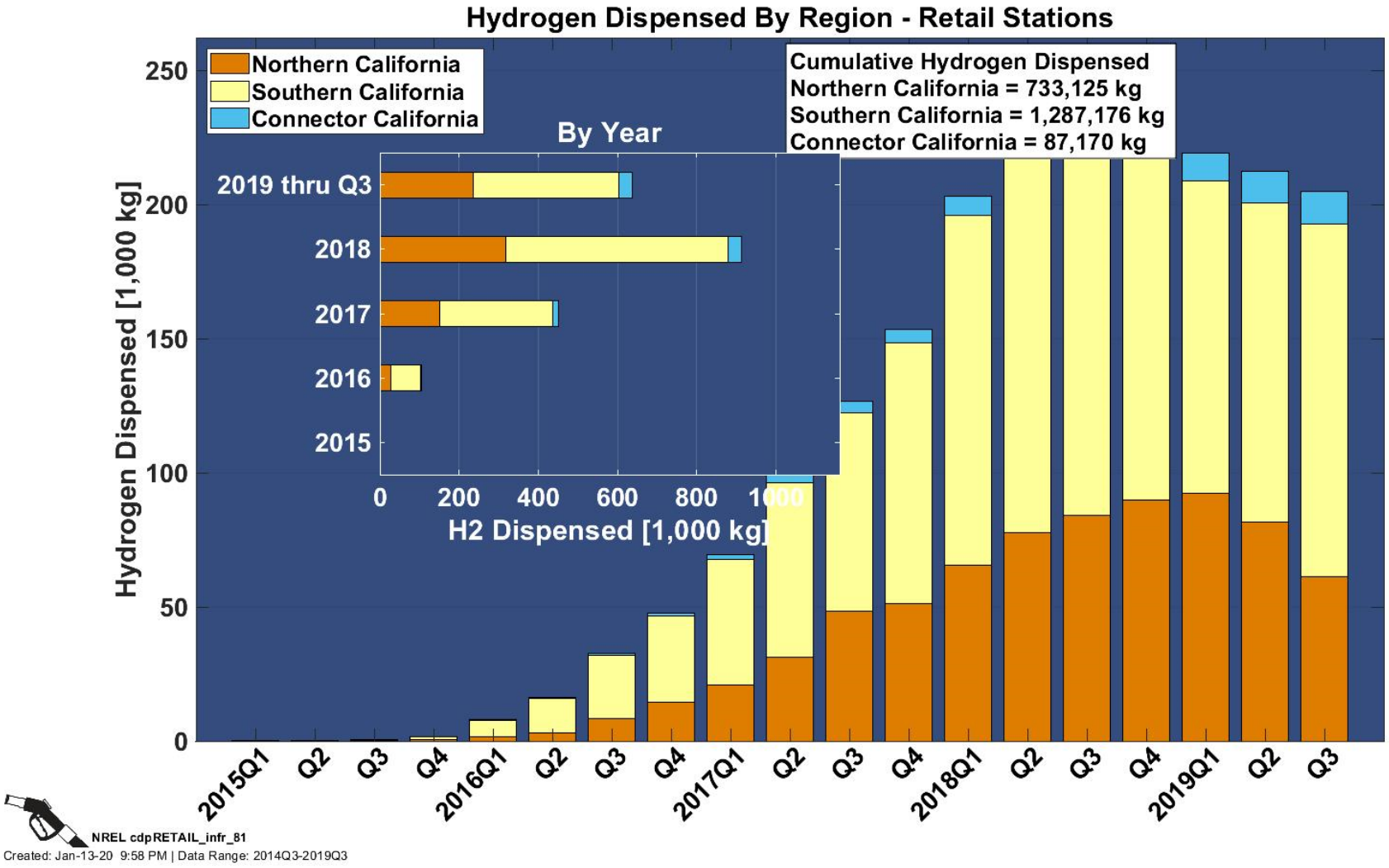
Note: Colors represent individual stations. Station count is number at bottom of bar.

CDP-INFR-58
Hydrogen Fills by Quarter

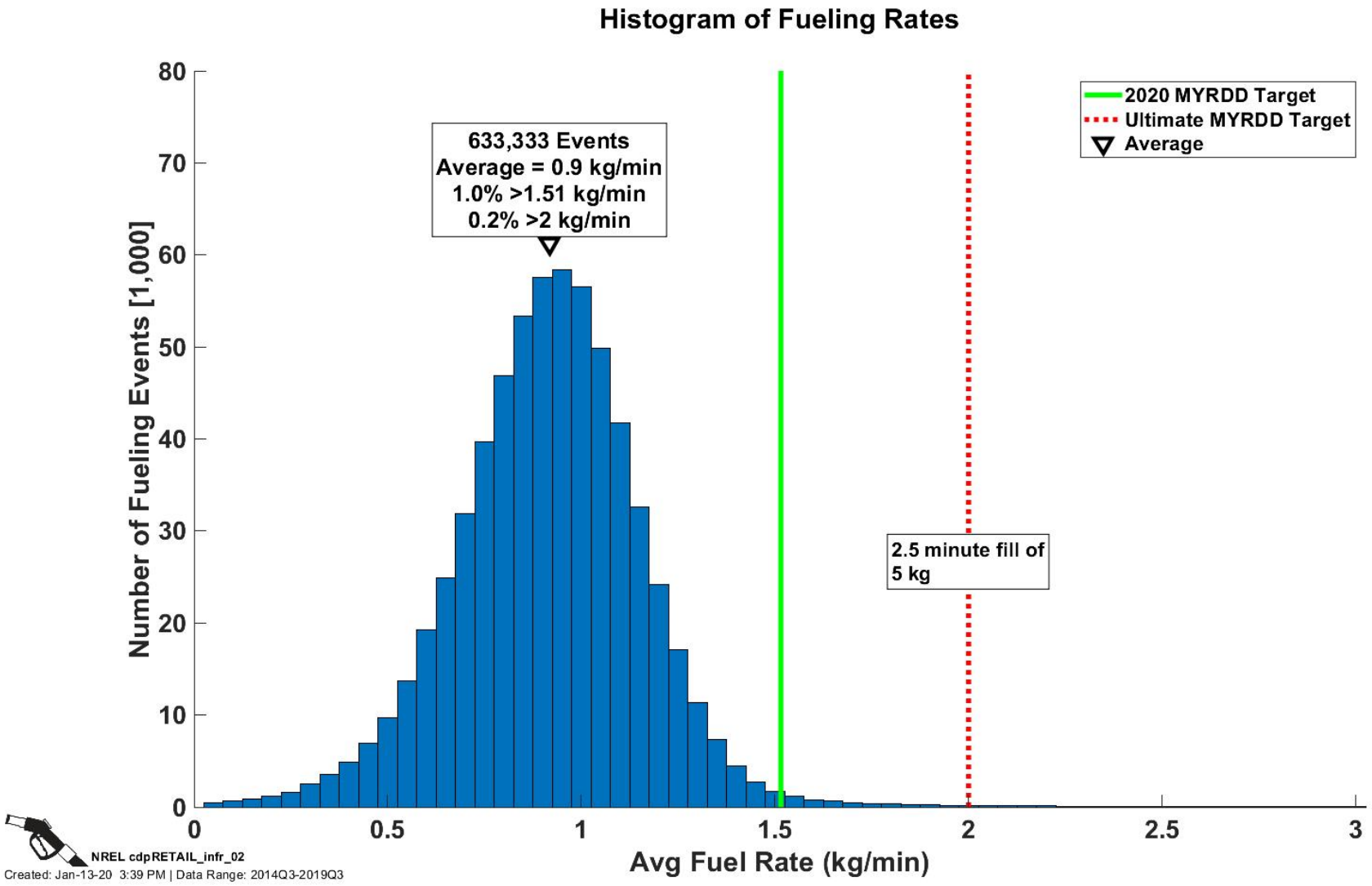


Note: Colors represent individual stations. Station count is number at bottom of bar.

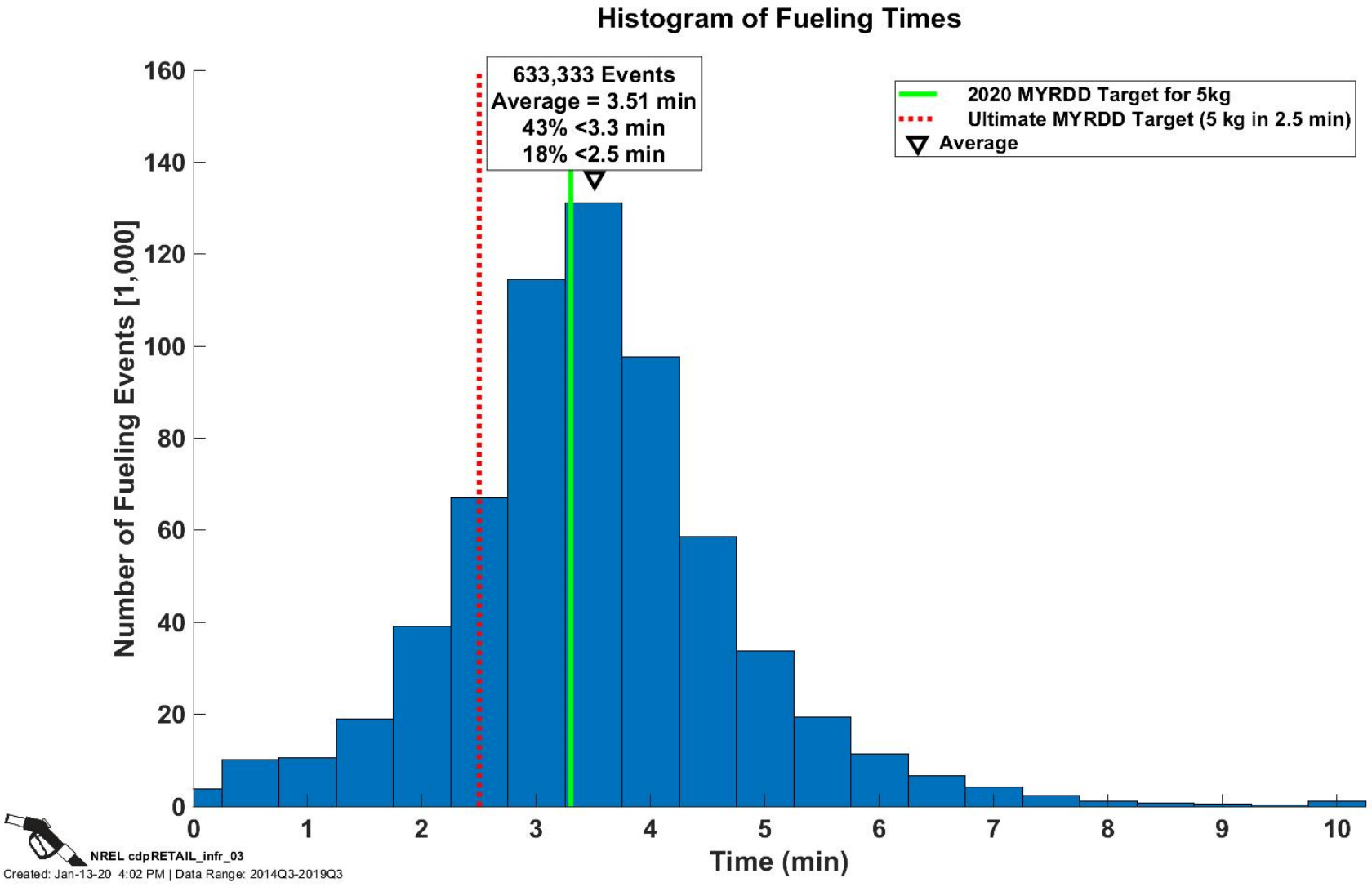
CDP-INFR-81
Hydrogen Dispensed by Region



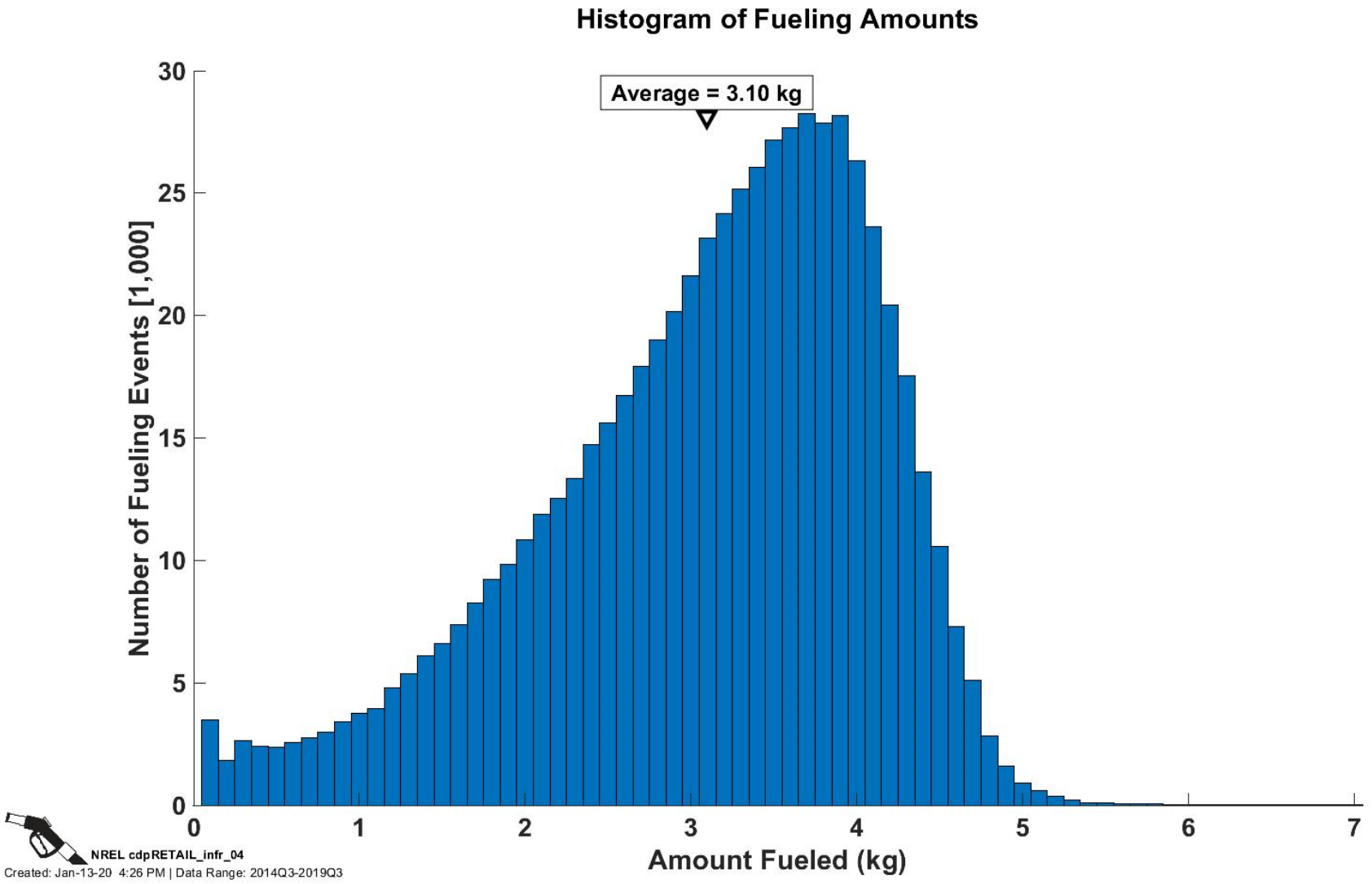
CDP-INFR-02
Histogram of Fueling Rates



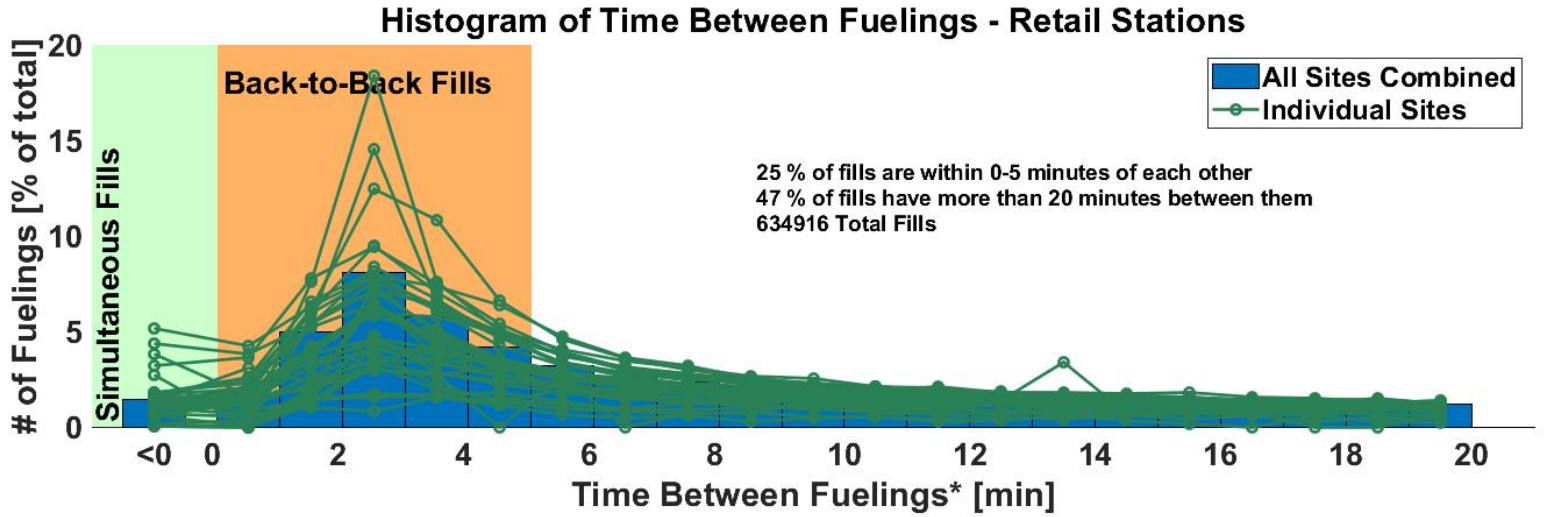
CDP-INFR-03
Histogram of Fueling Times

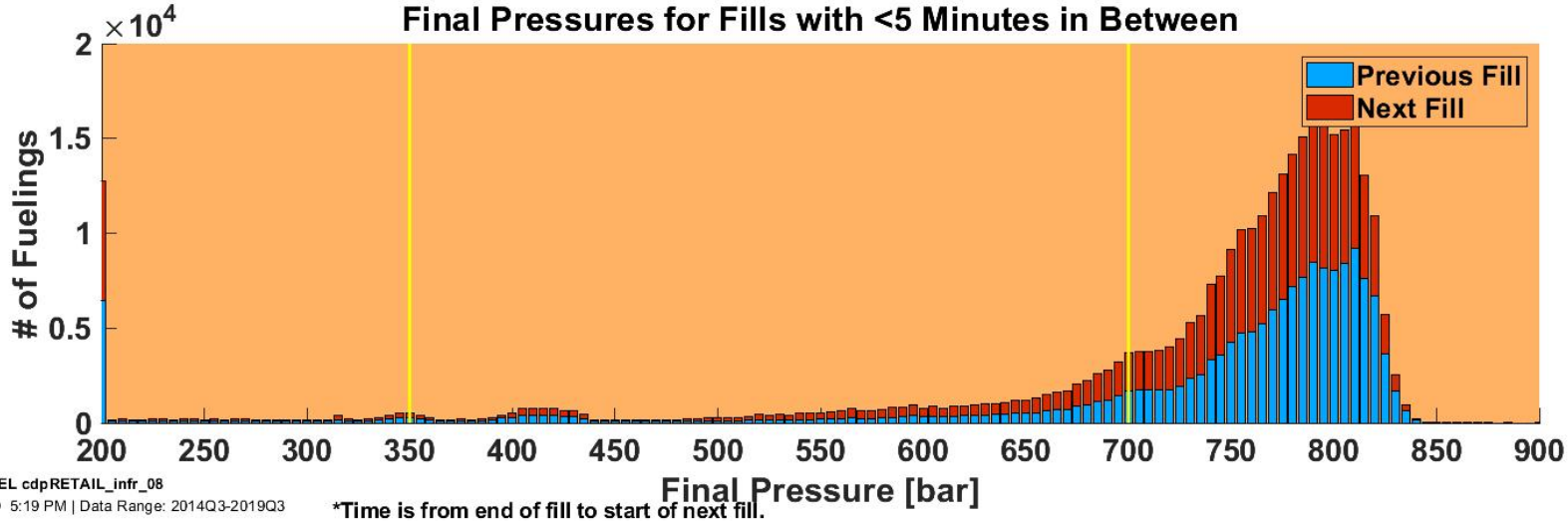


CDP-INFR-04
Histogram of Fueling Amounts



CDP-INFR-08
Time Between Fueling

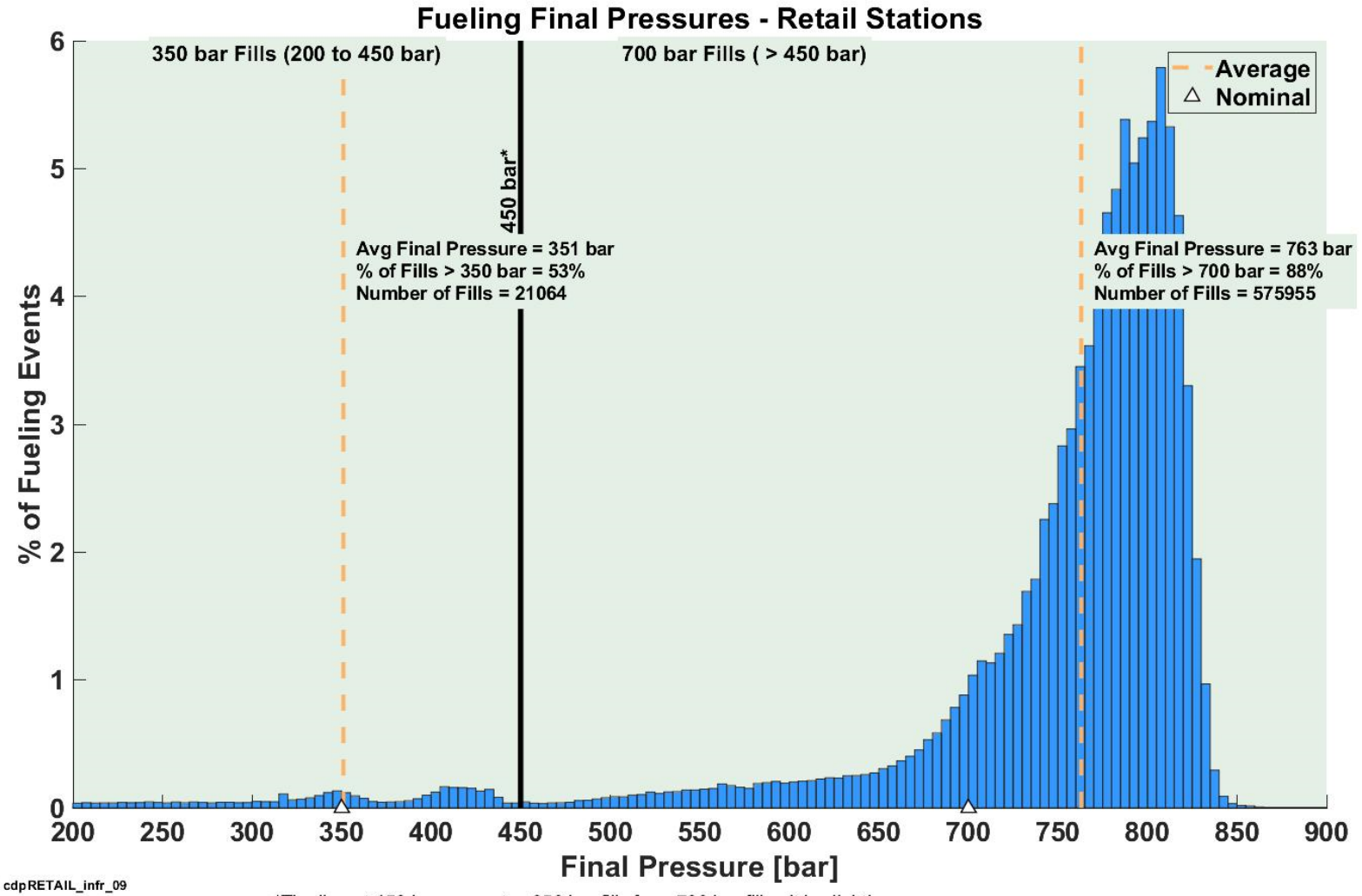




NREL cdpRETAIL_infr_08
Created: Jan-13-20 5:19 PM | Data Range: 2014Q3-2019Q3

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

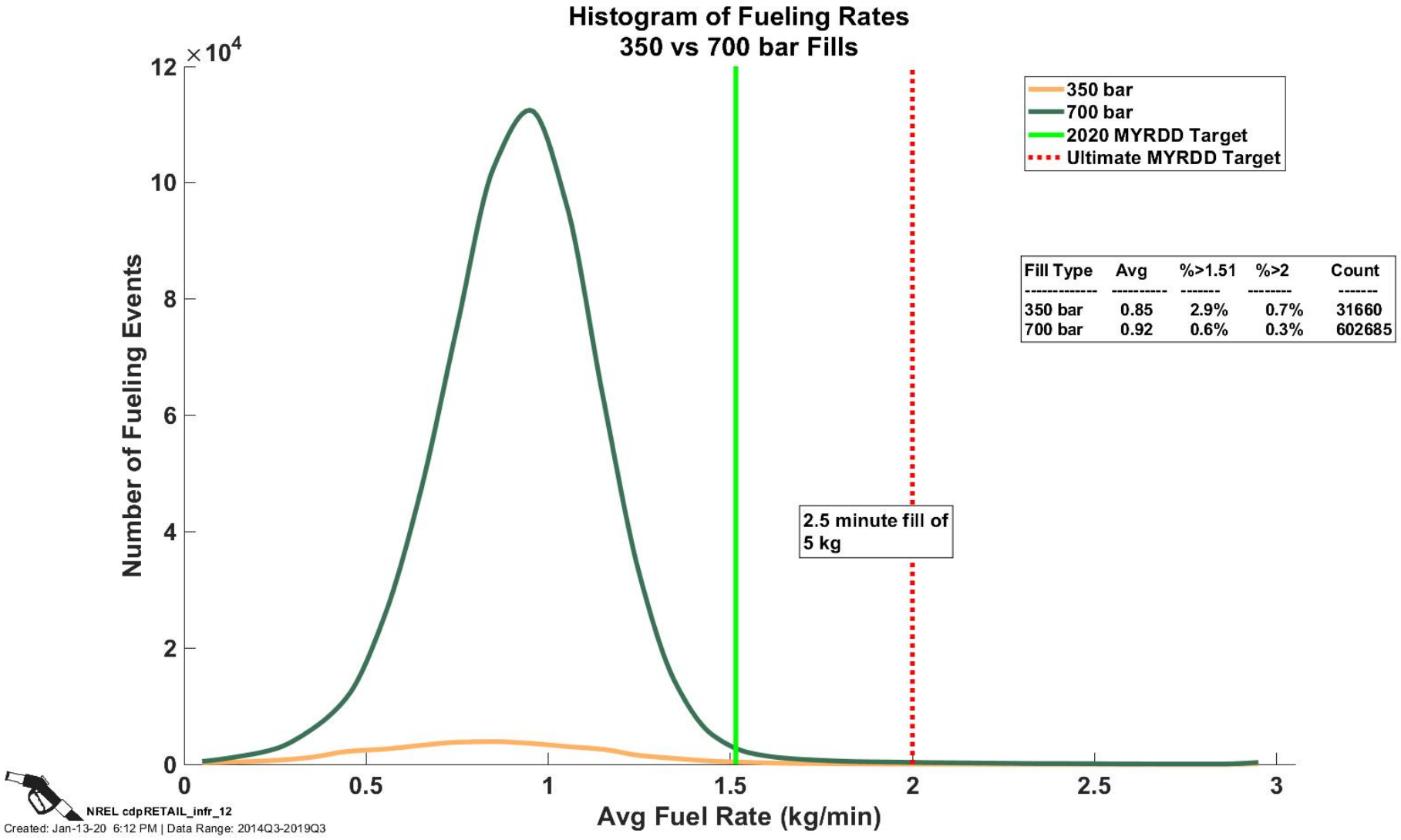
CDP-INFR-09
Fueling Final Pressures



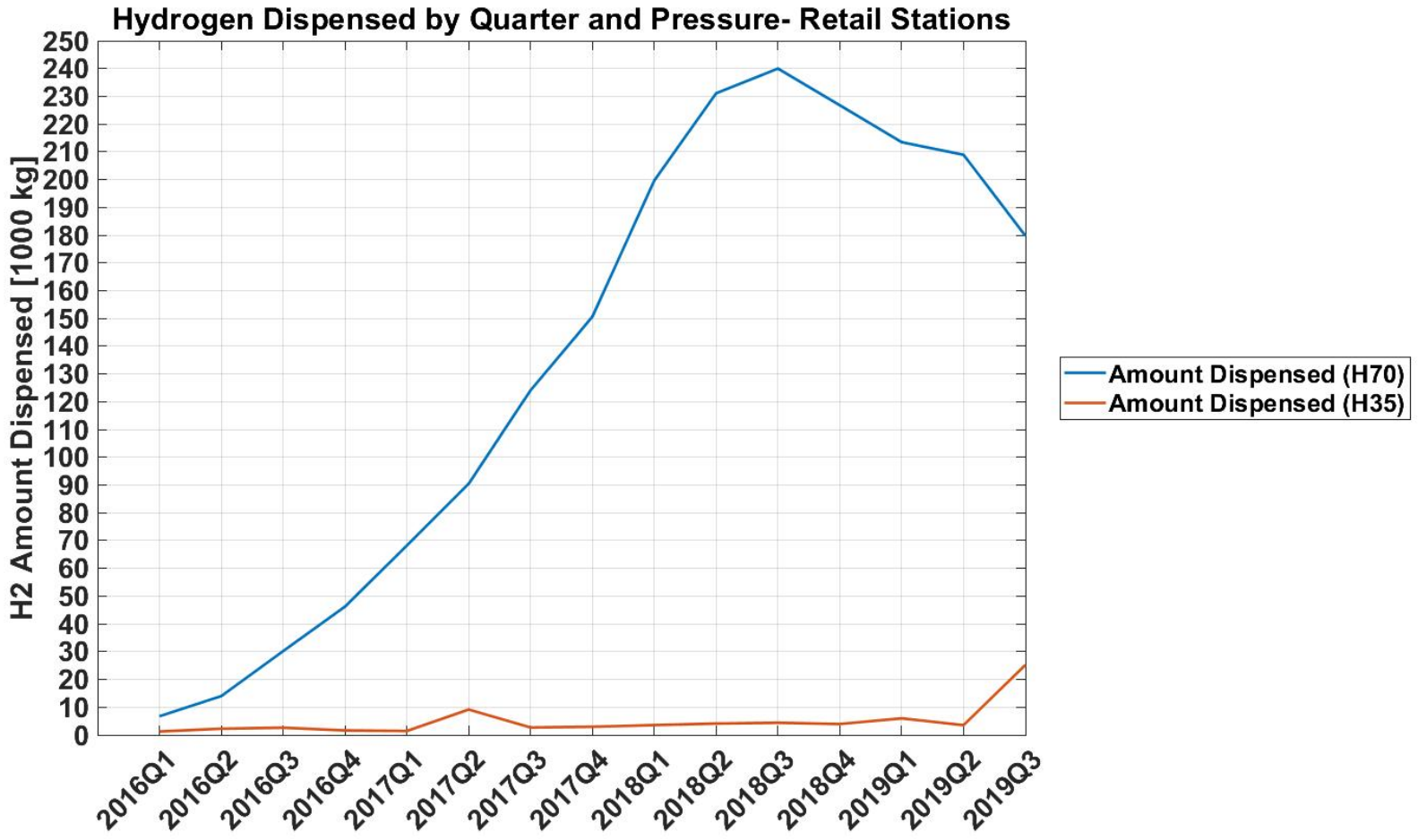
NREL cdpRETAIL_infr_09
Created: Jan-13-20 5:45 PM | Data Range: 2014Q3-2019Q3

*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

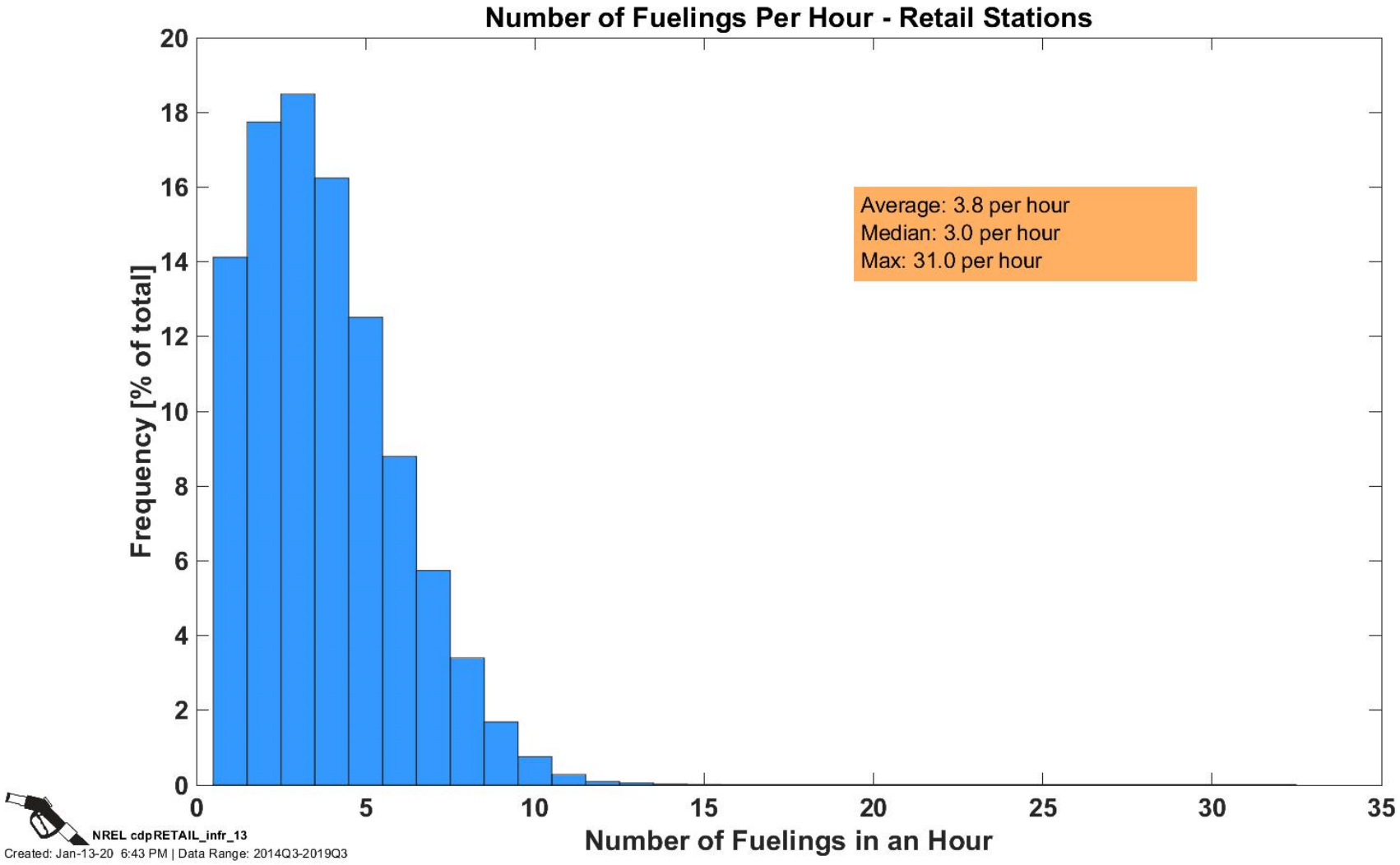


CDP-INFR-90
Hydrogen Dispensed by Quarter and Pressure

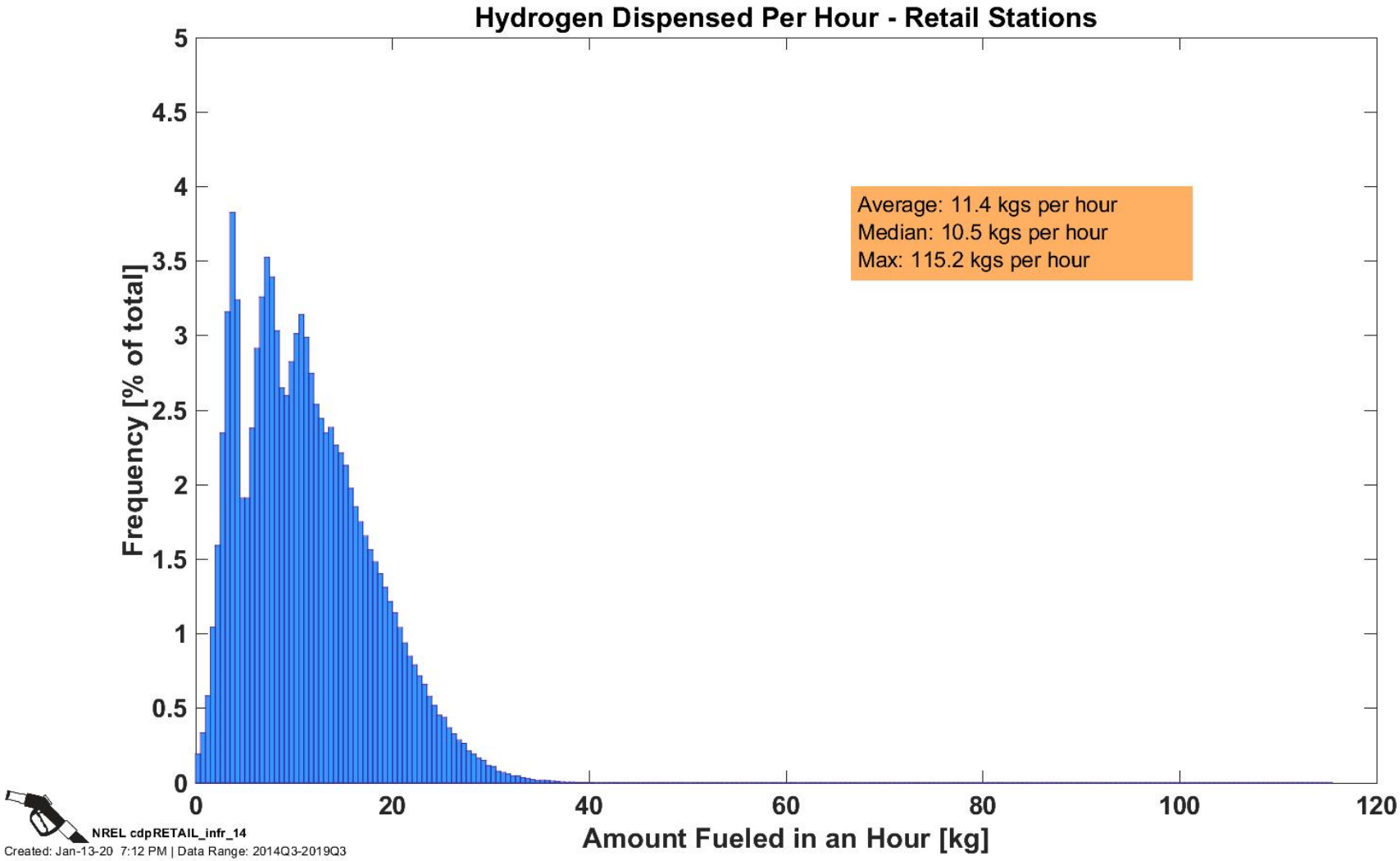


NREL cdpRETAIL_infr_90
Created: Jan-13-20 10:40 PM | Data Range: 2014Q3-2019Q3

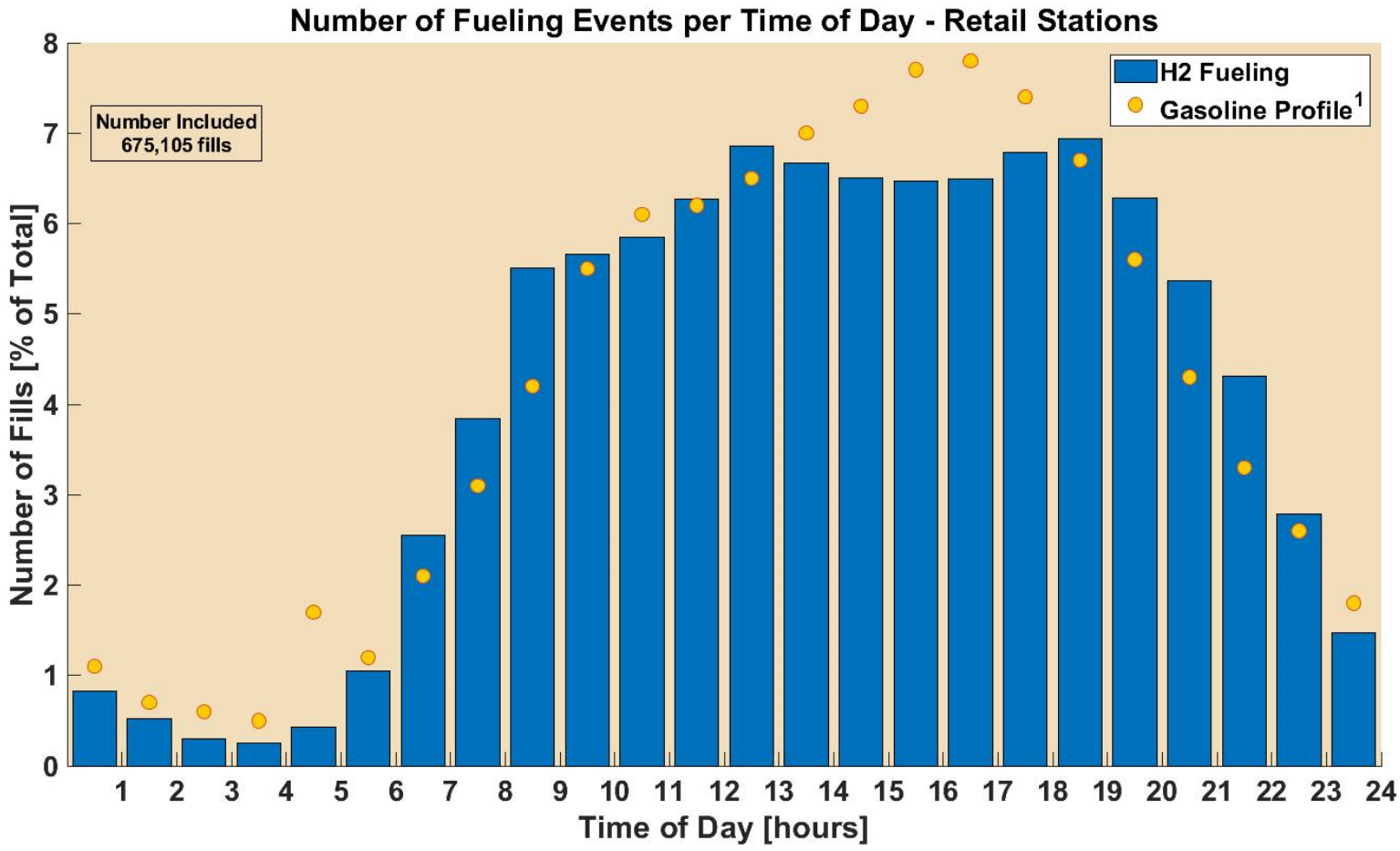
CDP-INFR-13
Number of Fueling Events per Hour



CDP-INFR-14
Hydrogen Dispensed per Hour



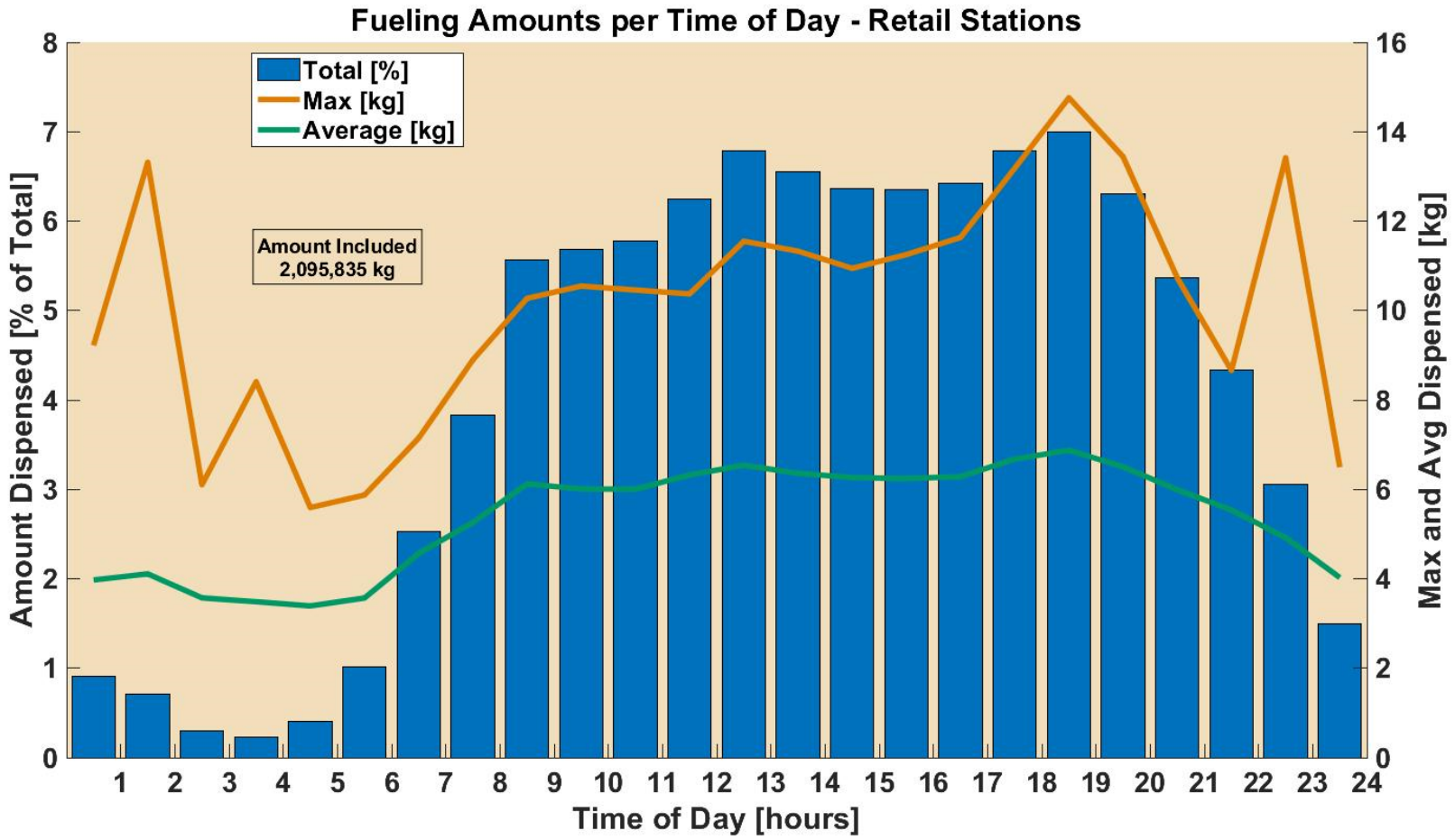
CDP-INFR-15
Number of Fills by Time of Day



NREL cdpRETAIL_infr_15
Created: Jan-13-20 7:36 PM | Data Range: 2014Q3-2019Q3

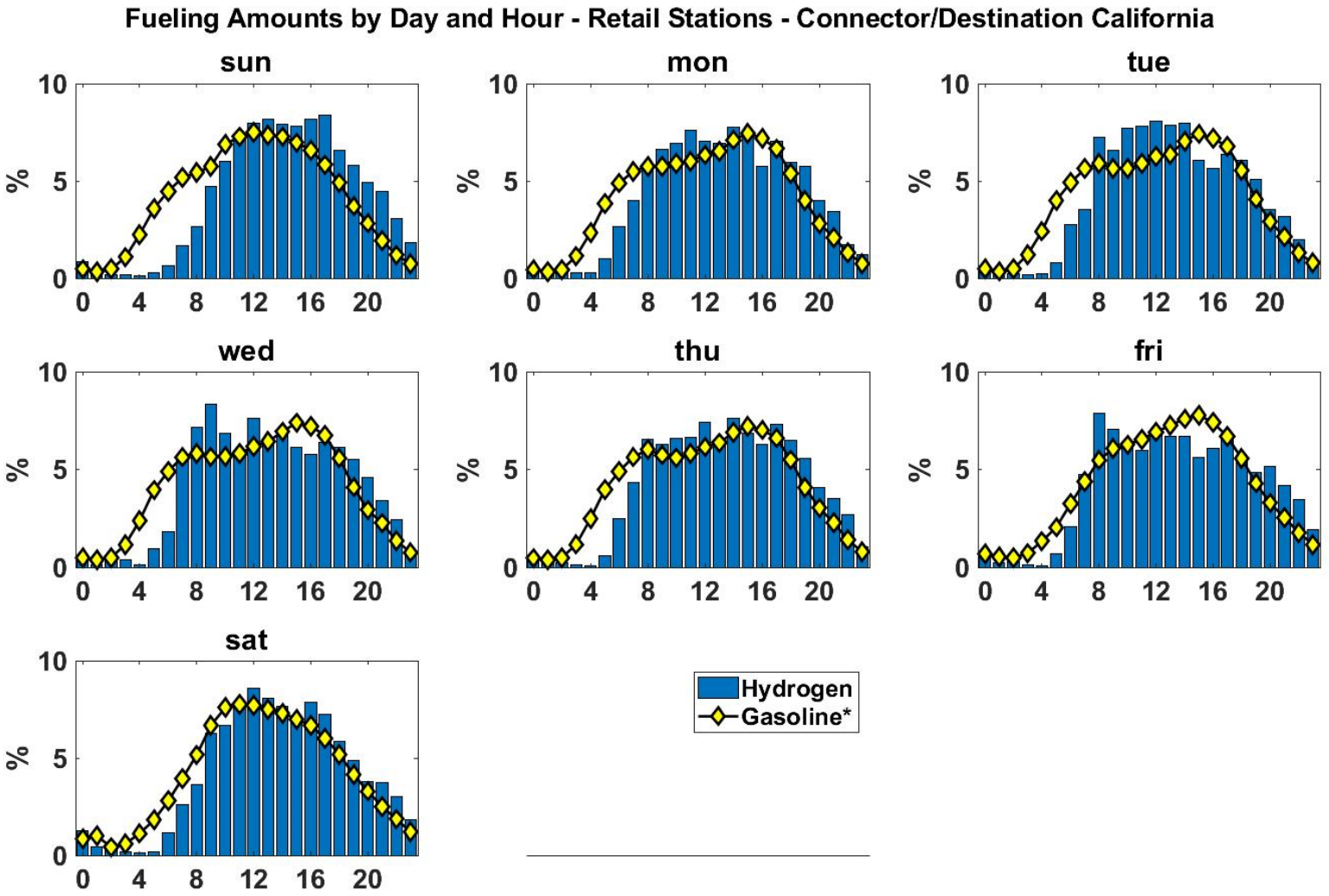
1. Friday Chevron profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

CDP-INFR-16
Fueling Amounts per Time of Day



NREL cdpRETAIL_infr_16
Created: Jan-14-20 11:58 AM | Data Range: 2014Q3-2019Q3

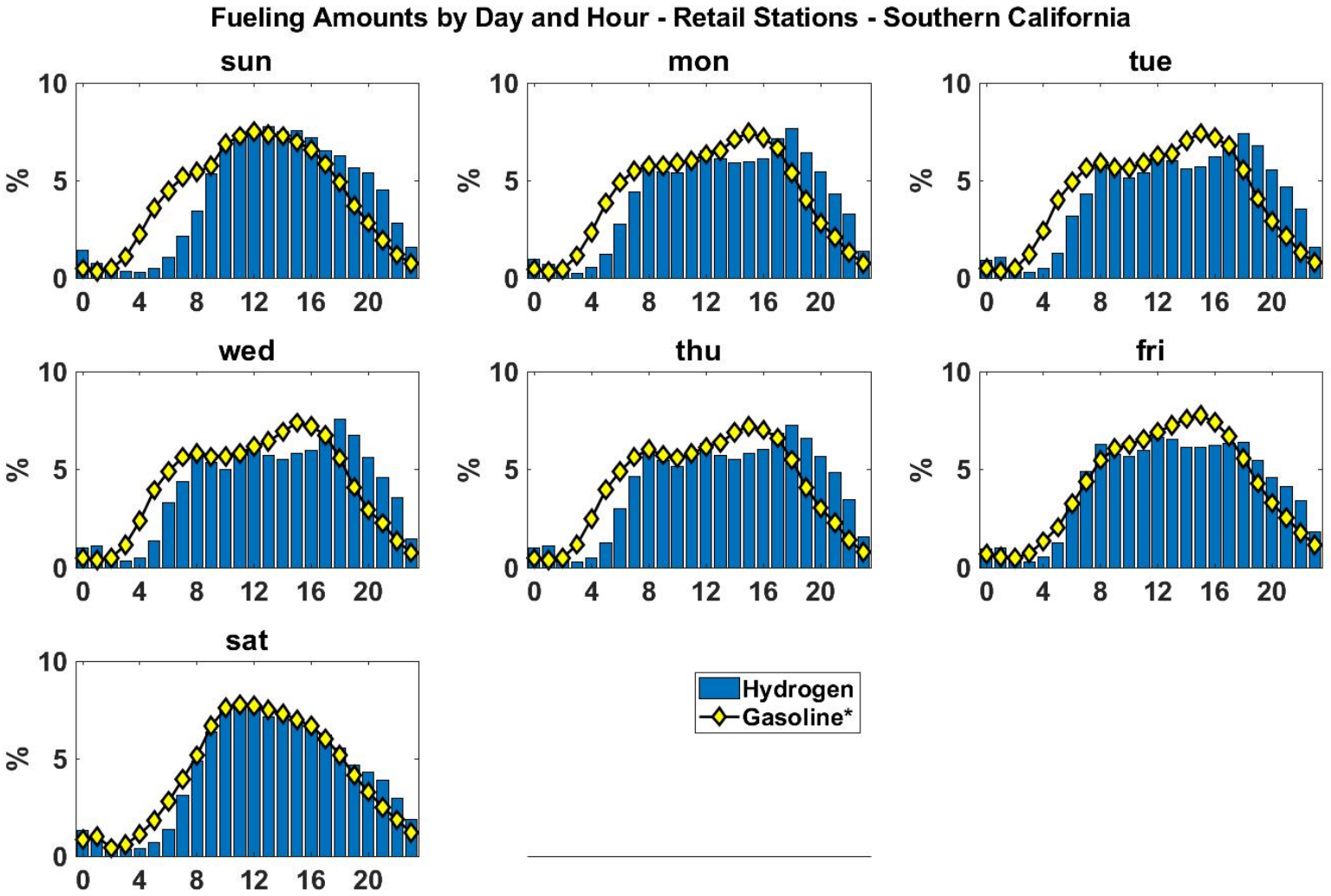
CDP-INFR-88a
Fueling Profile by Day and Hour: Connector/Destination Stations



NREL cdpRETAIL_infr_88a
Created: Jan-14-20 12:31 PM | Data Range: 2014Q3-2019Q3

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

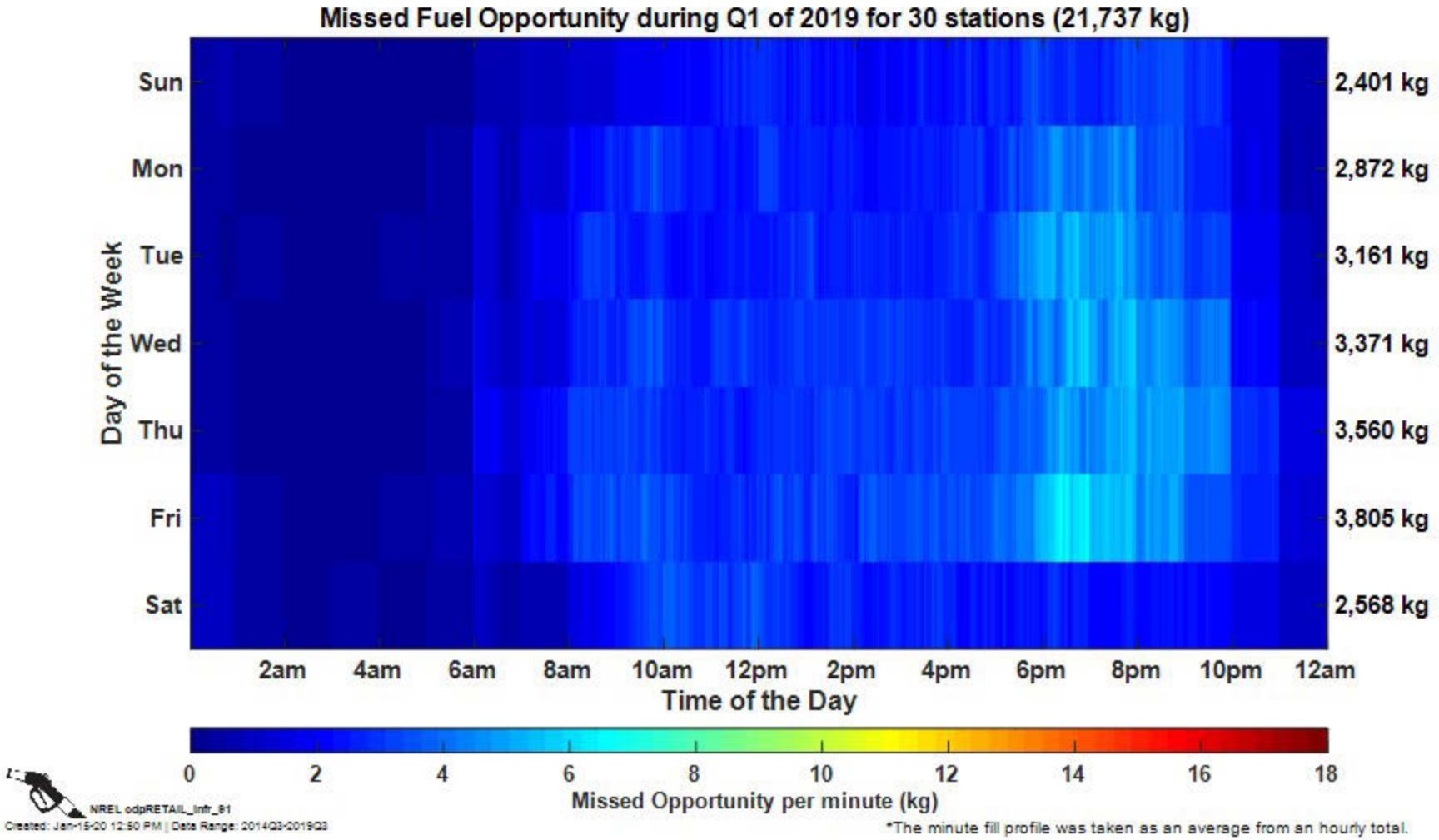
CDP-INFR-88c
Fueling Profile by Day and Hour: Southern California



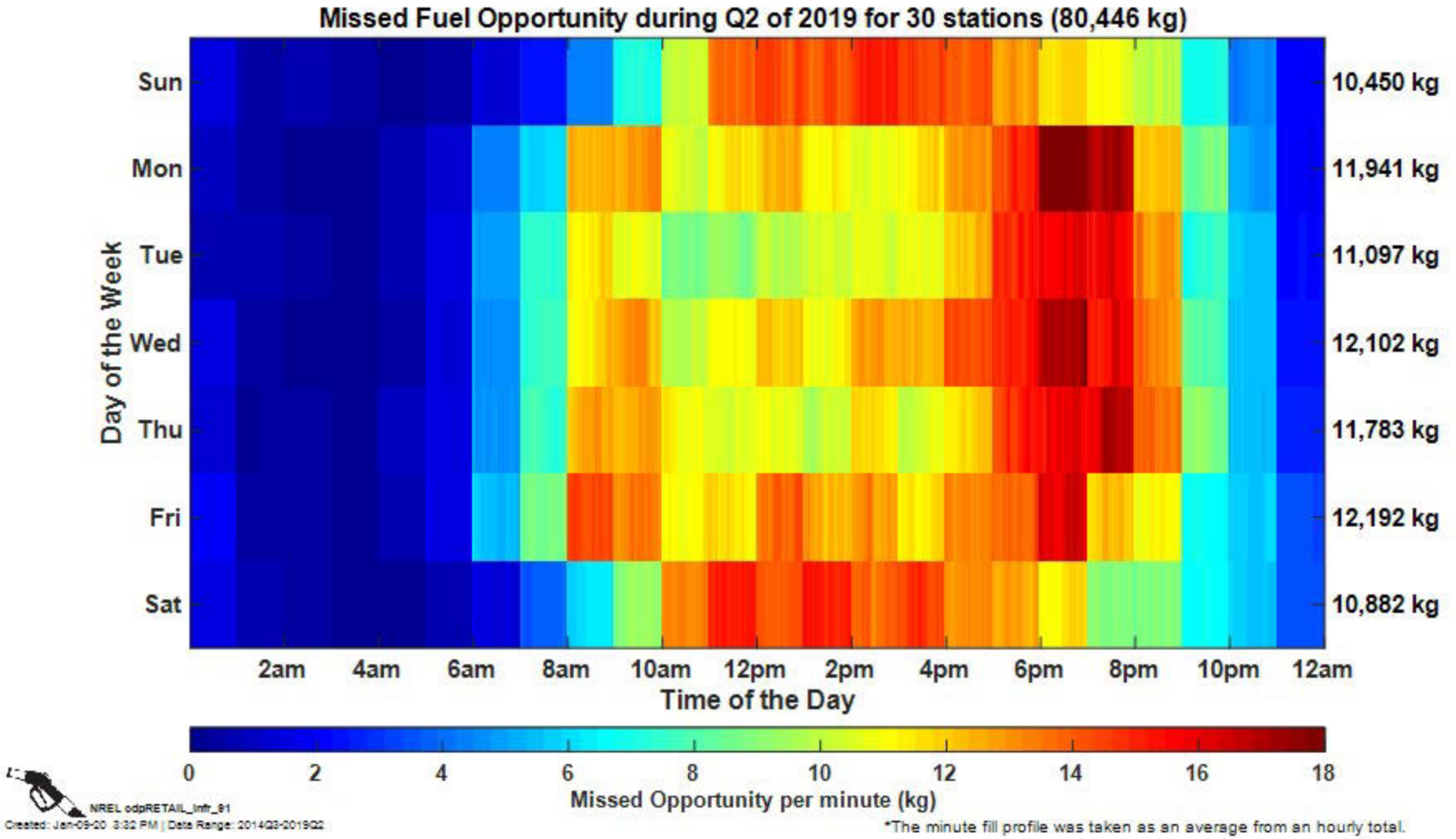
NREL cdpRETAIL_infr_88c
Created: Jan-14-20 12:44 PM | Data Range: 2014Q3-2019Q3

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

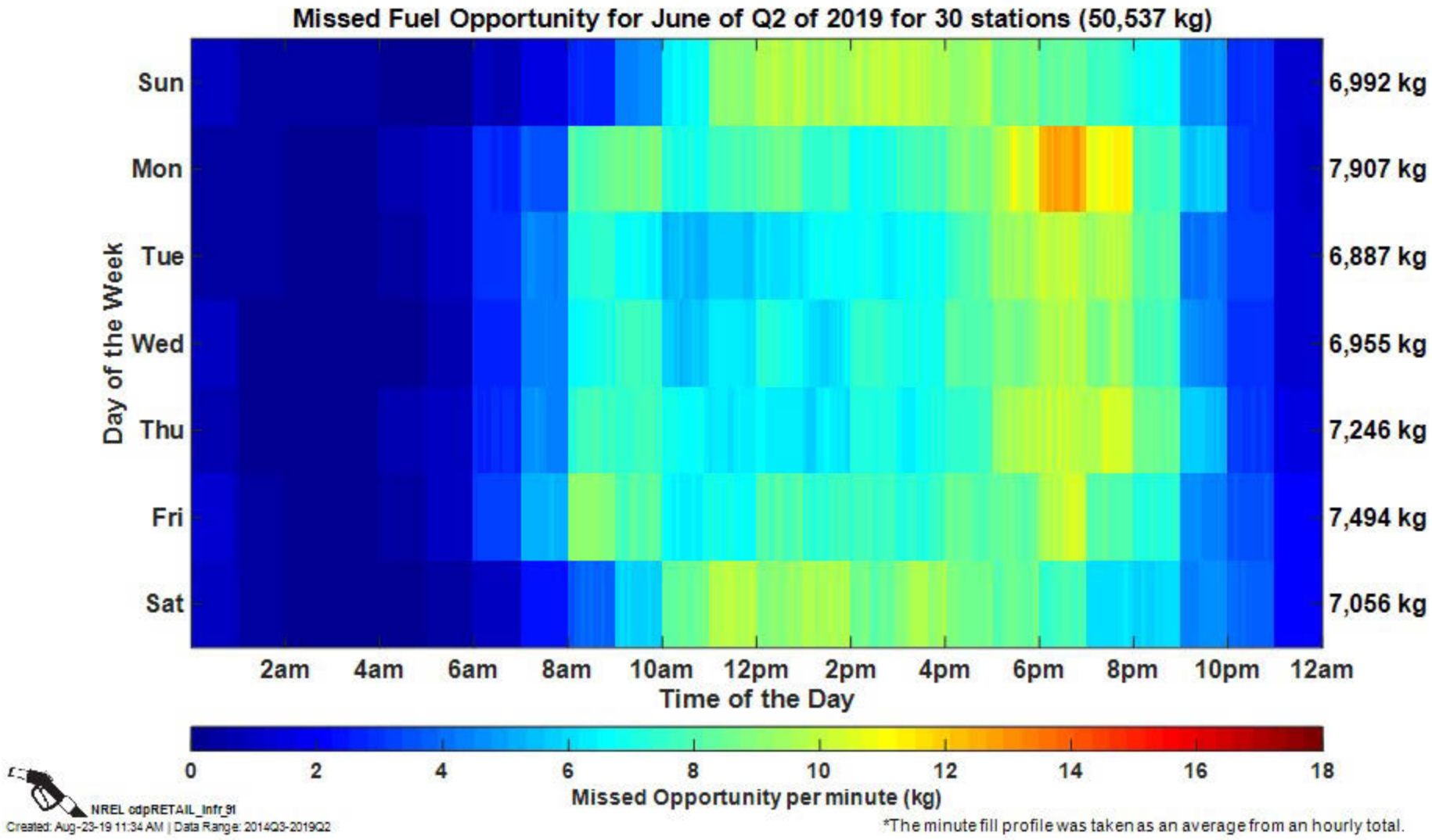
CDP-INFR-91
Missed Fuel Opportunity (Q1 2019)



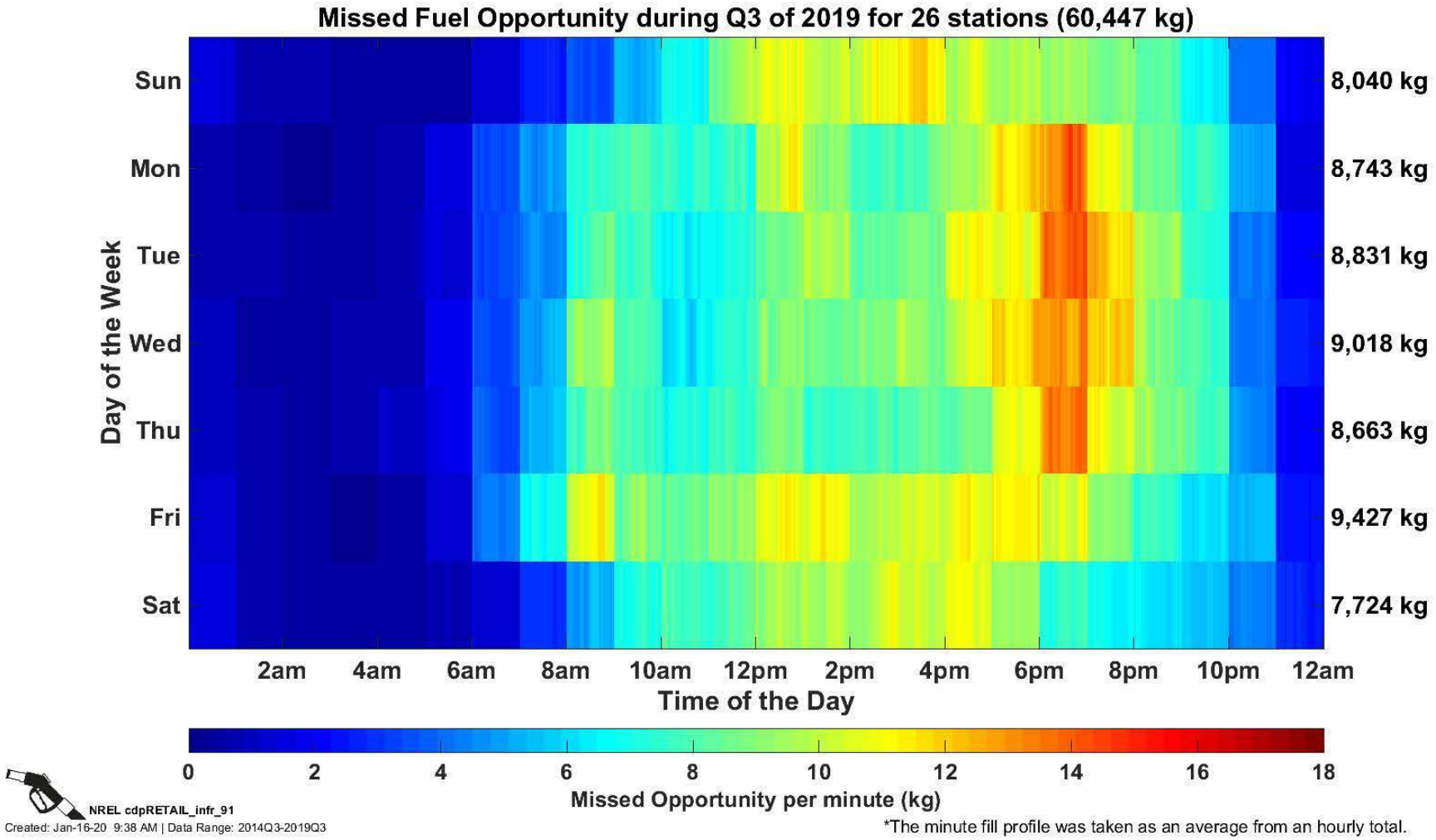
CDP-INFR-91
Missed Fuel Opportunity (Q2 2019)



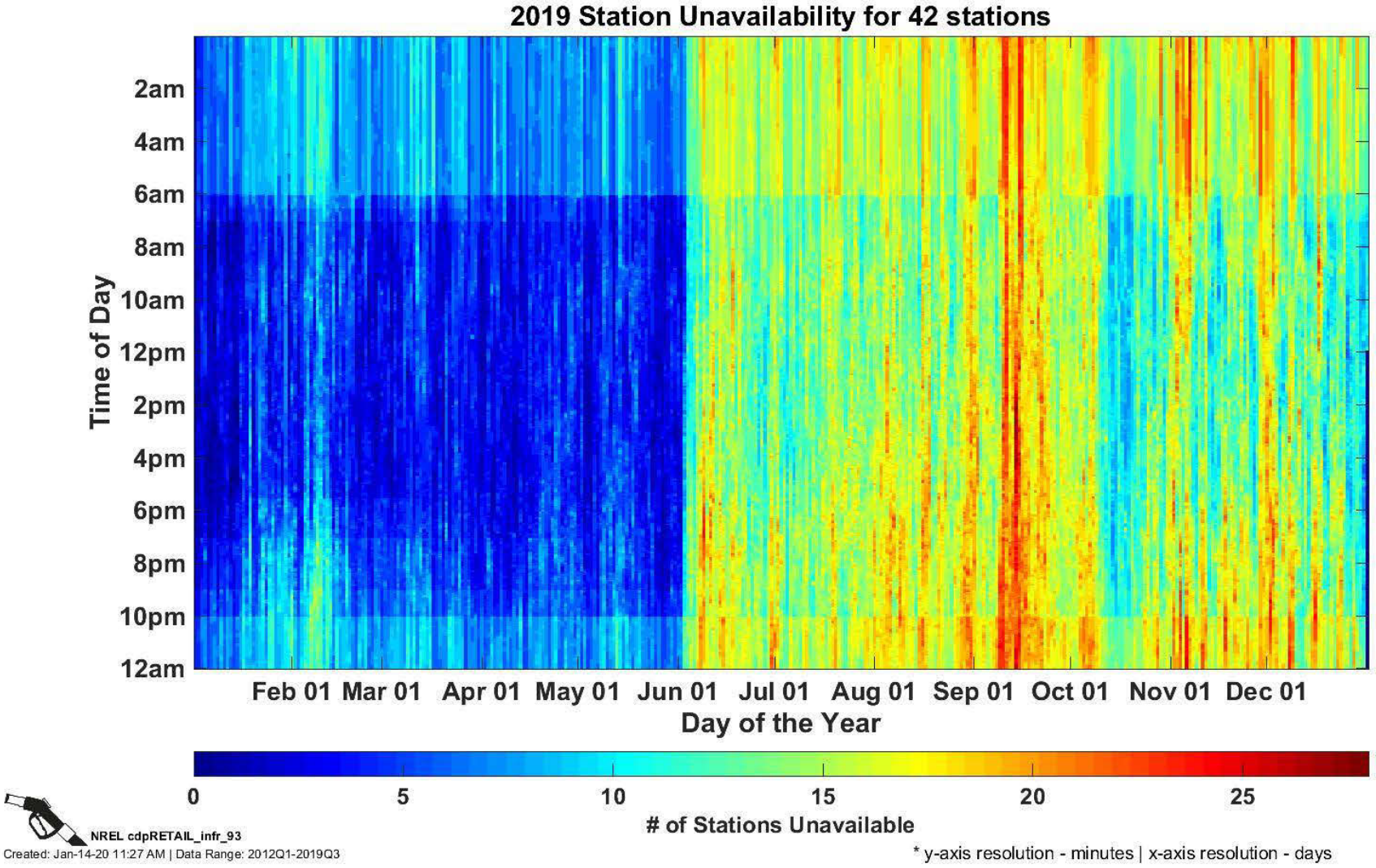
CDP-INFR-91
Missed Fuel Opportunity (June 2019)



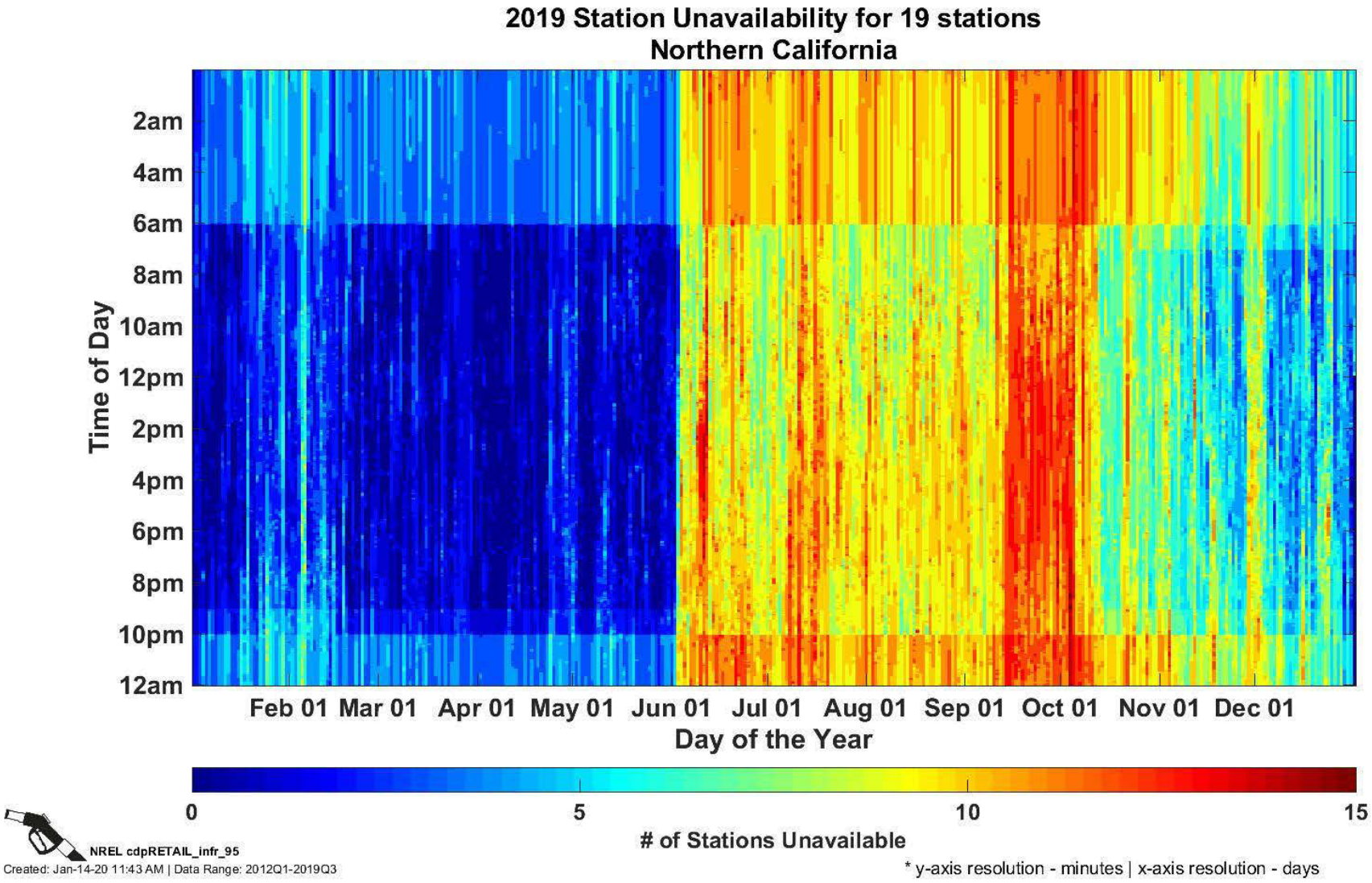
CDP-INFR-91
Missed Fuel Opportunity (Q3 2019)



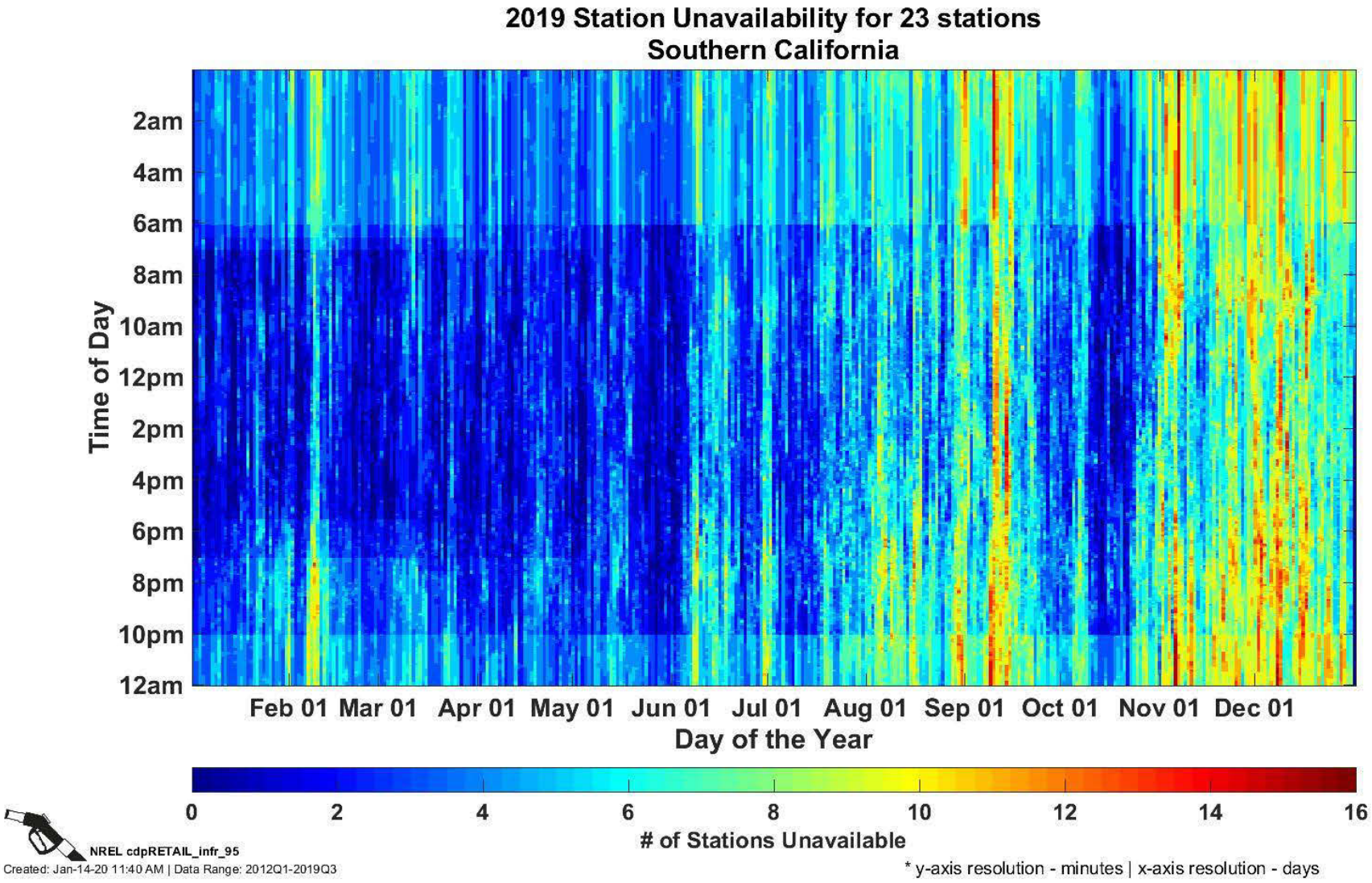
CDP-INFR-93
Station Unavailability



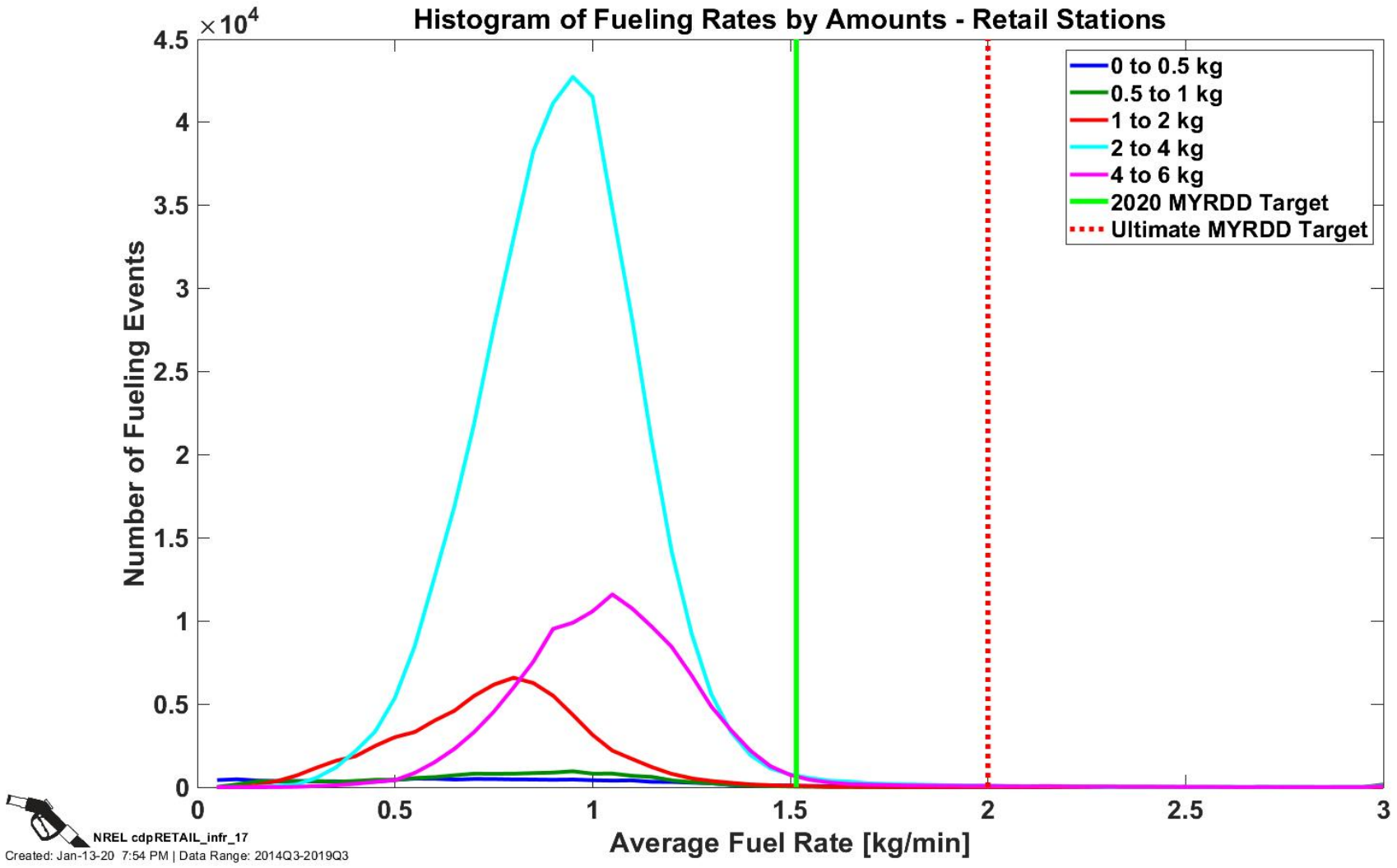
CDP-INFR-95
Station Unavailability: Northern California



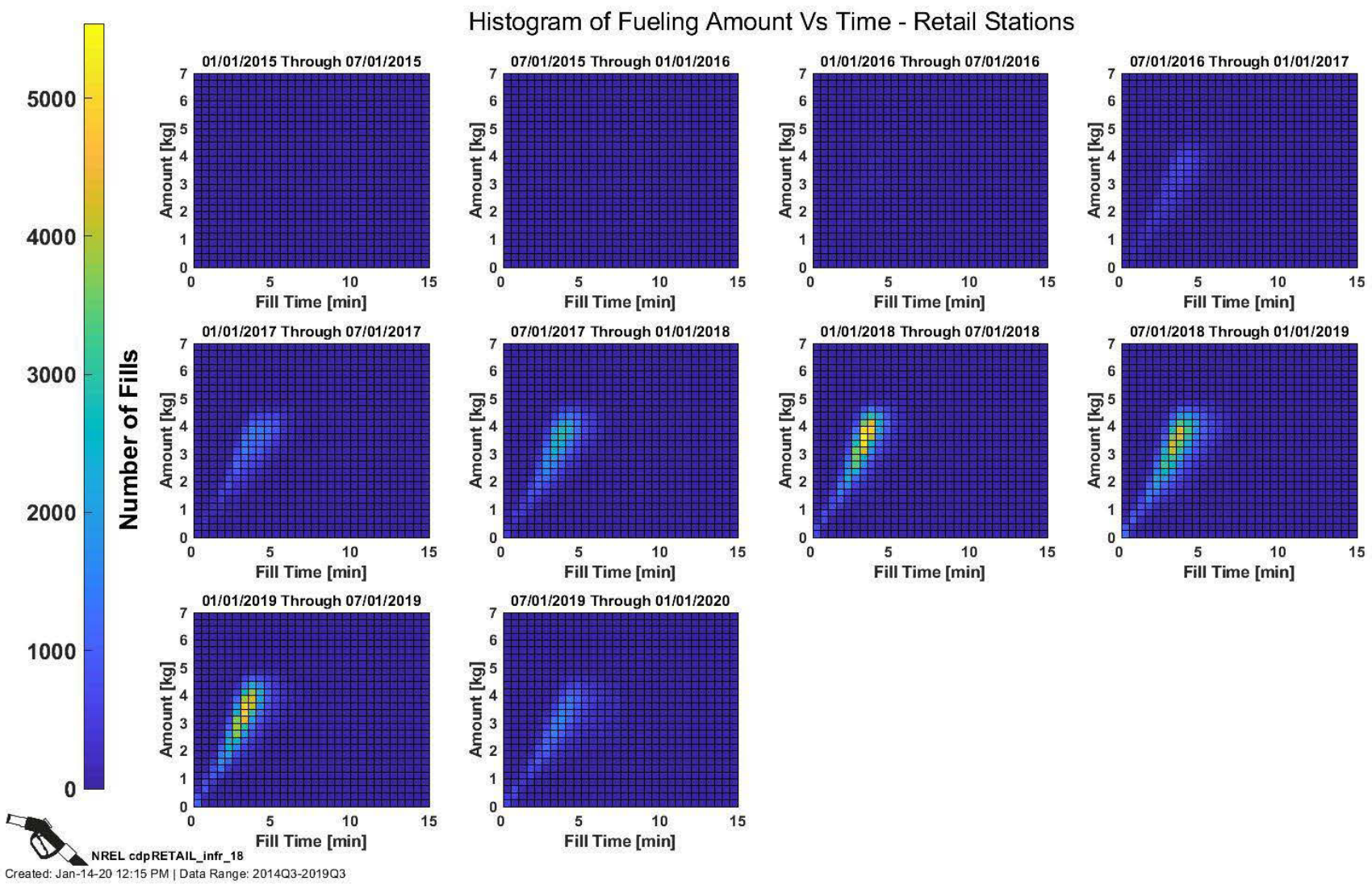
CDP-INFR-95
Station Unavailability: Southern California



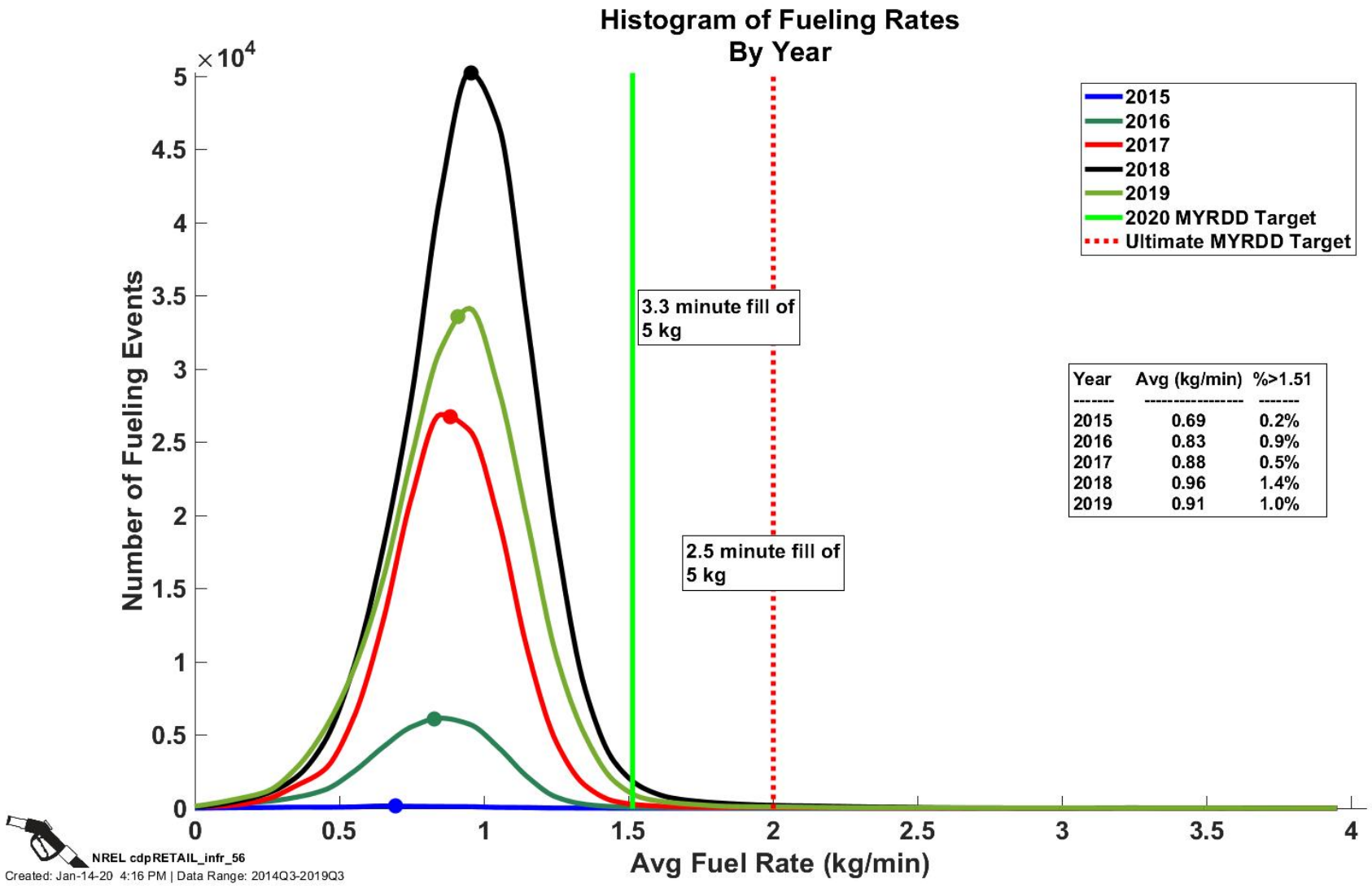
CDP-INFR-17
Fueling Rates by Amount Filled



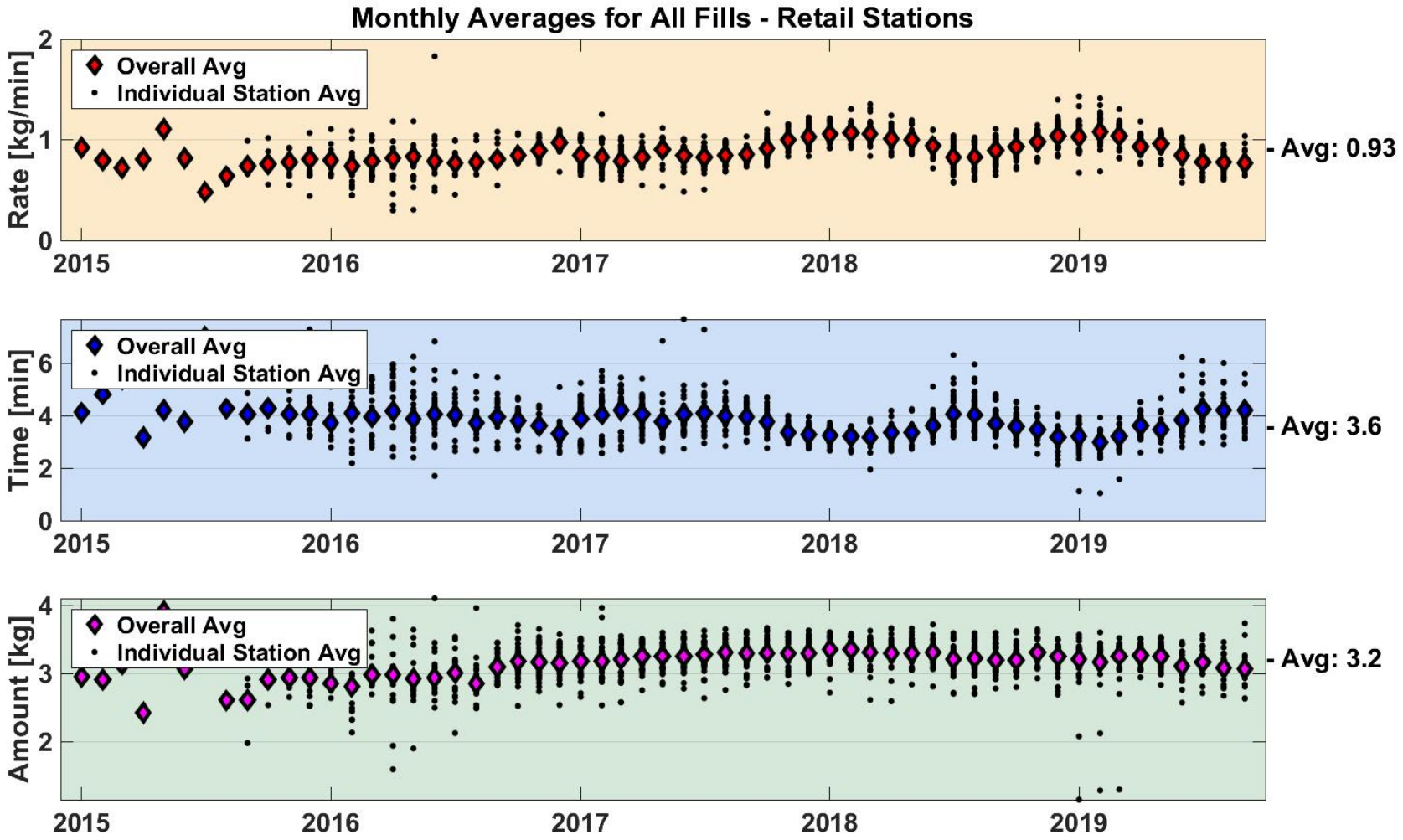
CDP-INFR-18
Fueling Amount vs. Time to Fill



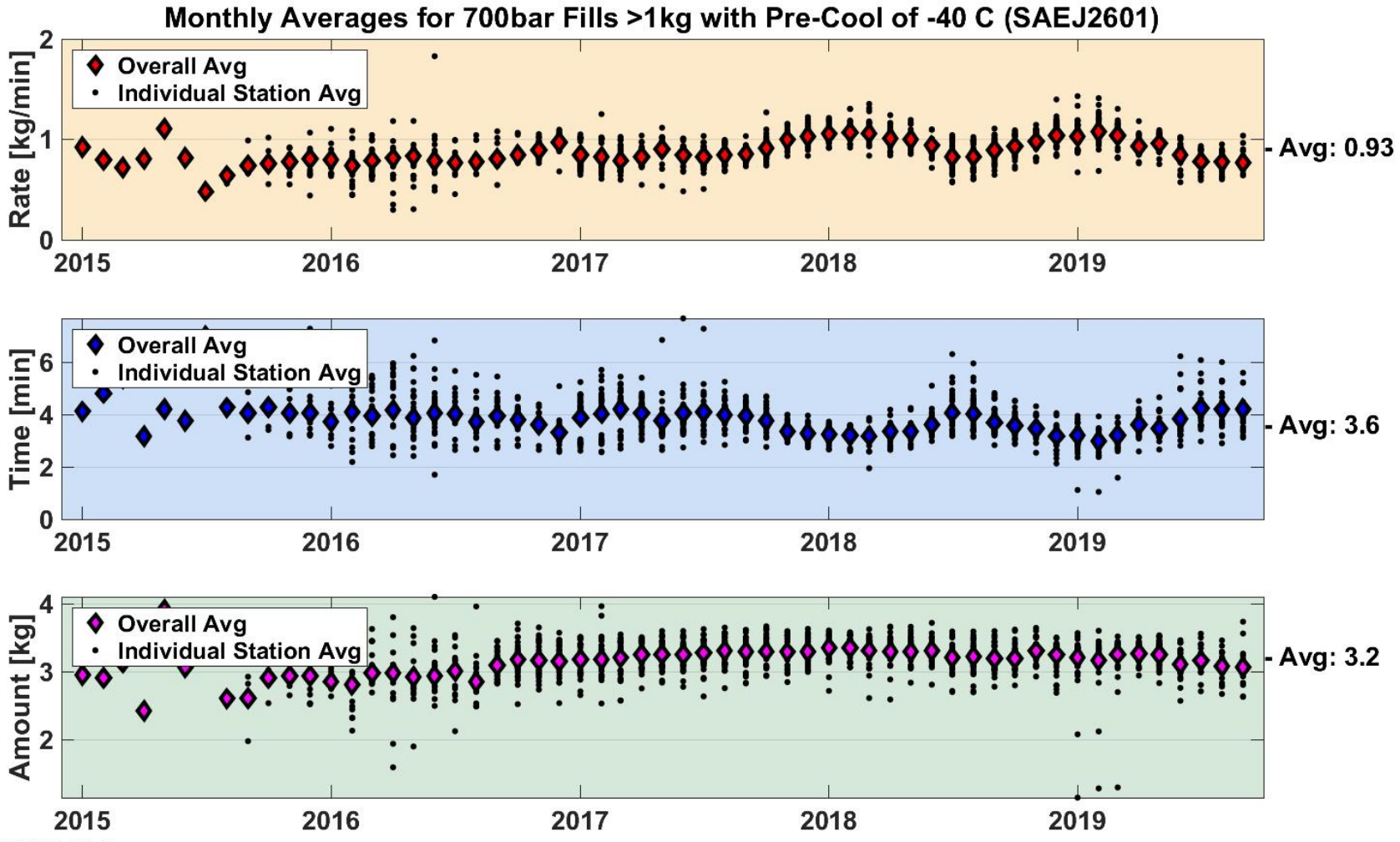
CDP-INFR-56
Fueling Rates by Year



CDP-INFR-55
Monthly Averages: All Fills

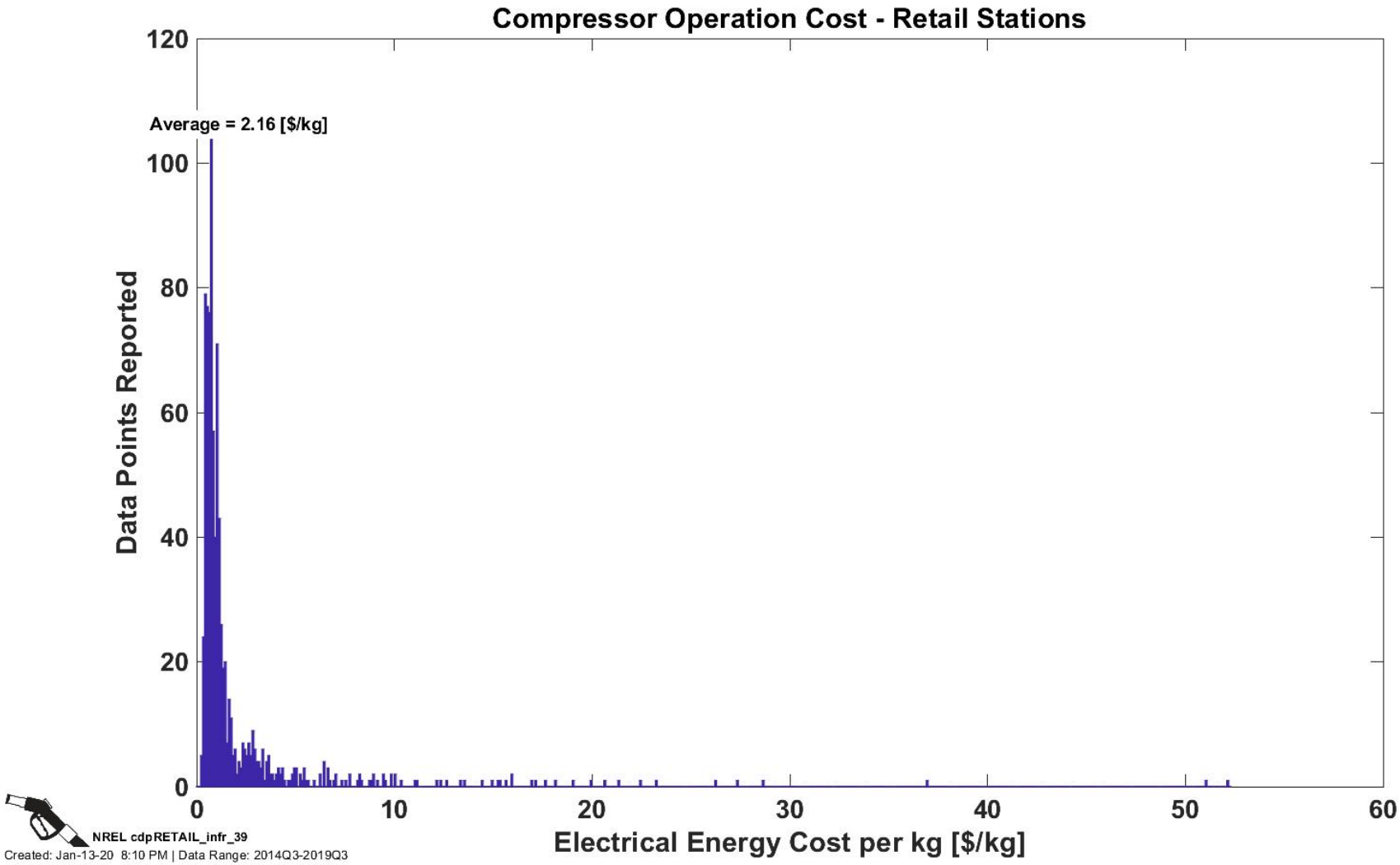


CDP-INFR-57
Monthly Averages: 700 bar Fills >1 kg with Pre-Cool of -40°C

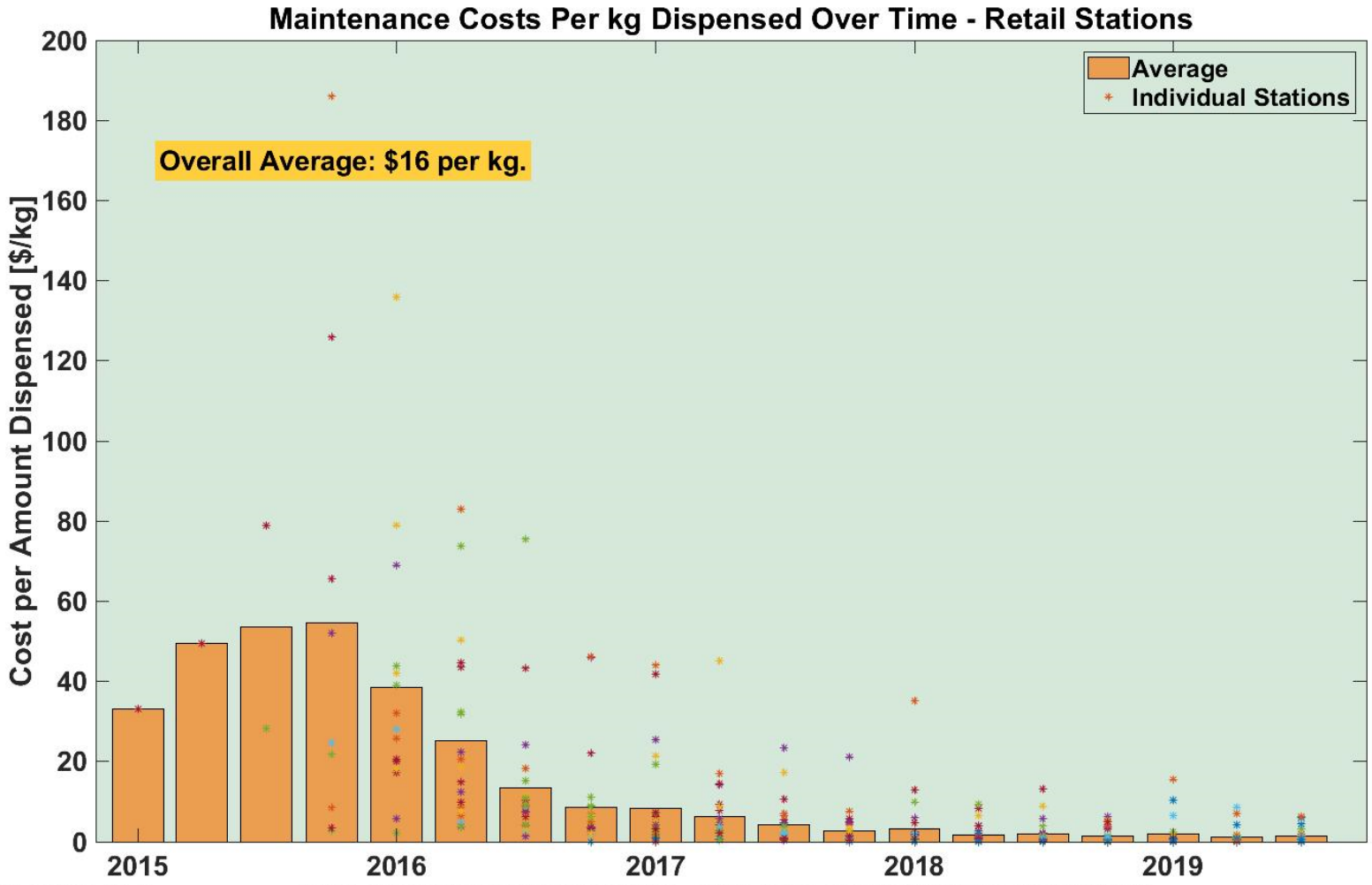


Cost

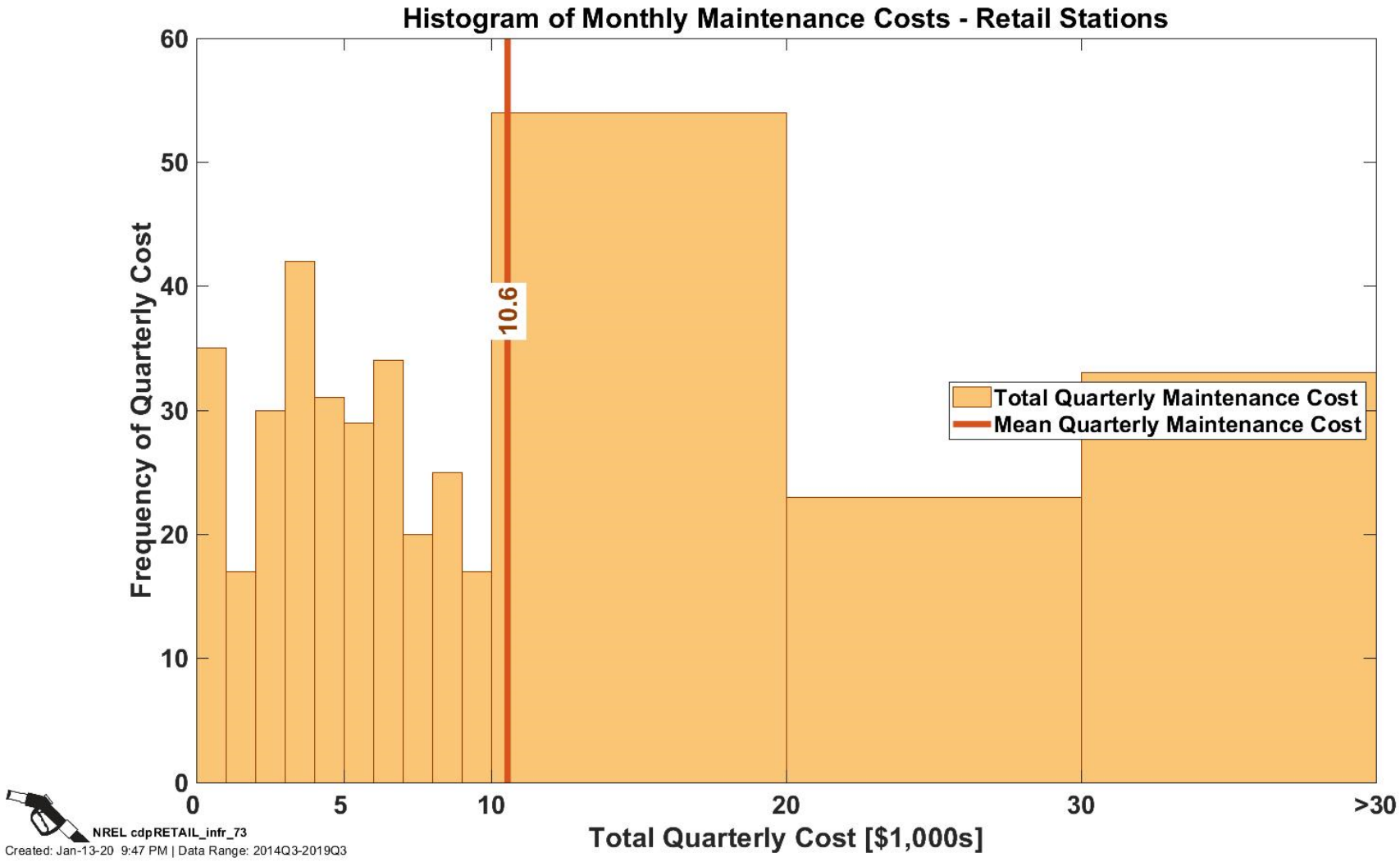
CDP-INFR-39
Compressor Operation Cost



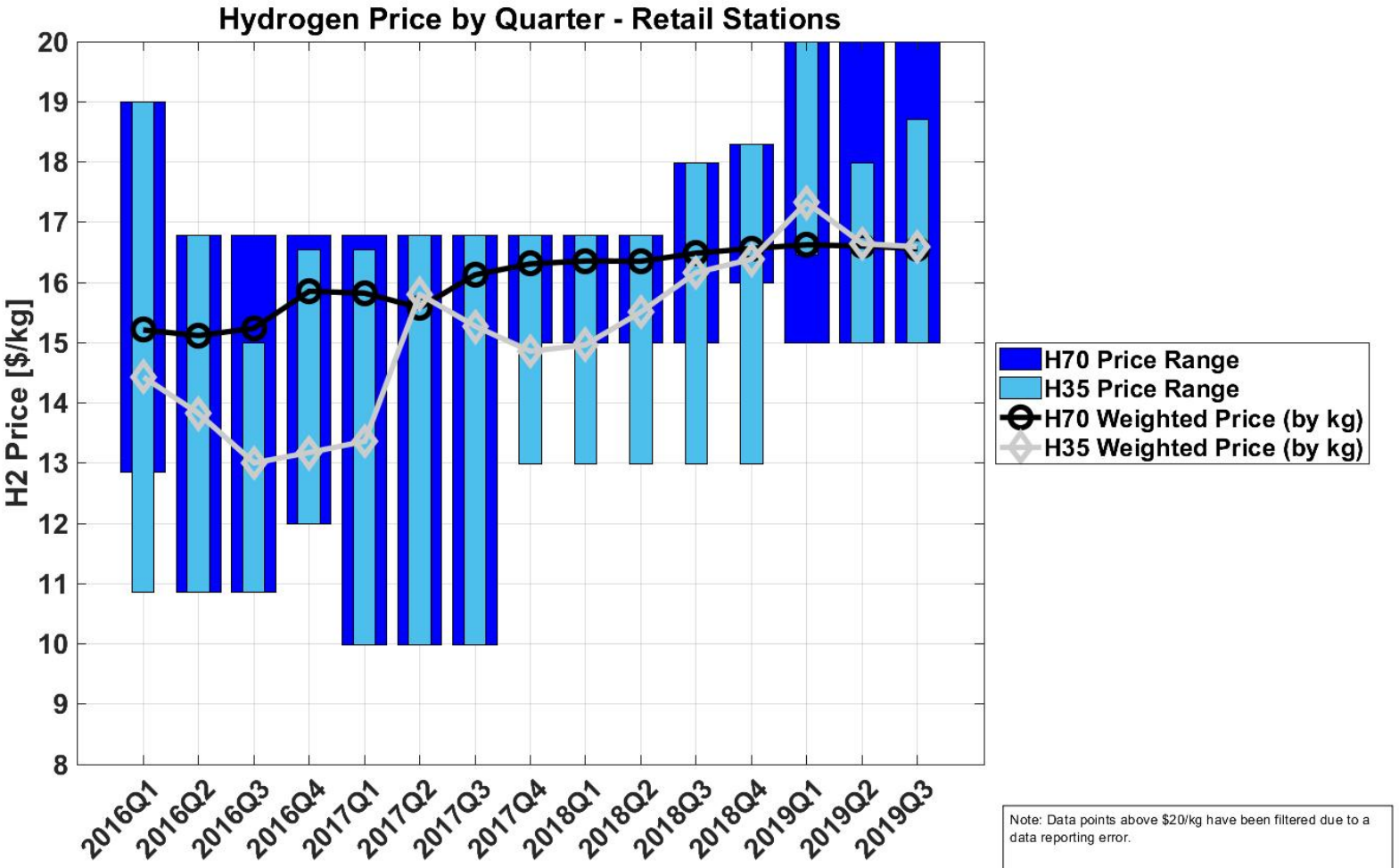
CDP-INFR-53
Maintenance Cost per kg of Hydrogen Dispensed



CDP-INFR-73
Histogram of Monthly Maintenance Costs



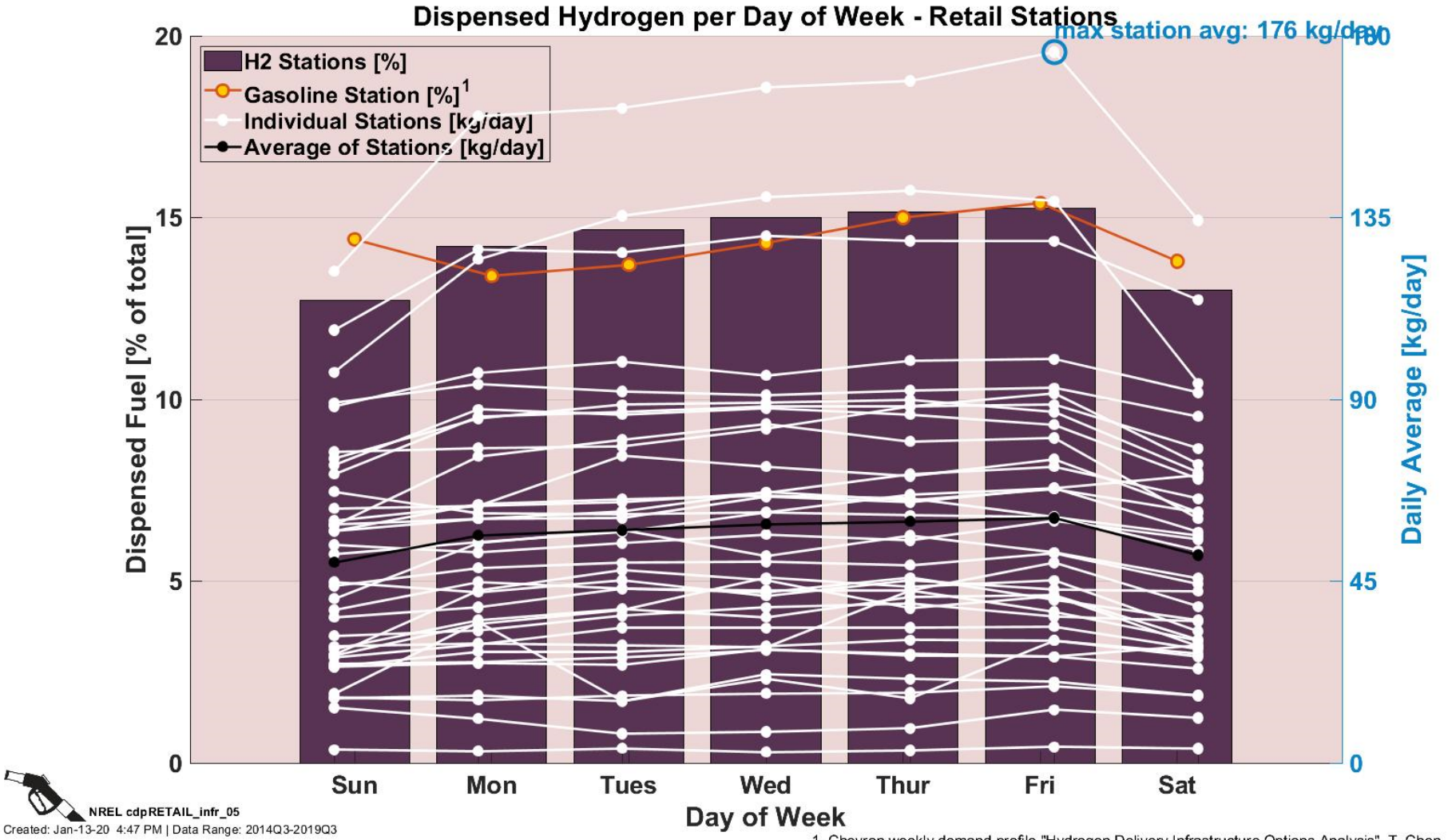
CDP-INFR-89
Hydrogen Price by Quarter



NREL cdpRETAIL_infr_89
Created: Jan-16-20 3:52 PM | Data Range: 2014Q3-2019Q3

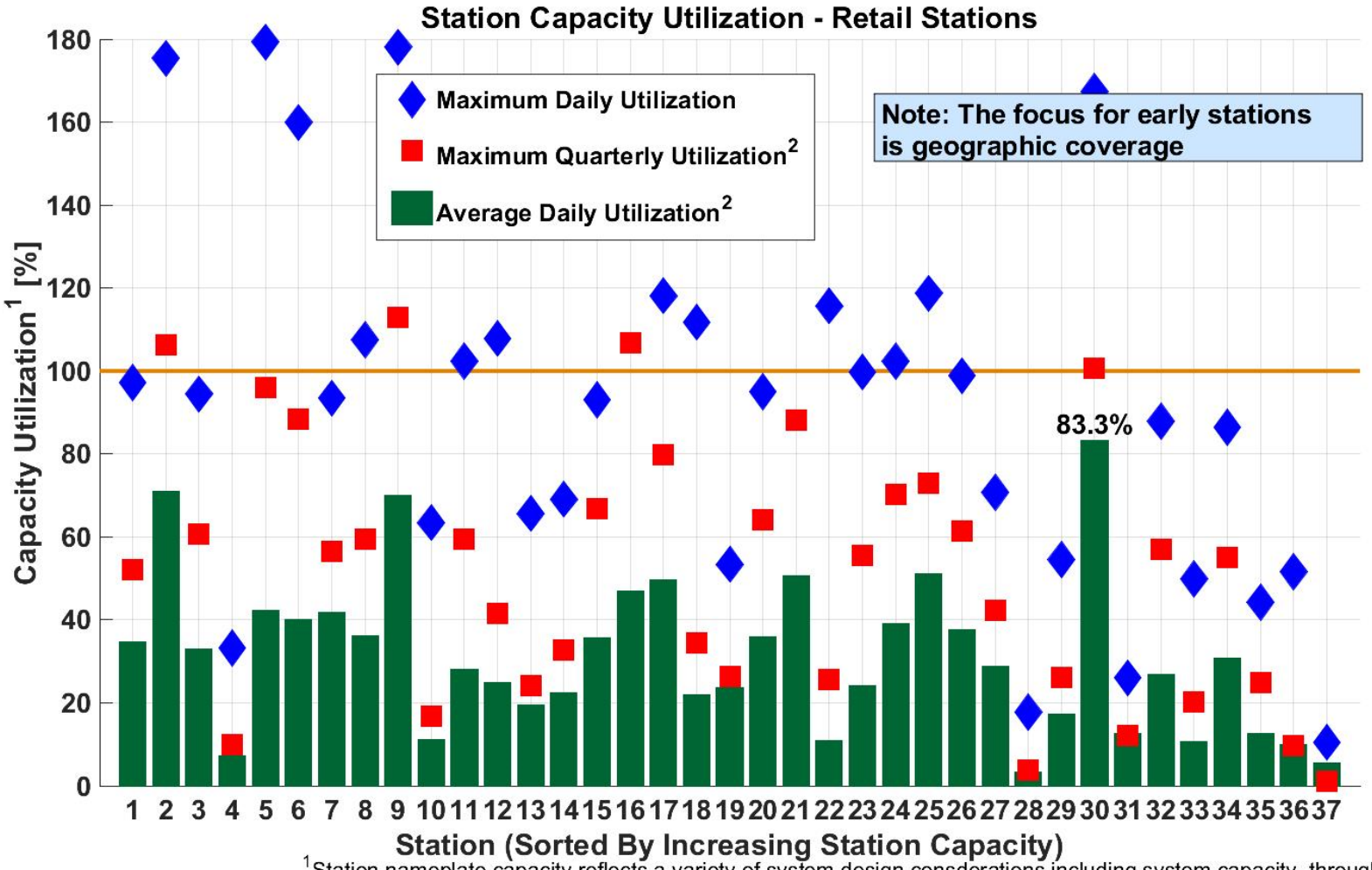
Utilization

CDP-INFR-05
Dispensed Hydrogen per Day of Week



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

CDP-INFR-06
Station Capacity Utilization

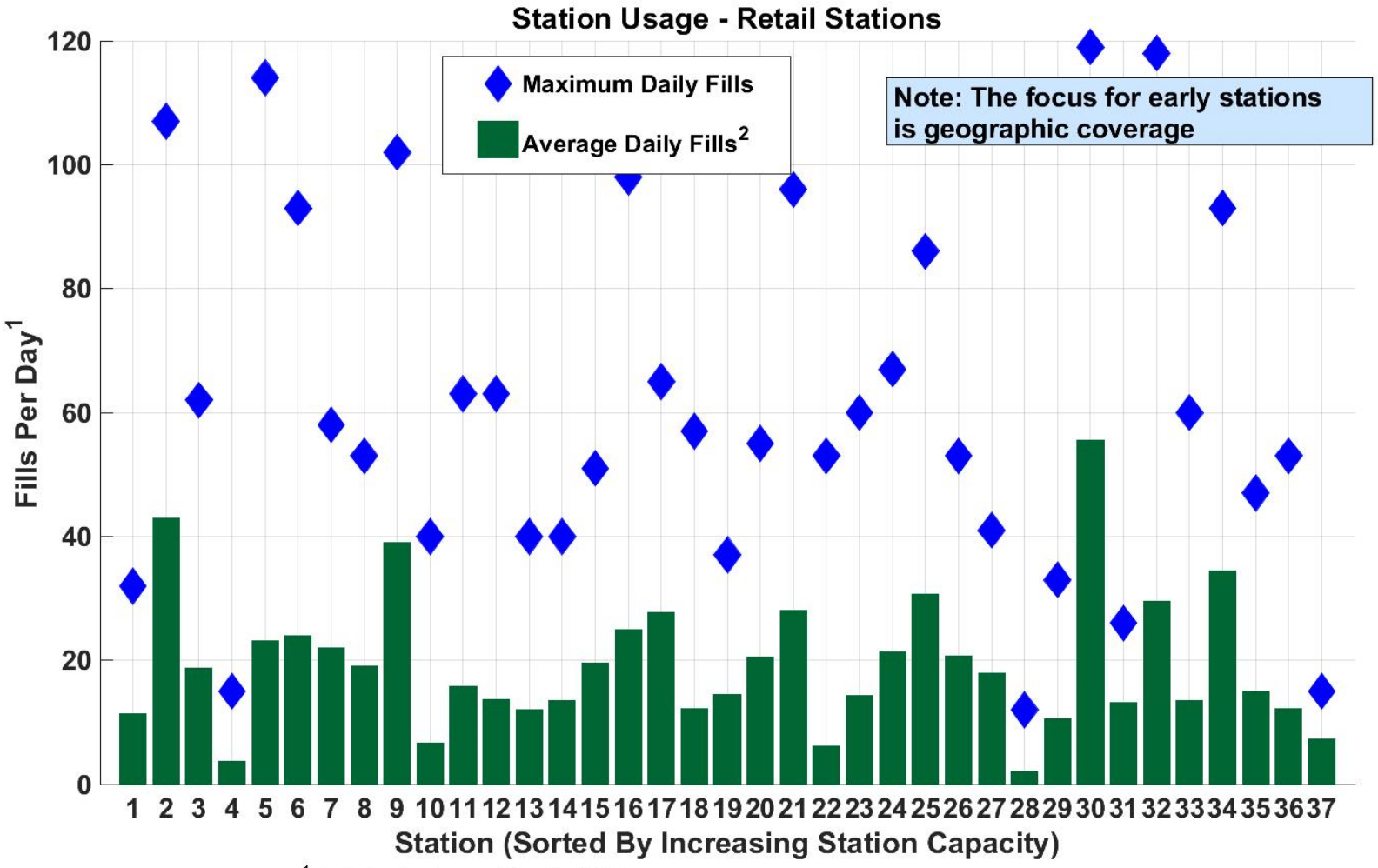


NREL cdpRETAIL_infr_06
Created: Jan-15-20 10:17 AM | Data Range: 2014Q3-2019Q3

[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 occurre

CDP-INFR-07
Station Usage

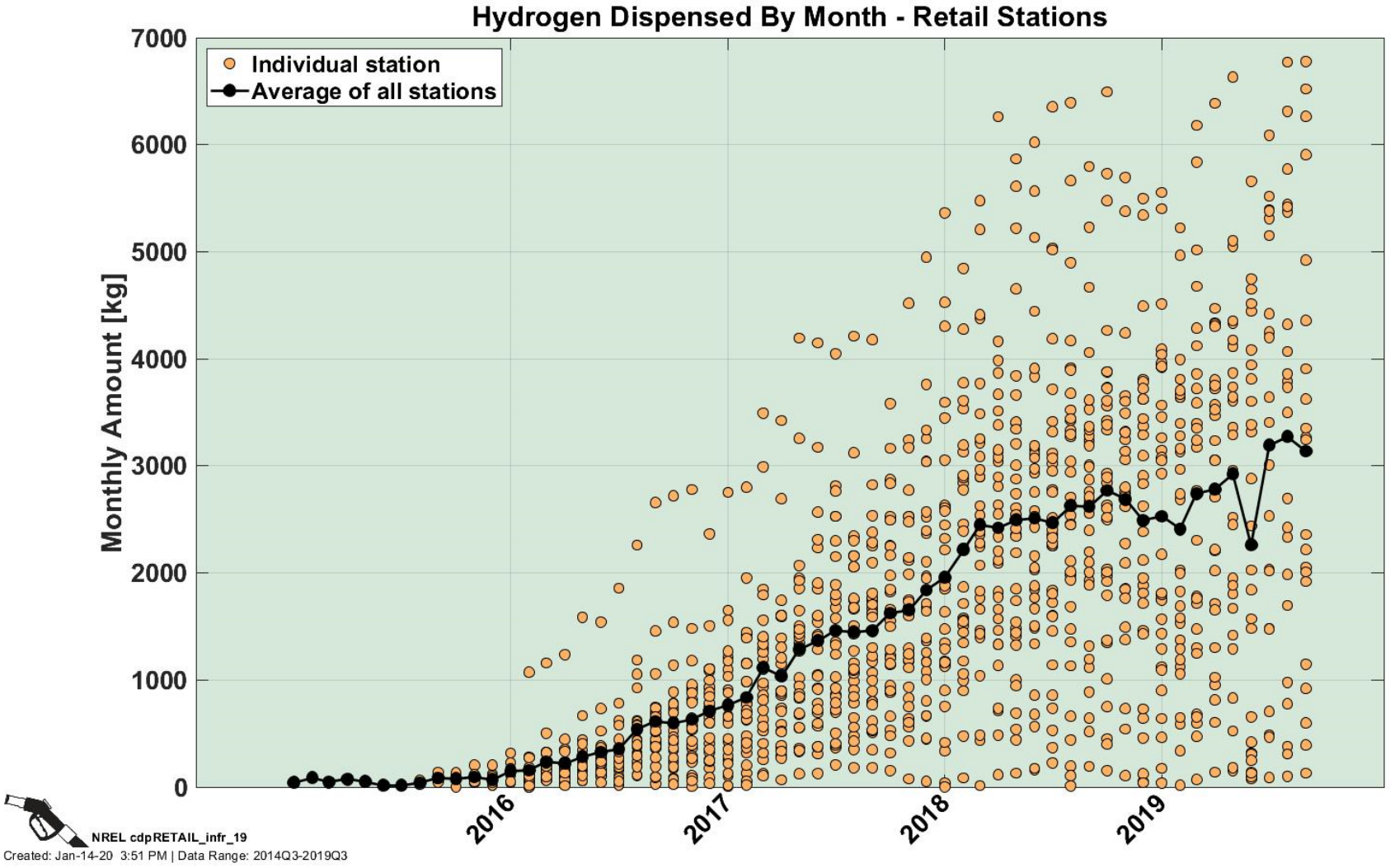


NREL cdpRETAIL_infr_07
Created: Jan-14-20 3:48 PM | Data Range: 2014Q3-2019Q3

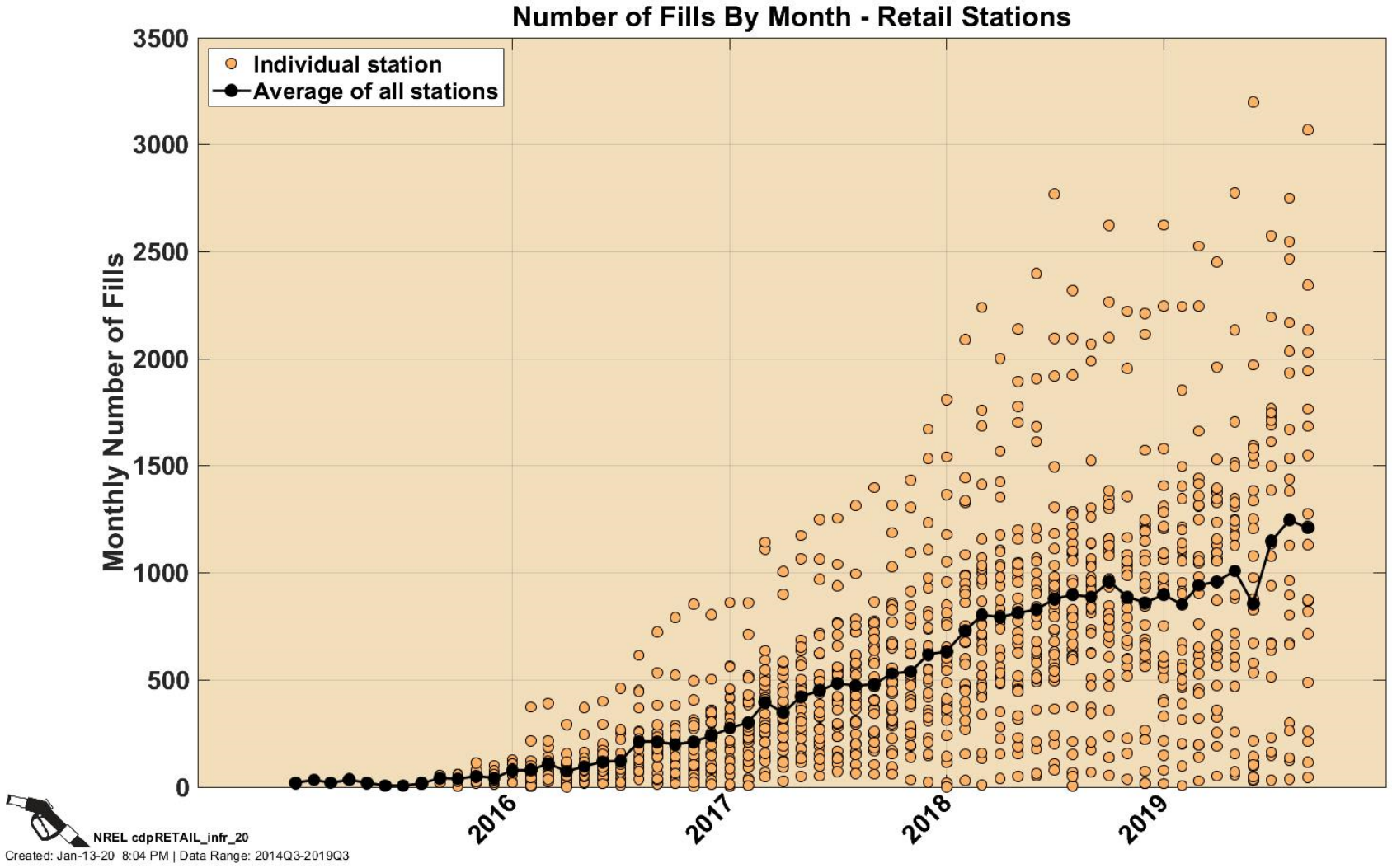
[1]Excludes hydrogen fills of < 0.5 kg

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

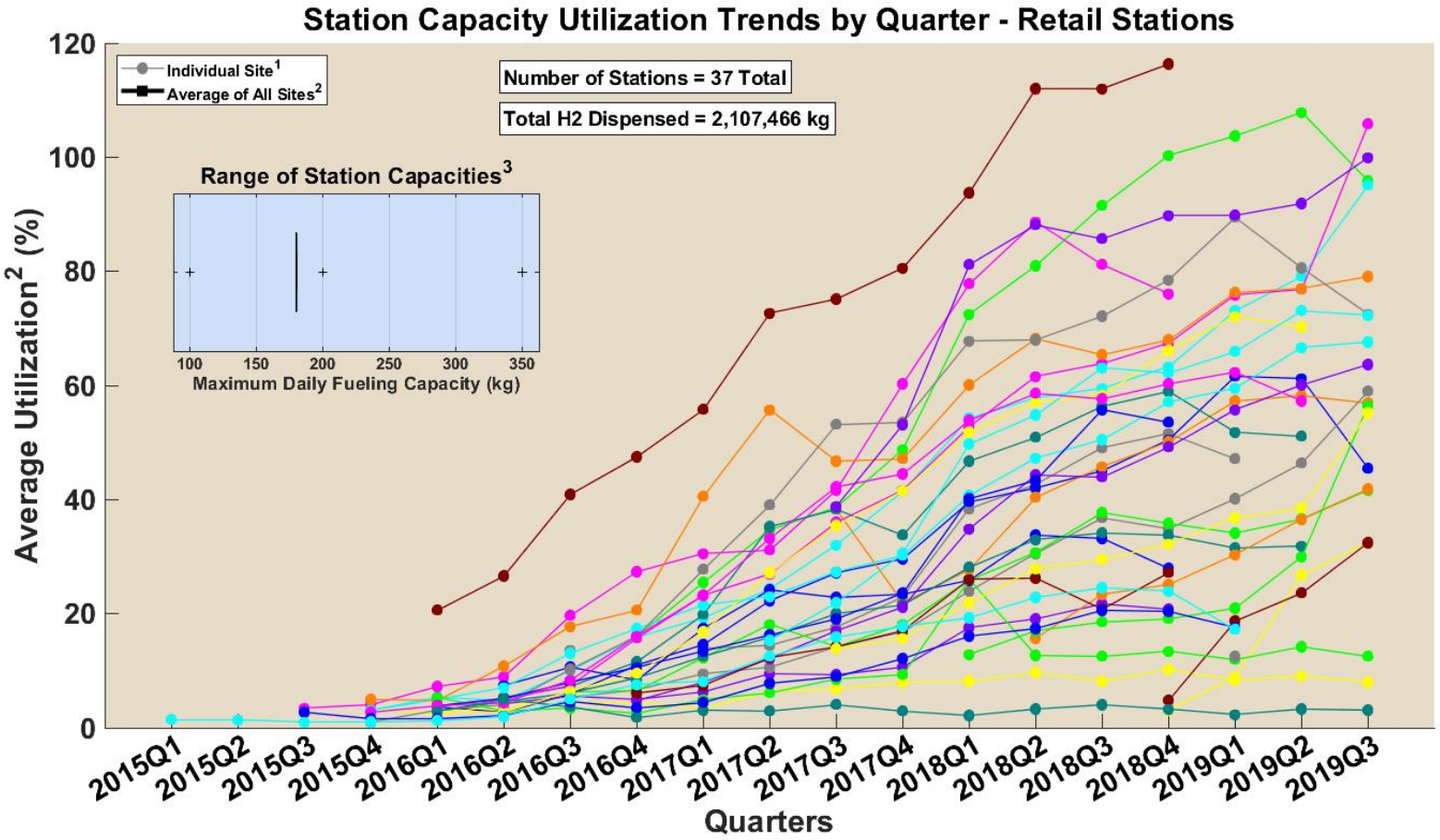
CDP-INFR-19
Hydrogen Dispensed by Month



CDP-INFR-20
Number of Fills by Month



CDP-INFR-44
Station Capacity Utilization Trends by Quarter



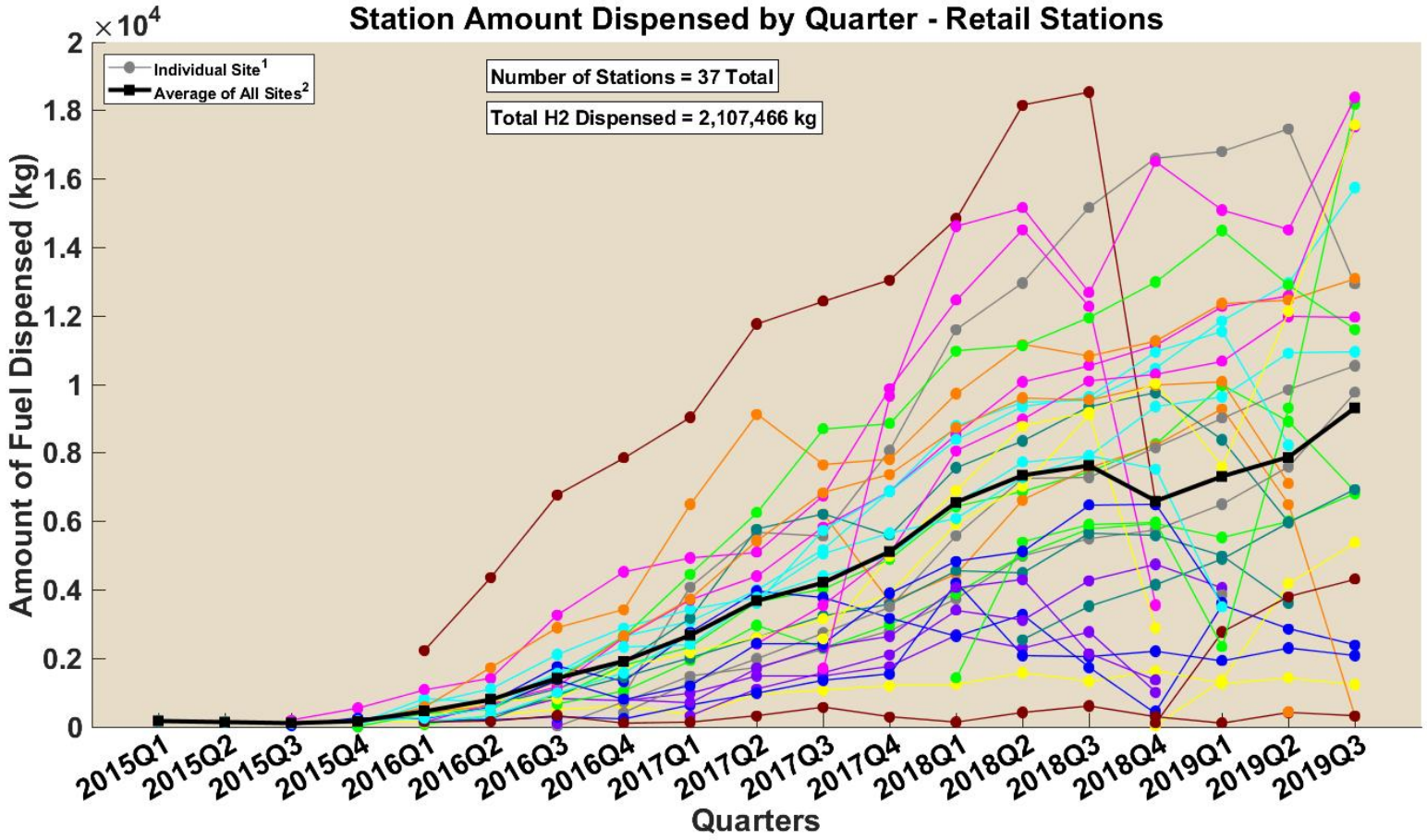
[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station was offline or missing data. Each station is represented by a unique color.

[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: Jan-13-20 8:16 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-45
Station Amount Dispensed by Quarter

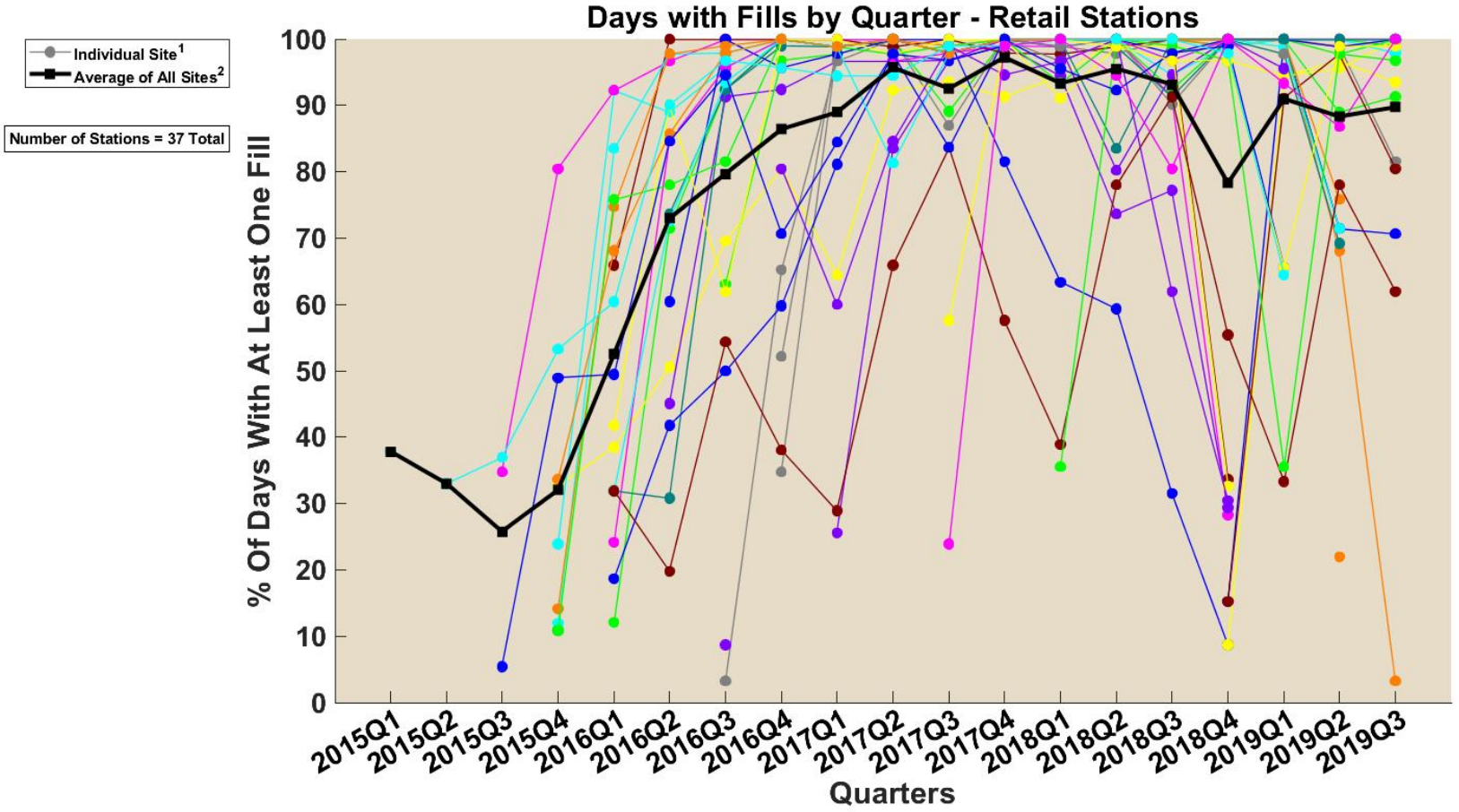


[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station was offline or missing data. Each station is represented by a unique color.

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

NREL cdpRETAIL_infr_45
Created: Jan-13-20 8:25 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-46
Days with Fills by Quarter

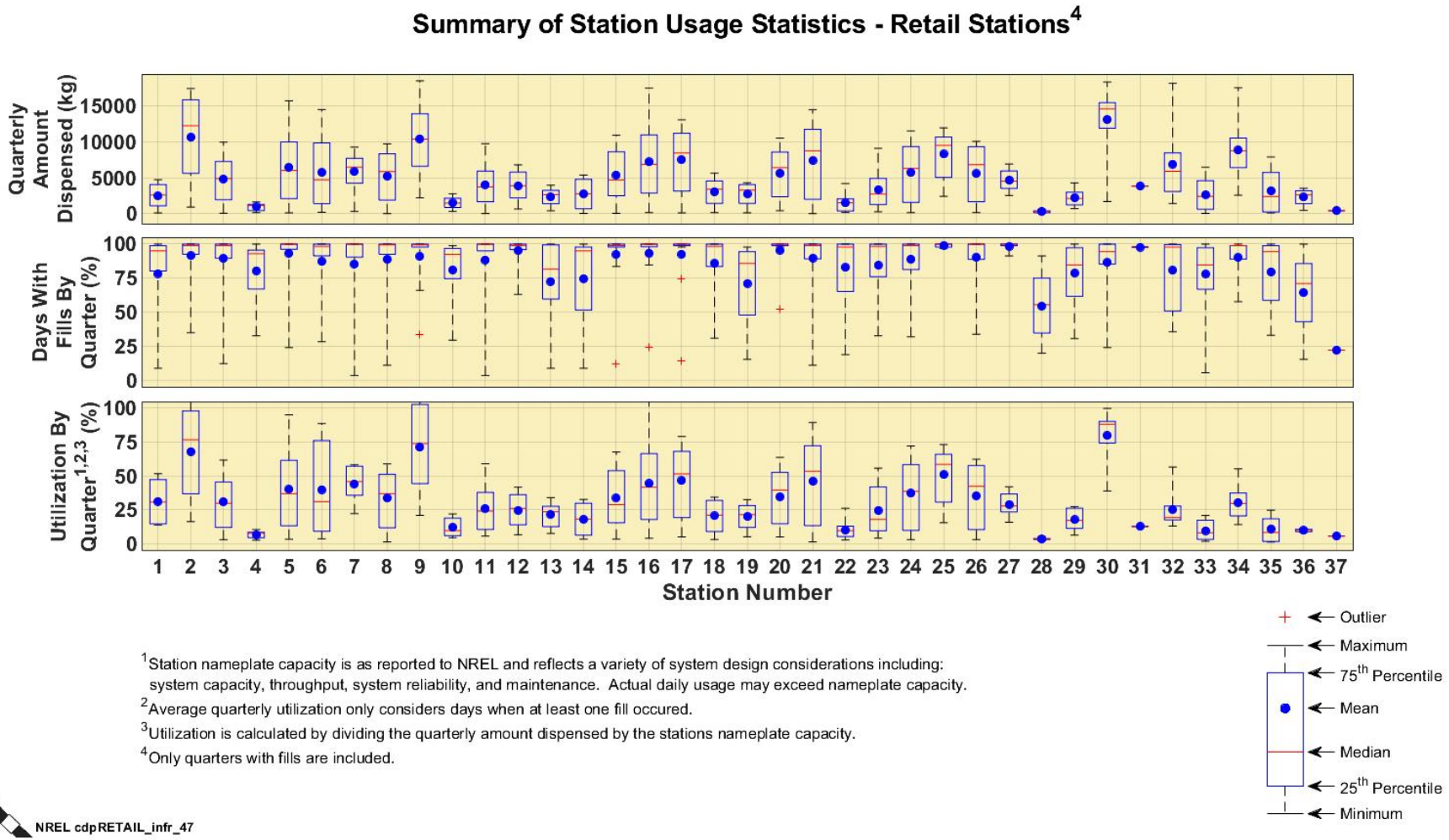


[1] Trendlines connect continuous quarters of operation for a single station. Gaps in trendlines represent quarters in which a station had no fills or was missing data. Each station is represented by a unique color.

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

NREL cdpRETAIL_infr_46
Created: Jan-13-20 8:33 PM | Data Range: 2014Q3-2019Q3

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.

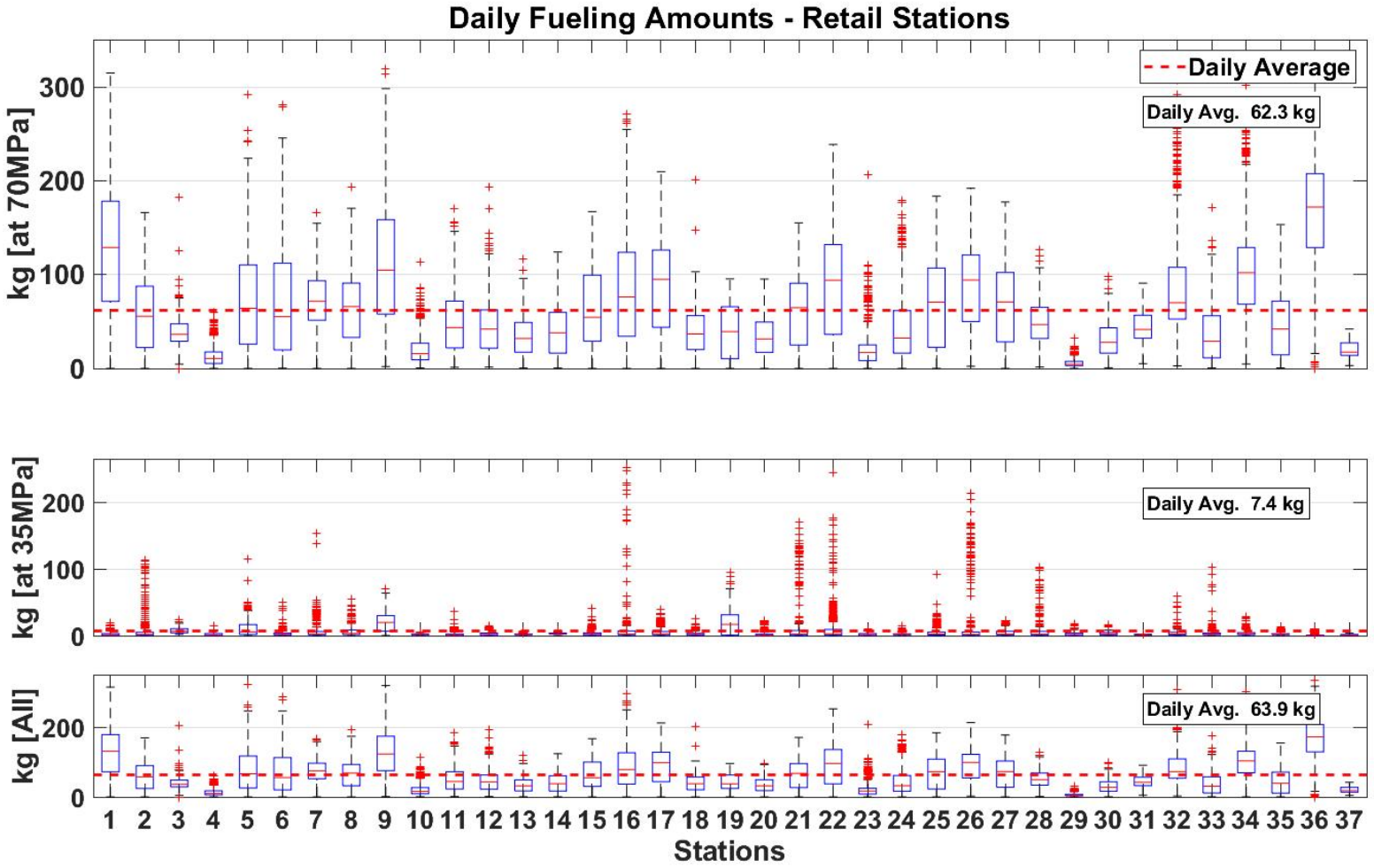
[2]Average quarterly utilization only considers days when at least one fill occured.

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

[4]Only quarters with fills are included.

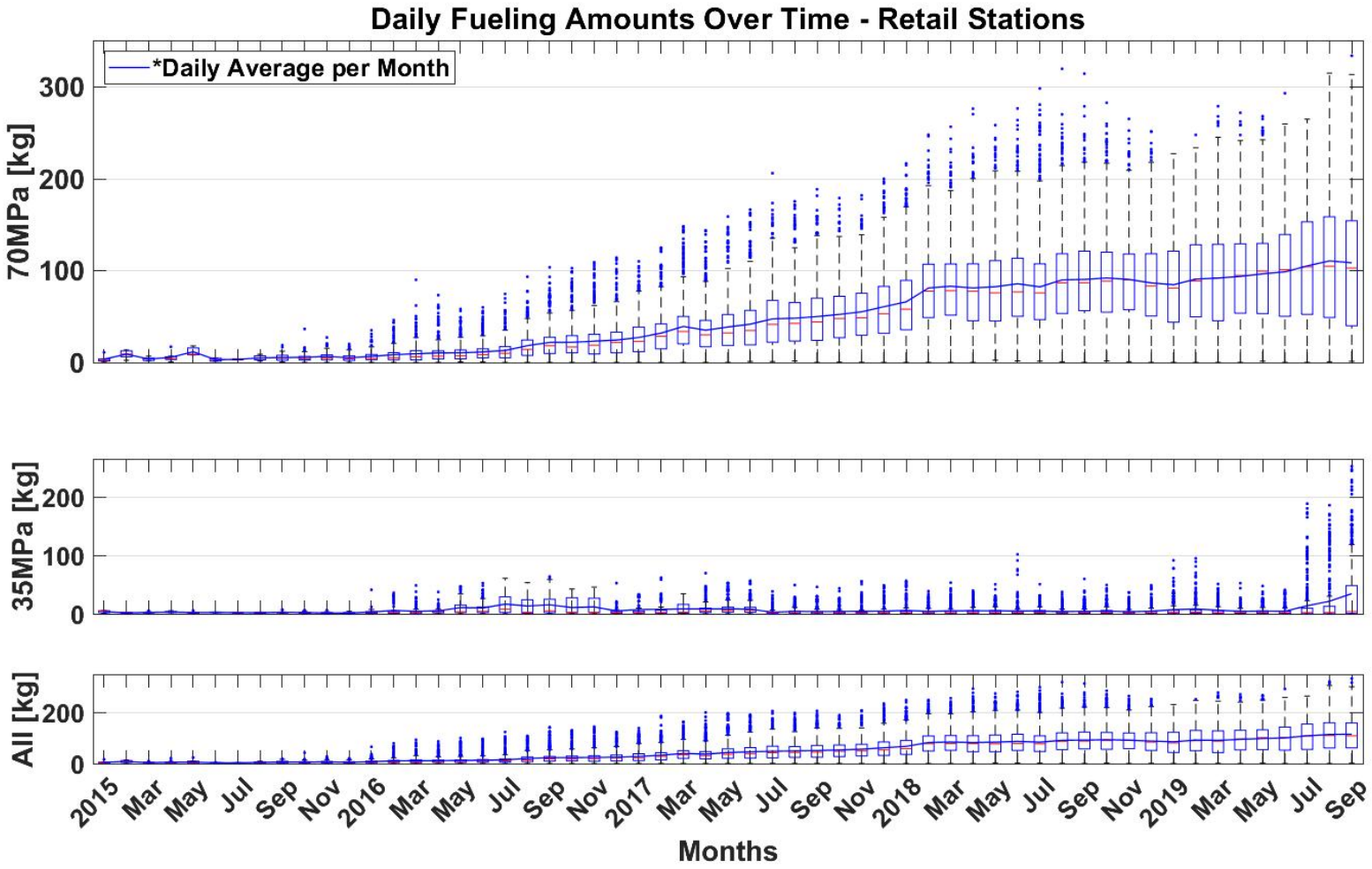
NREL cdpRETAIL_infr_47
Created: Jan-14-20 3:59 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-80
Daily Fueling Amounts by Station



NREL cdpRETAIL_infr_80
Created: Jan-13-20 9:51 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-82
Daily Fueling Amounts by Month

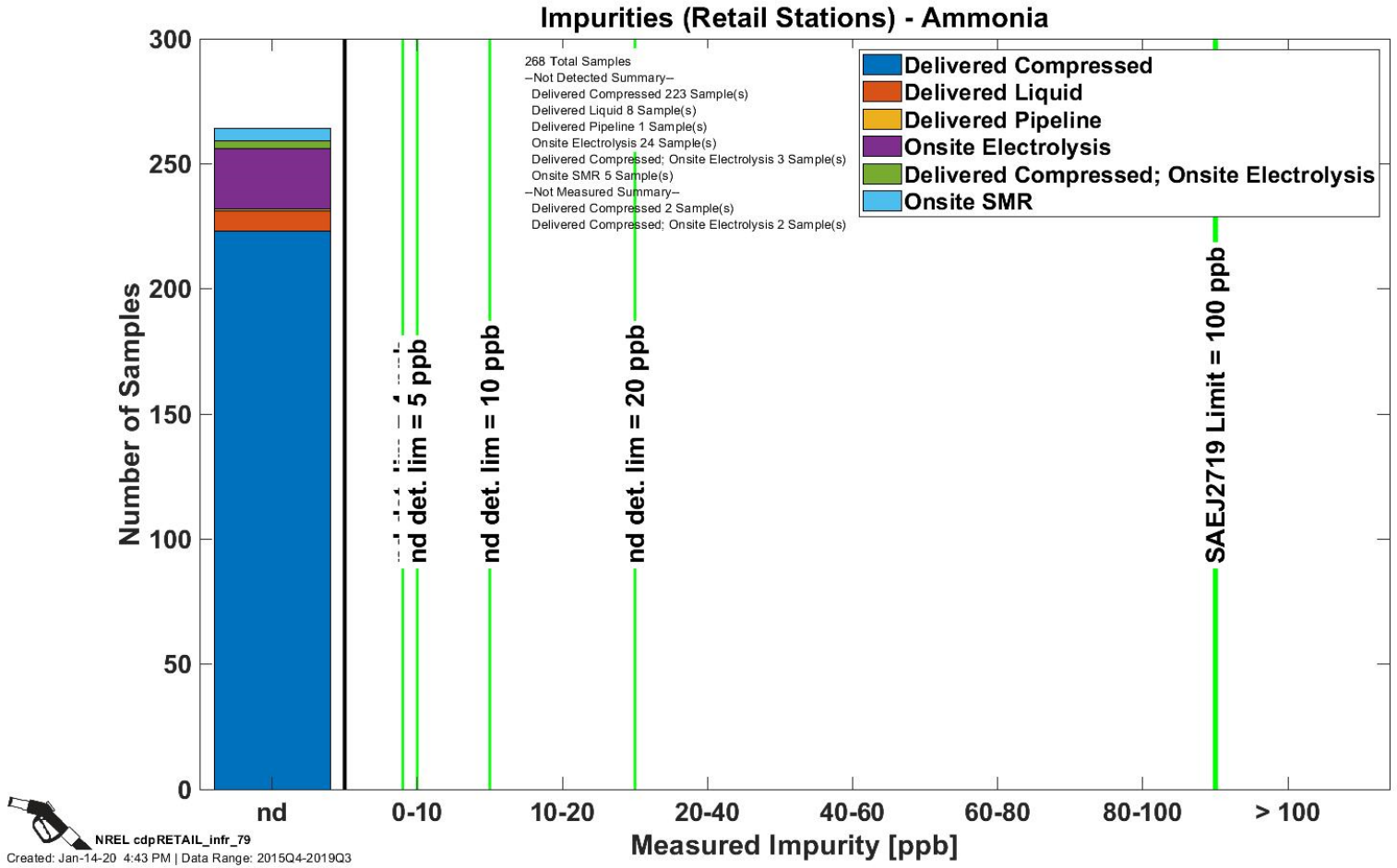


NREL cdpRETAIL_infr_82
Created: Jan-13-20 9:58 PM | Data Range: 2014Q3-2019Q3

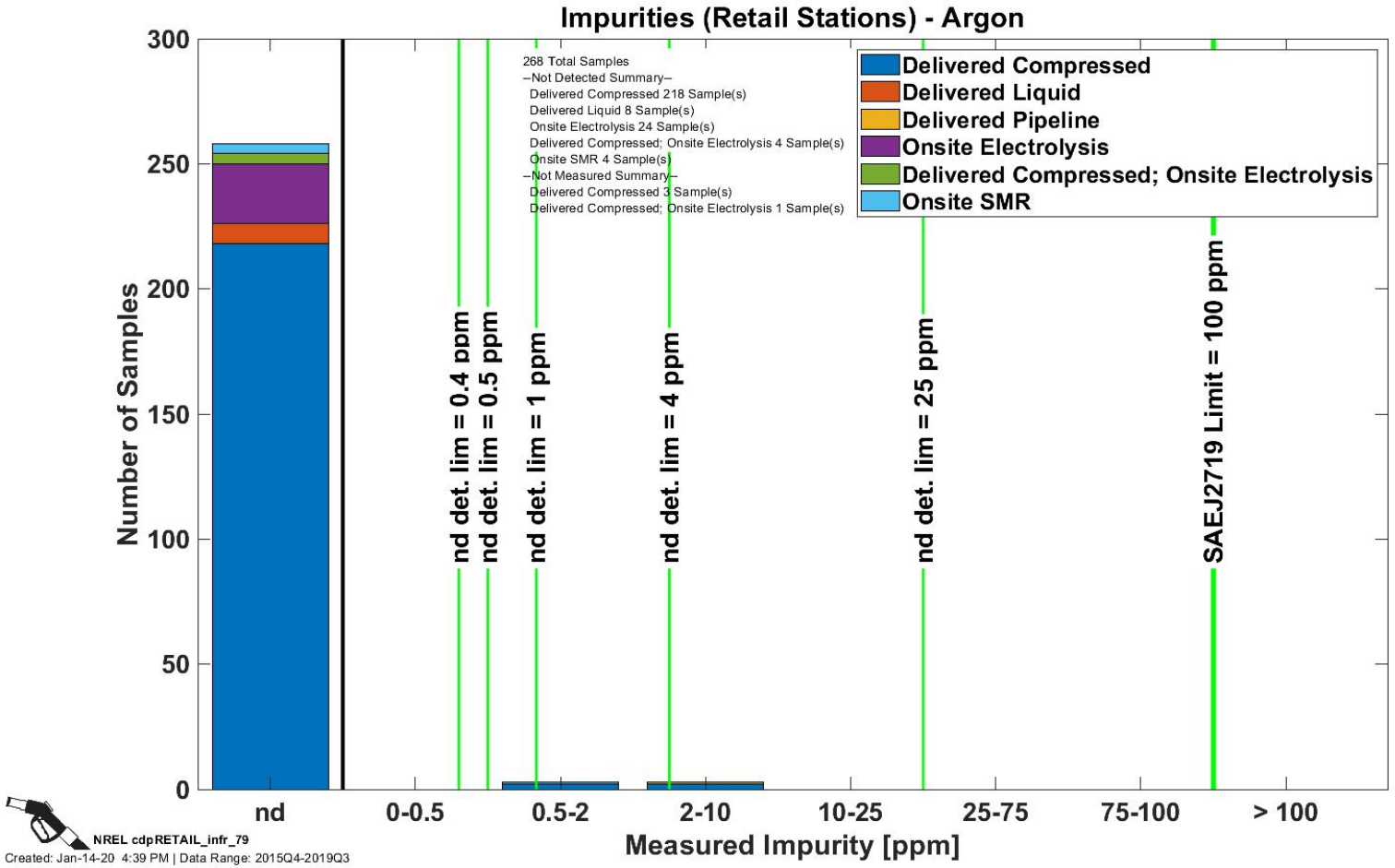
*Daily average only includes days with fills.

Hydrogen Quality

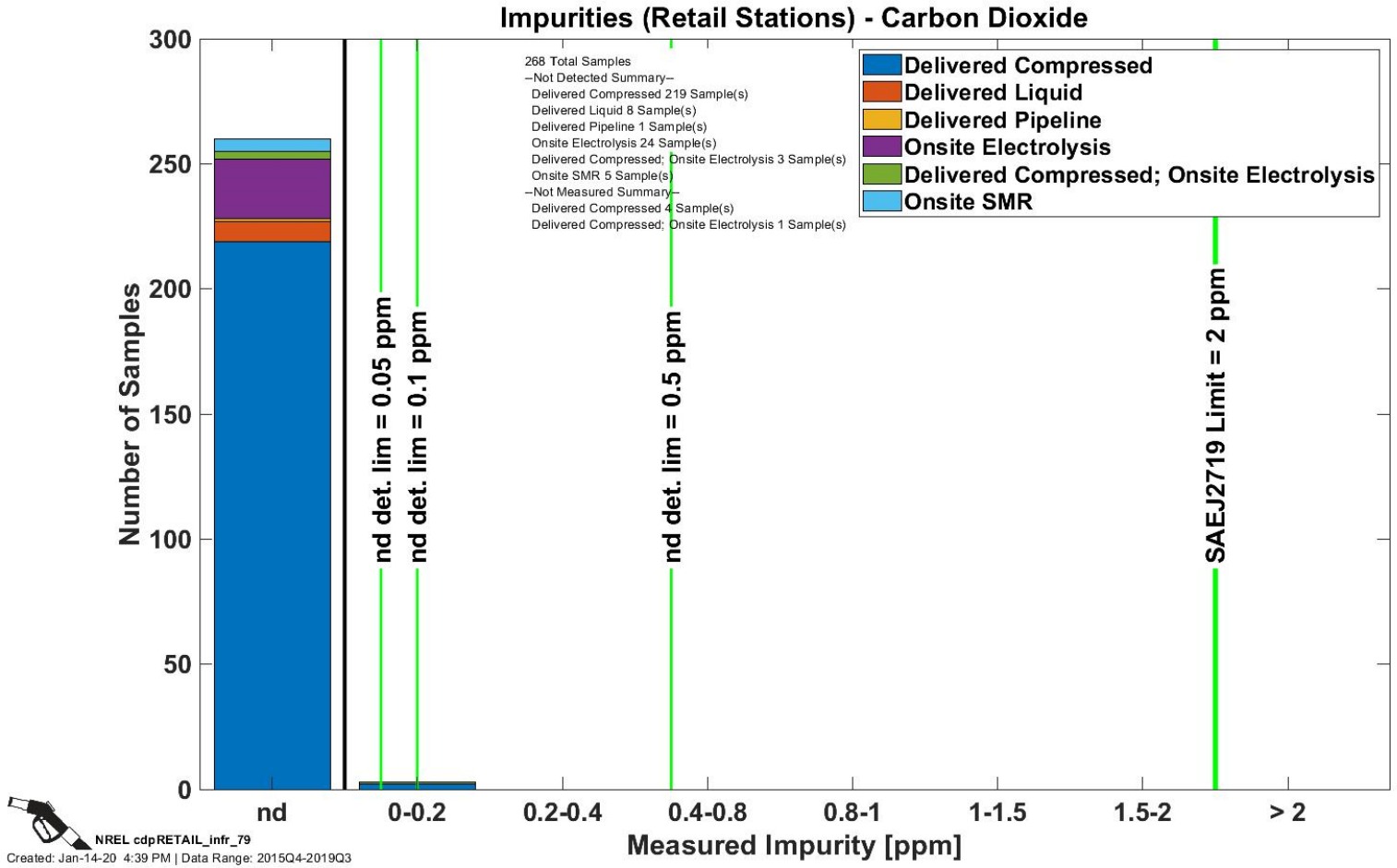
CDP-INFR-79
Impurities—Ammonia



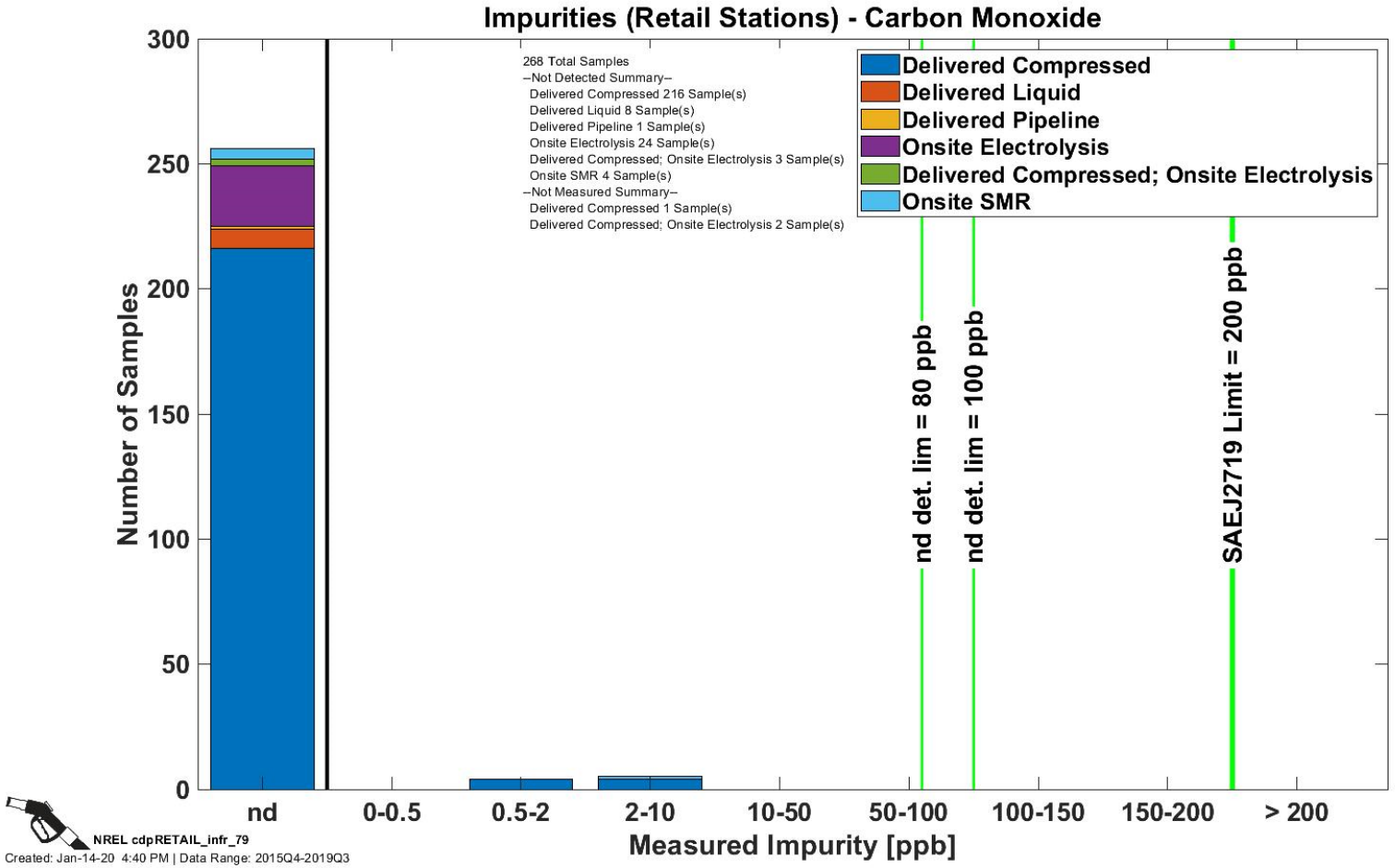
CDP-INFR-79
Impurities—Argon



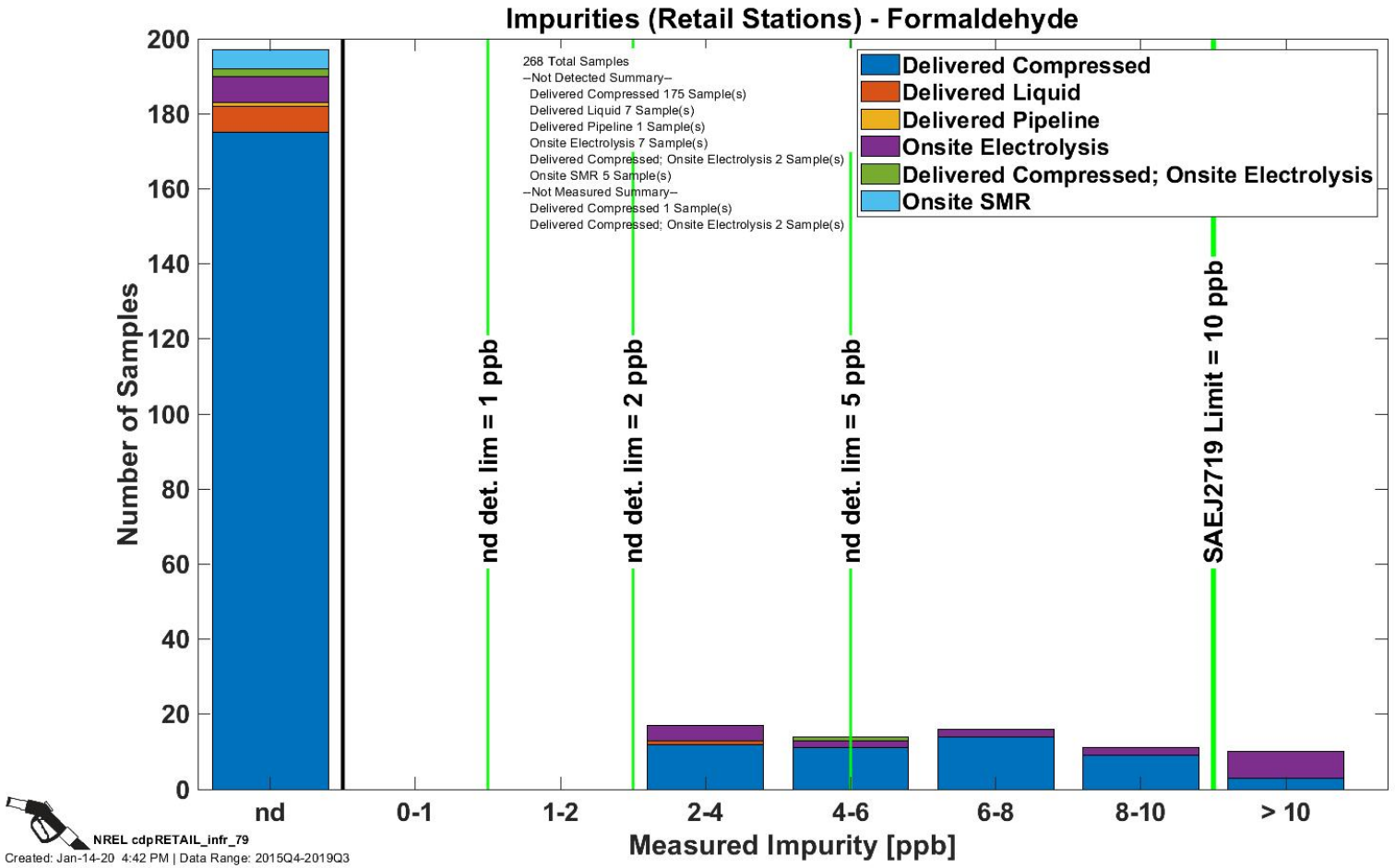
CDP-INFR-79
Impurities—Carbon Dioxide



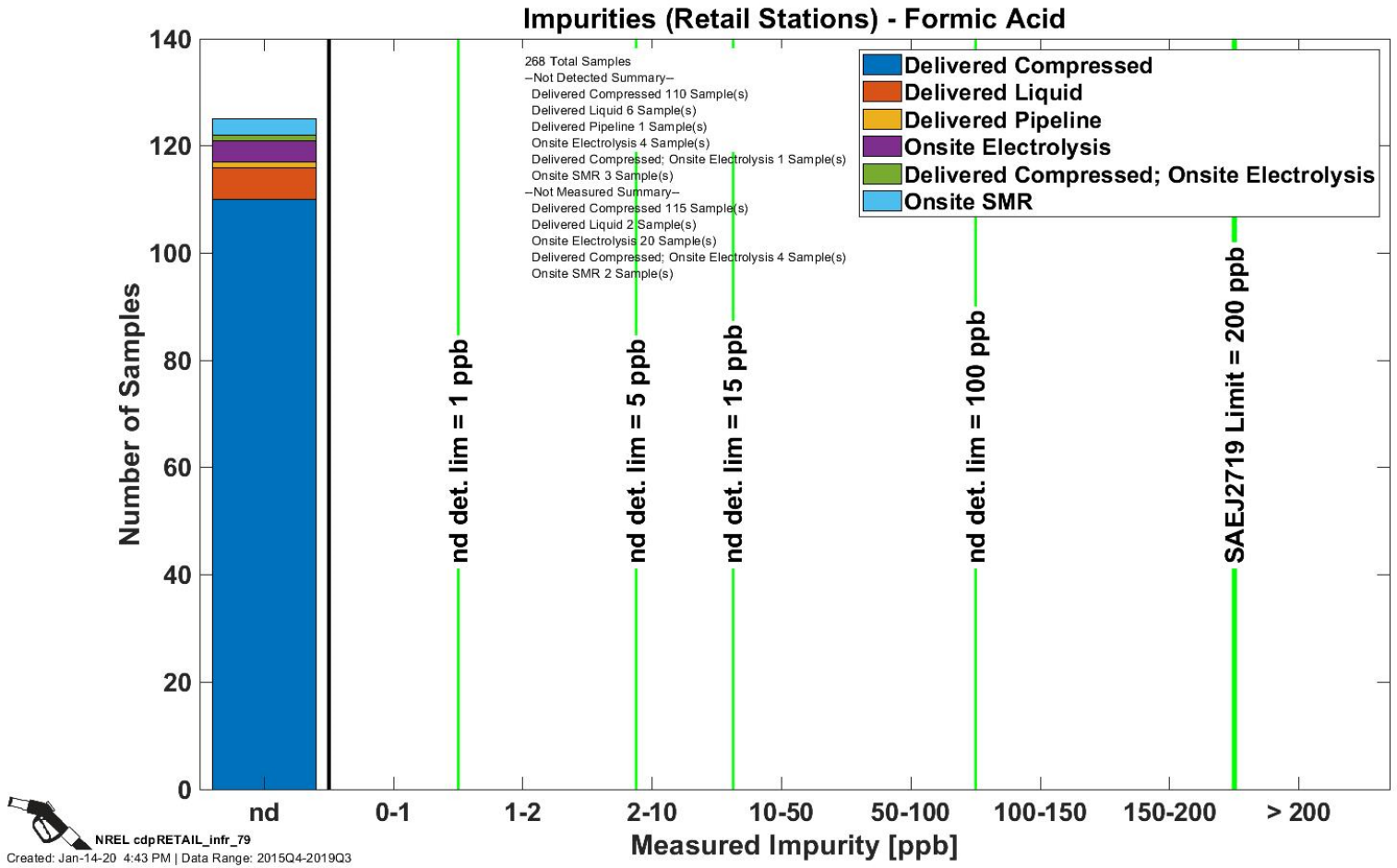
CDP-INFR-79
Impurities—Carbon Monoxide



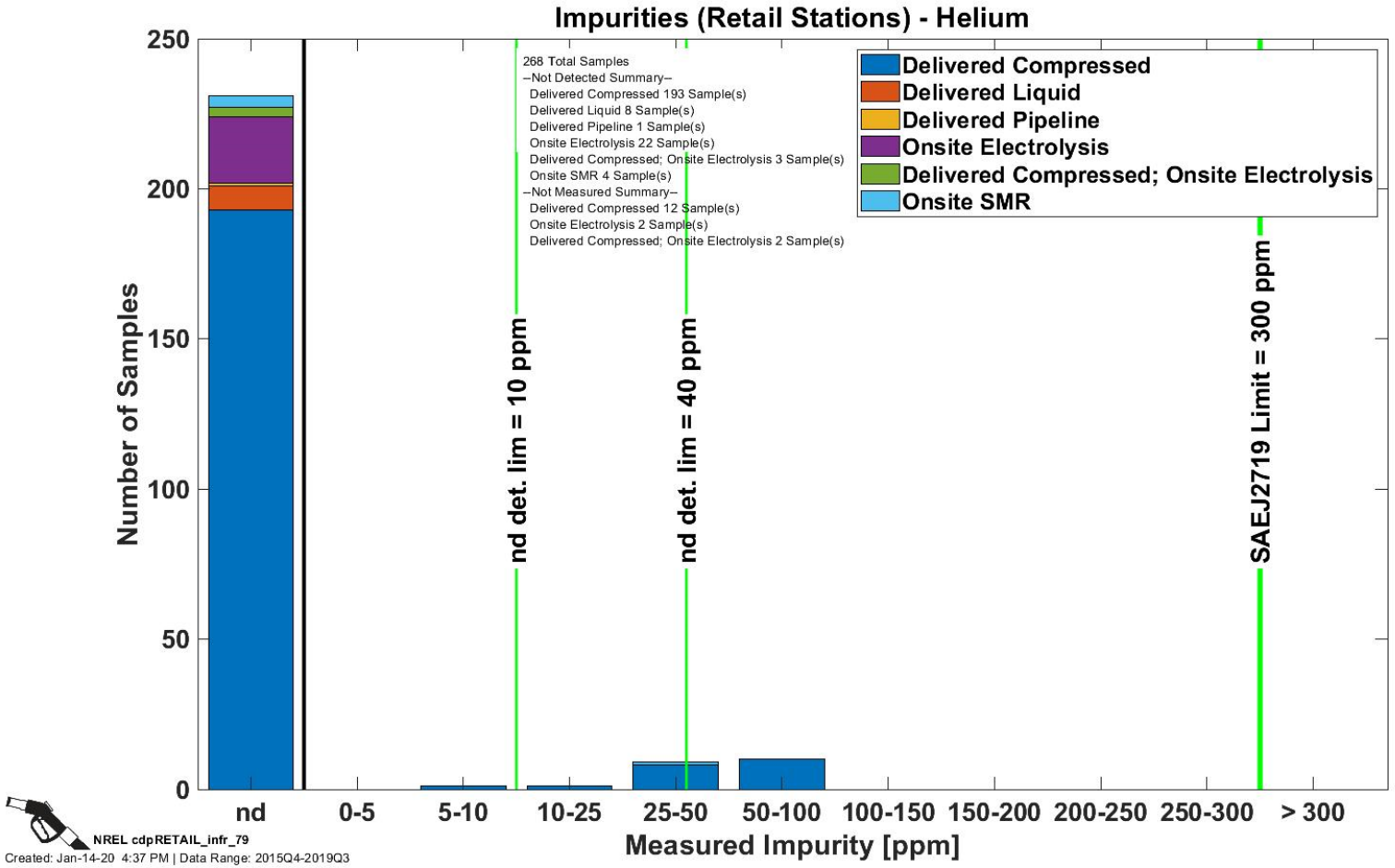
CDP-INFR-79
Impurities—Formaldehyde



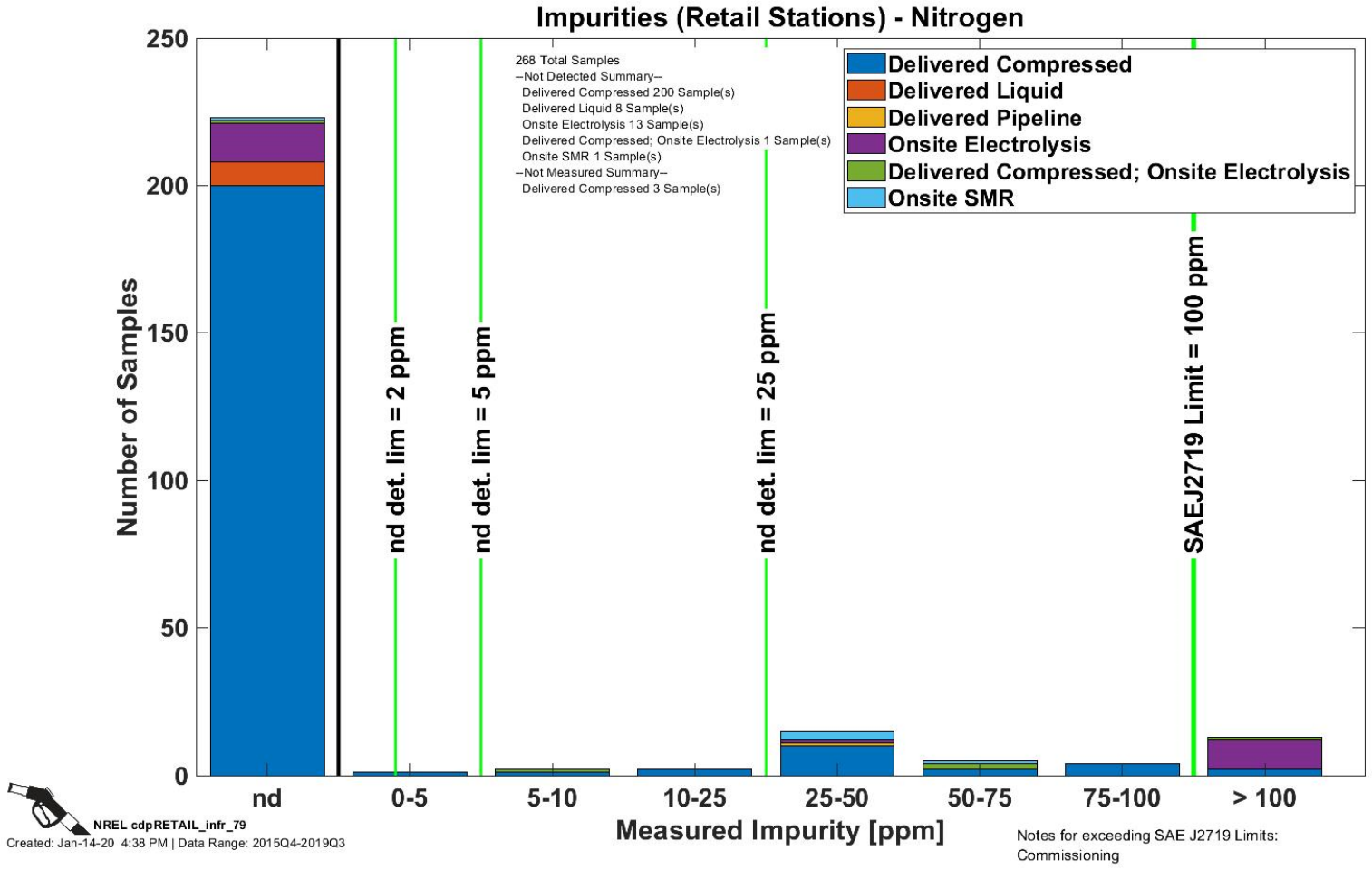
CDP-INFR-79
Impurities—Formic Acid



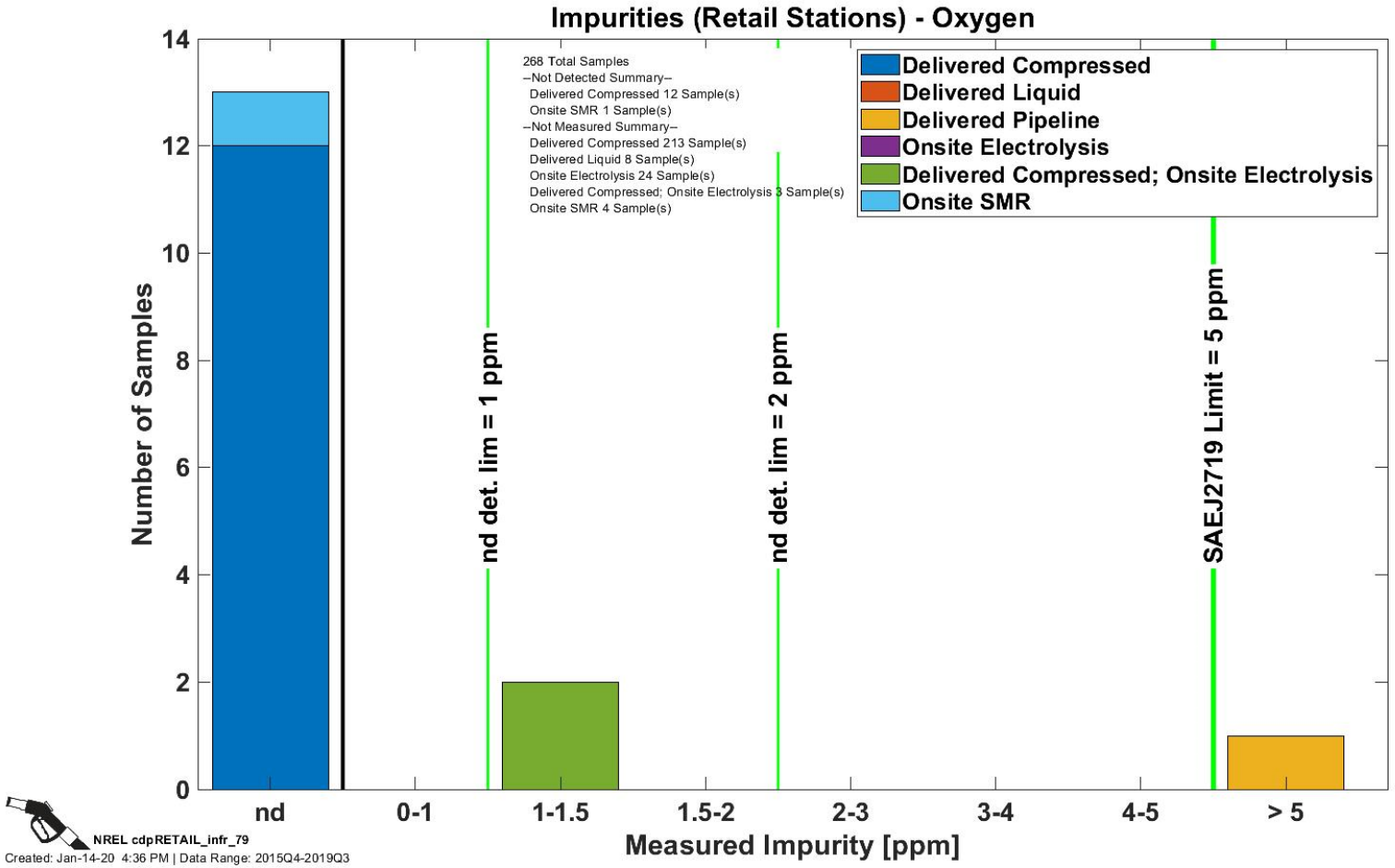
CDP-INFR-79
Impurities—Helium



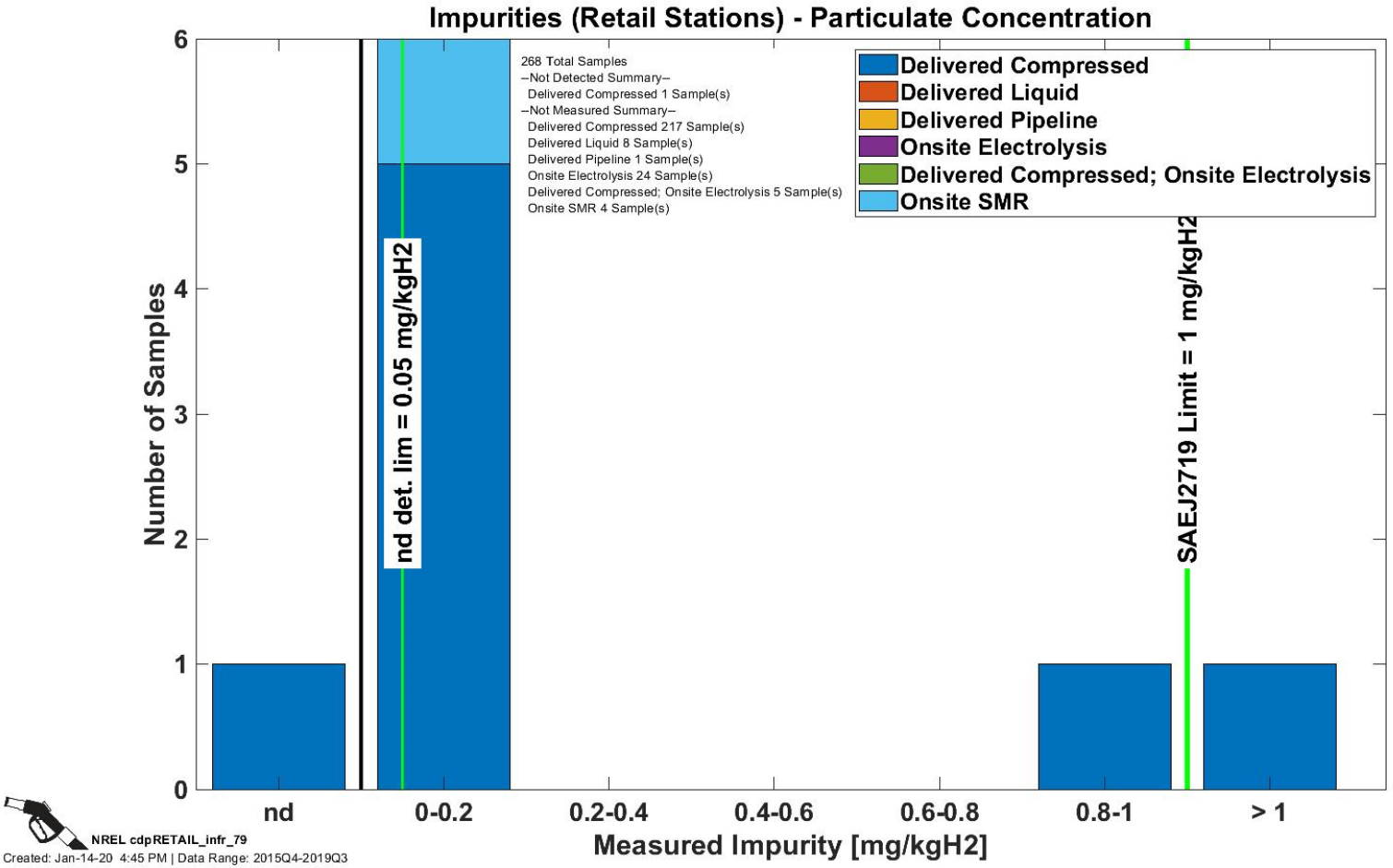
CDP-INFR-79
Impurities—Nitrogen



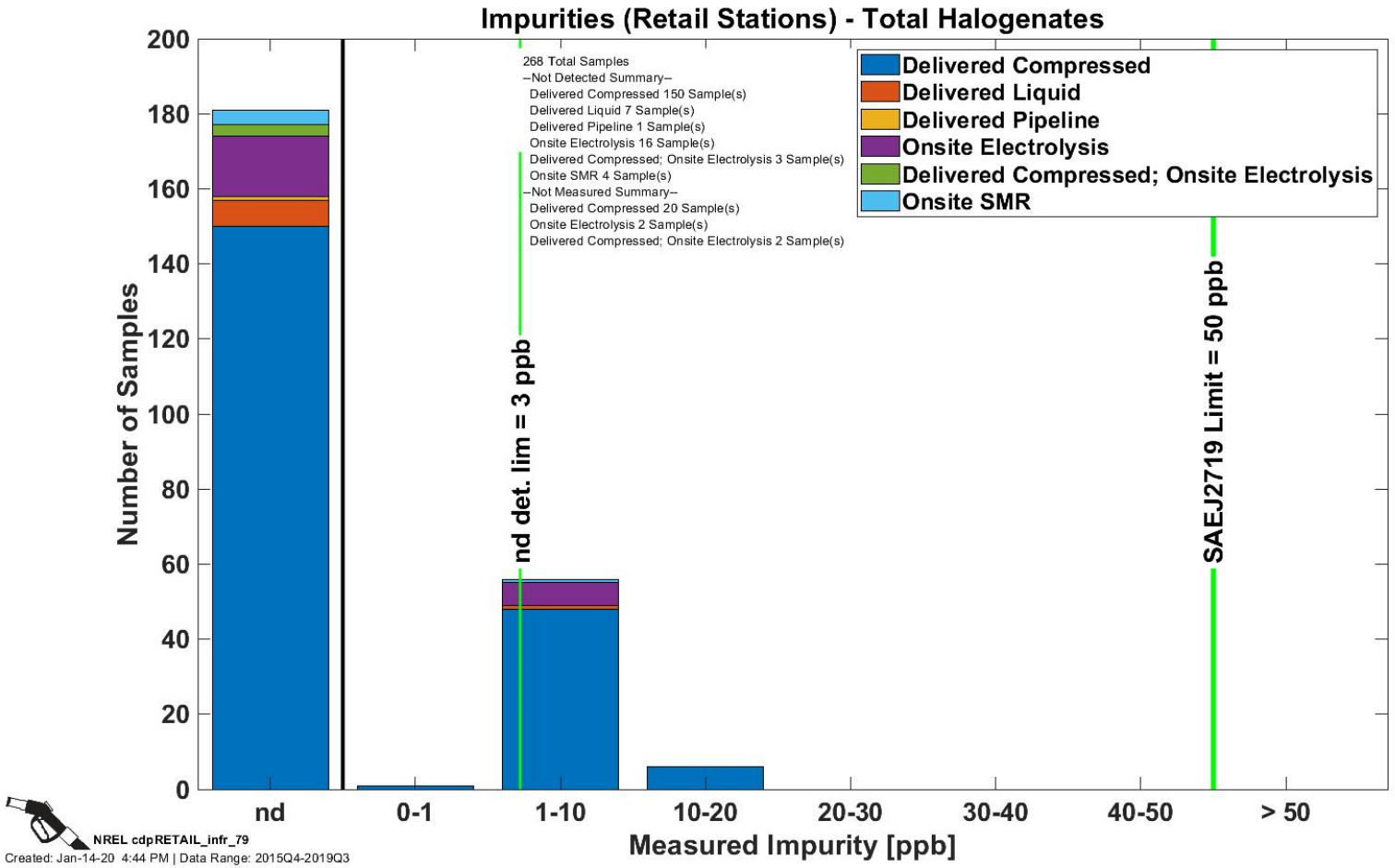
CDP-INFR-79
Impurities—Oxygen



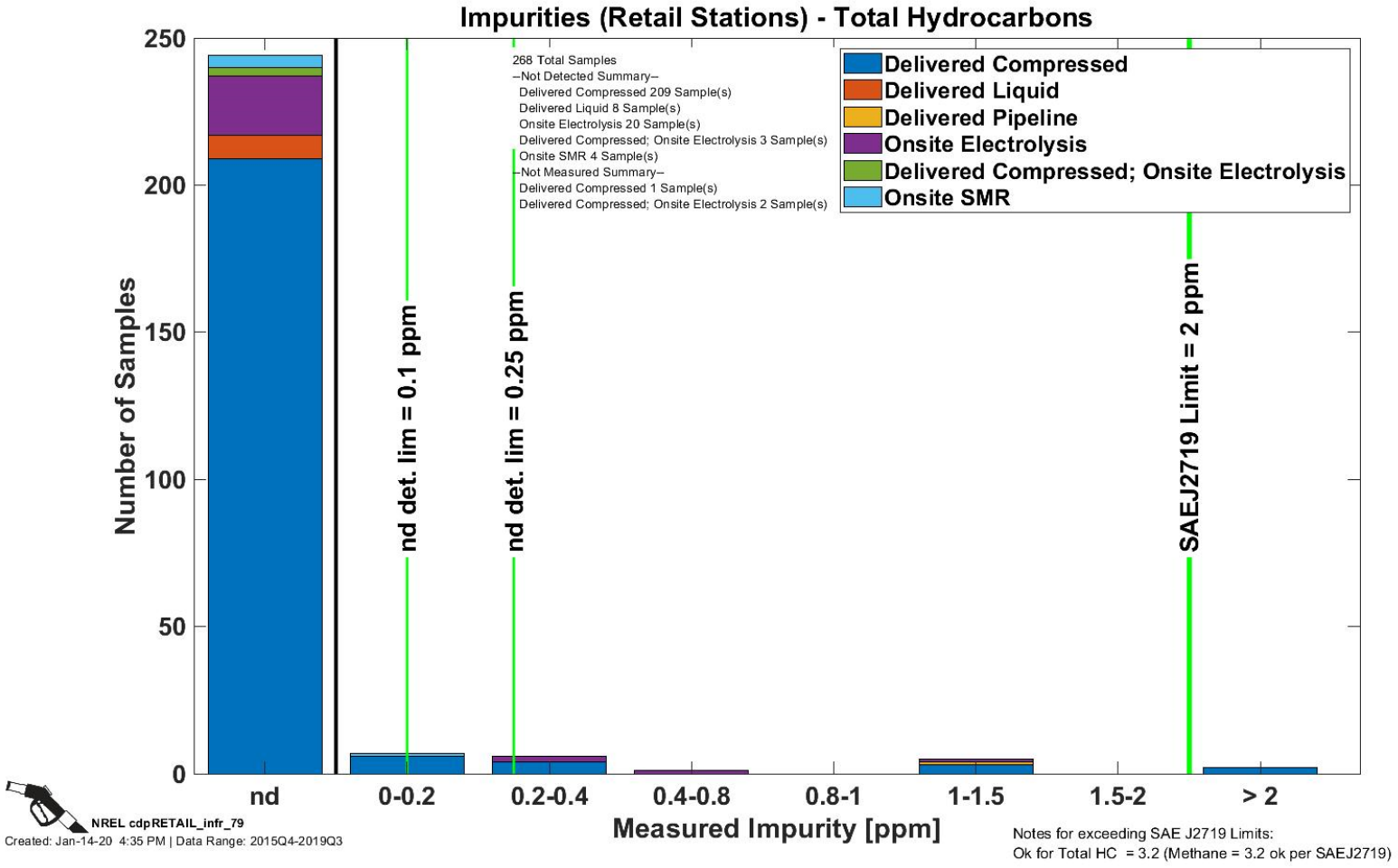
CDP-INFR-79
Impurities—Particulate Concentration



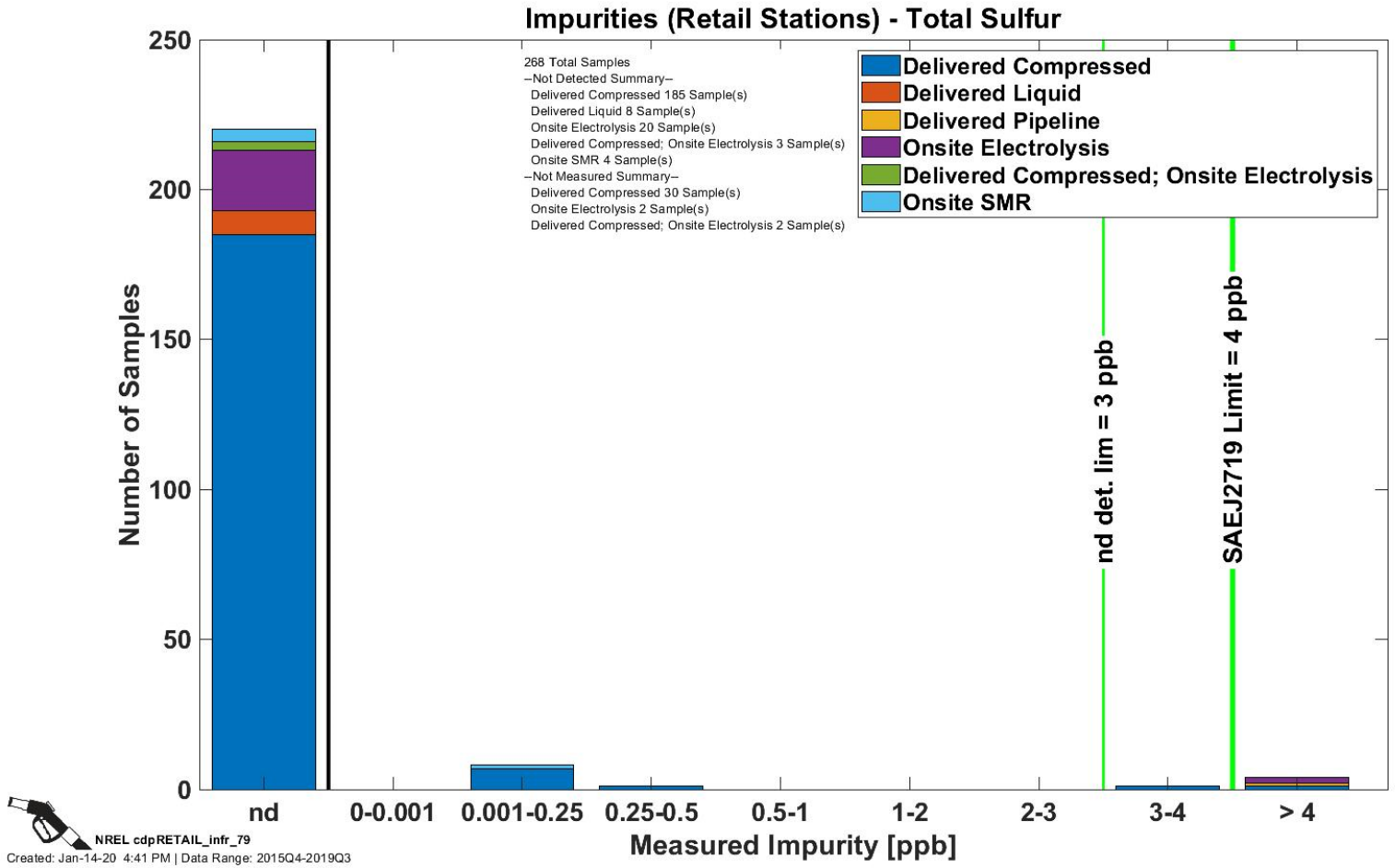
CDP-INFR-79
Impurities—Total Halogenates



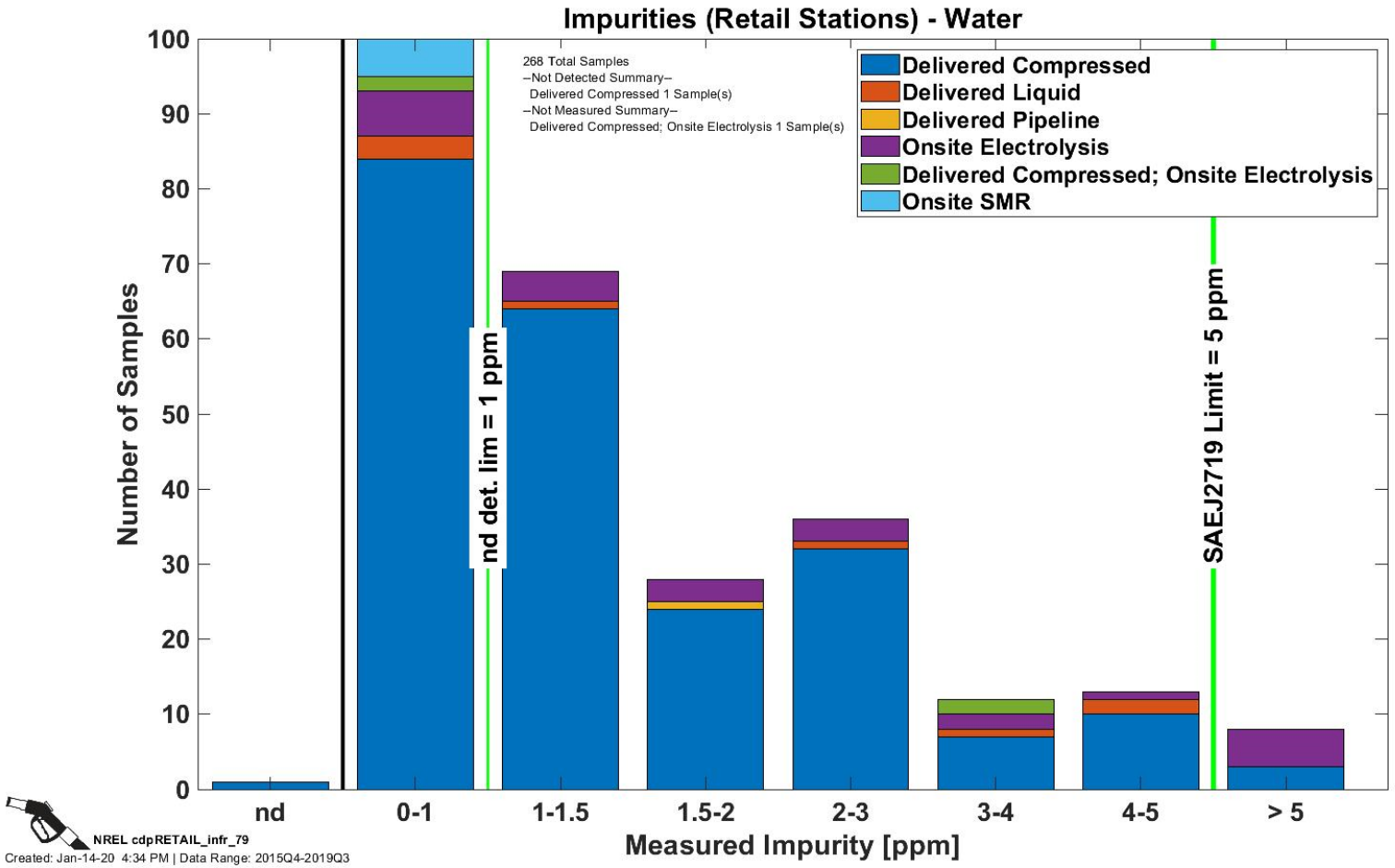
CDP-INFR-79
Impurities—Total Hydrocarbons



CDP-INFR-79
Impurities—Total Sulfur

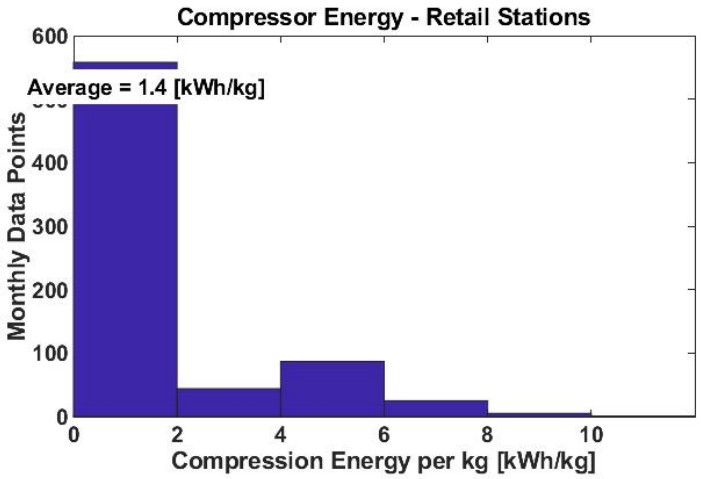


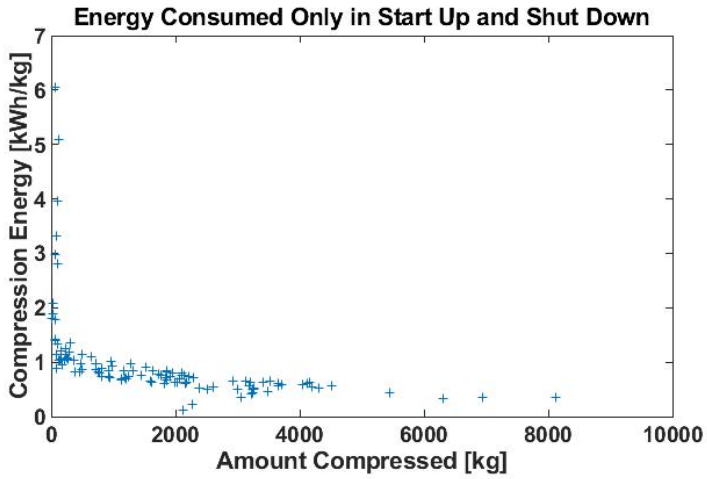
CDP-INFR-79
Impurities—Water

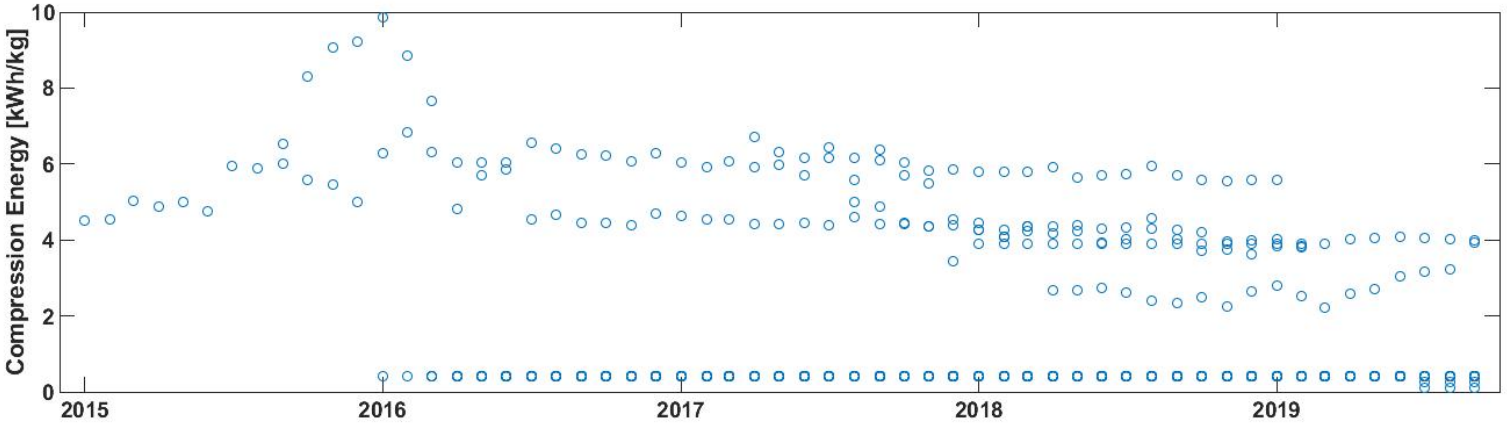


Component Energy

CDP-INFR-35
Compressor Energy







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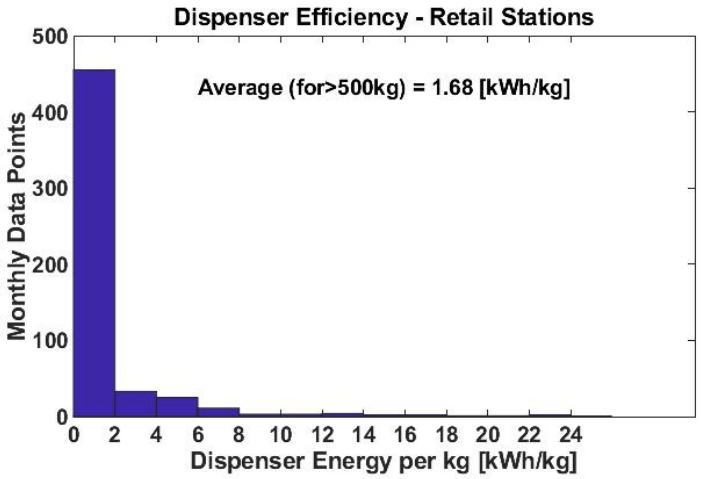
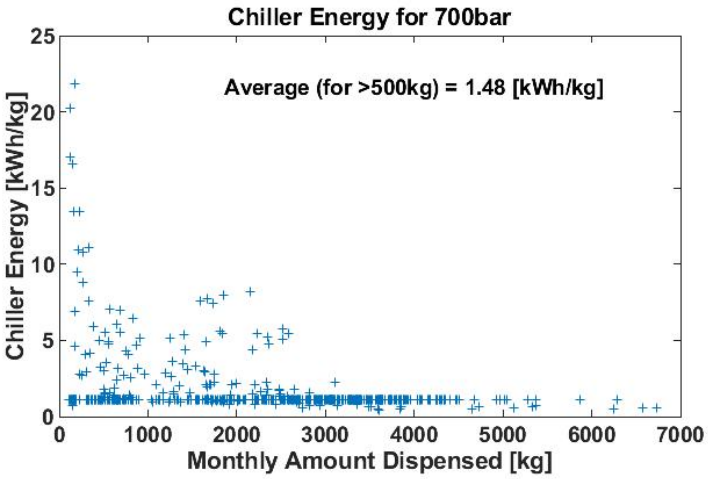
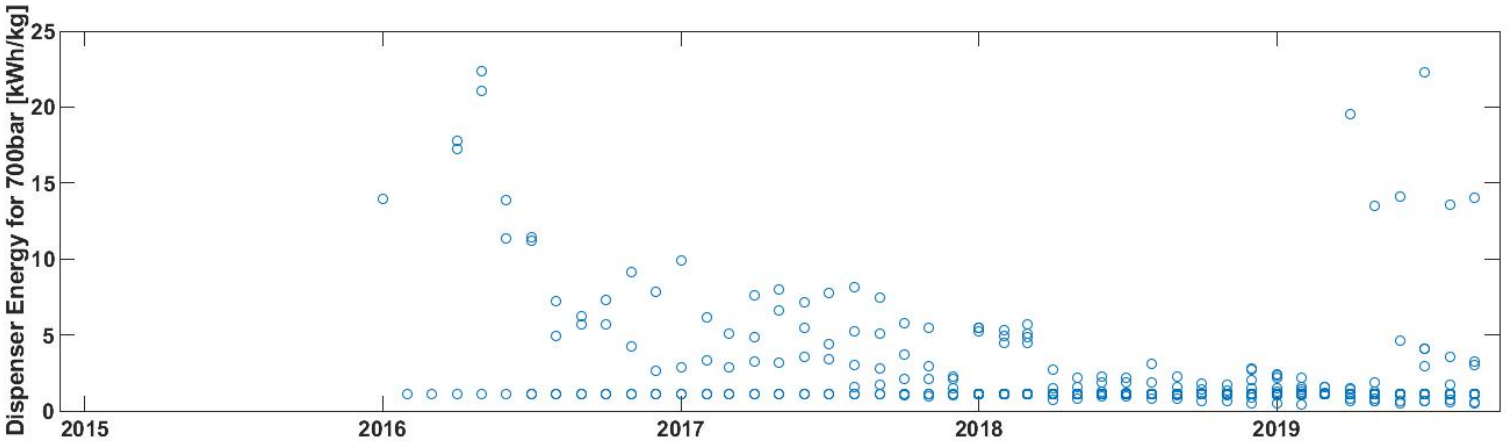
Created: Jan-13-20 8:08 PM | Data Range: 2014Q3-2019Q3

CDP-INFR-92
Dispenser Energy







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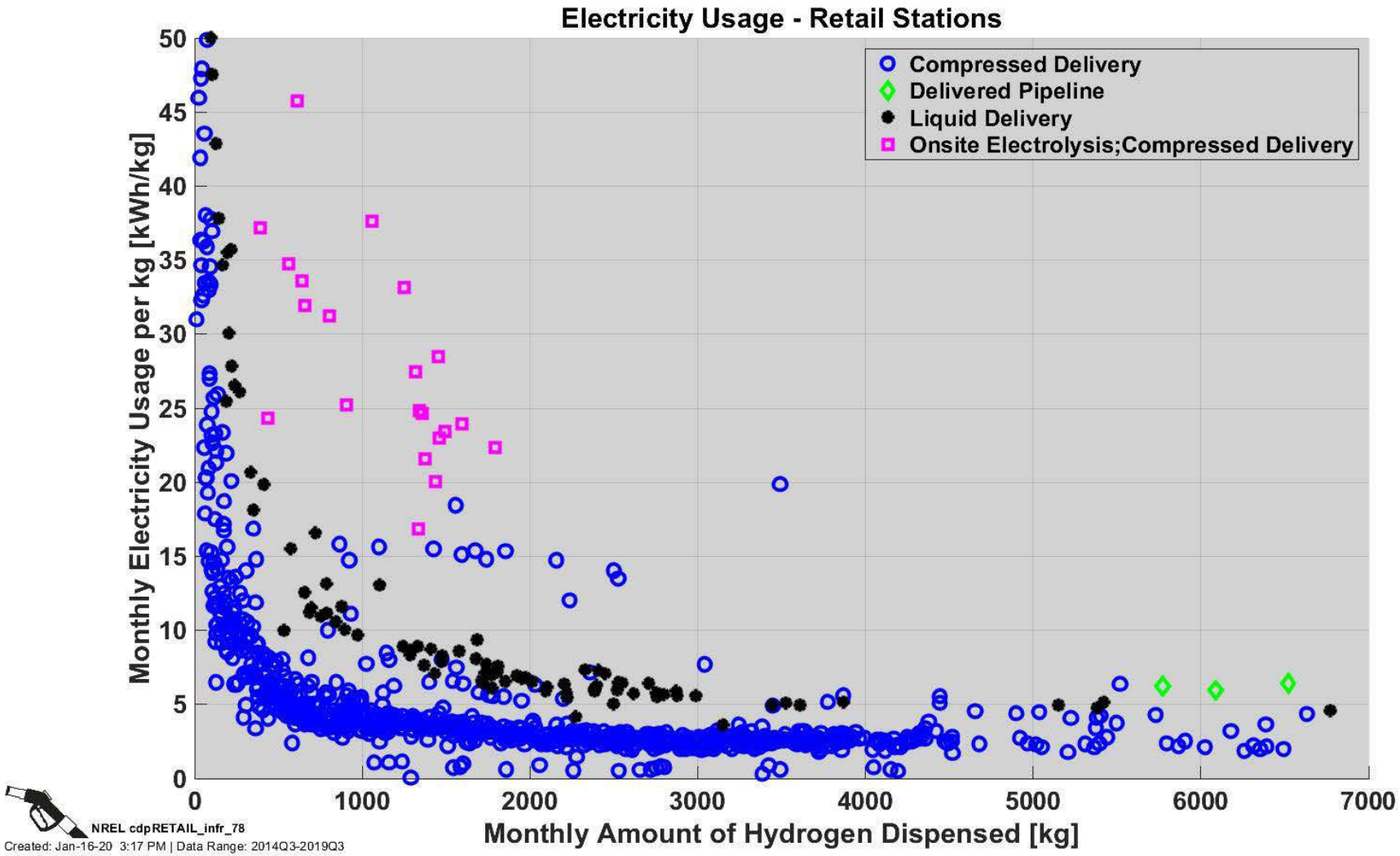
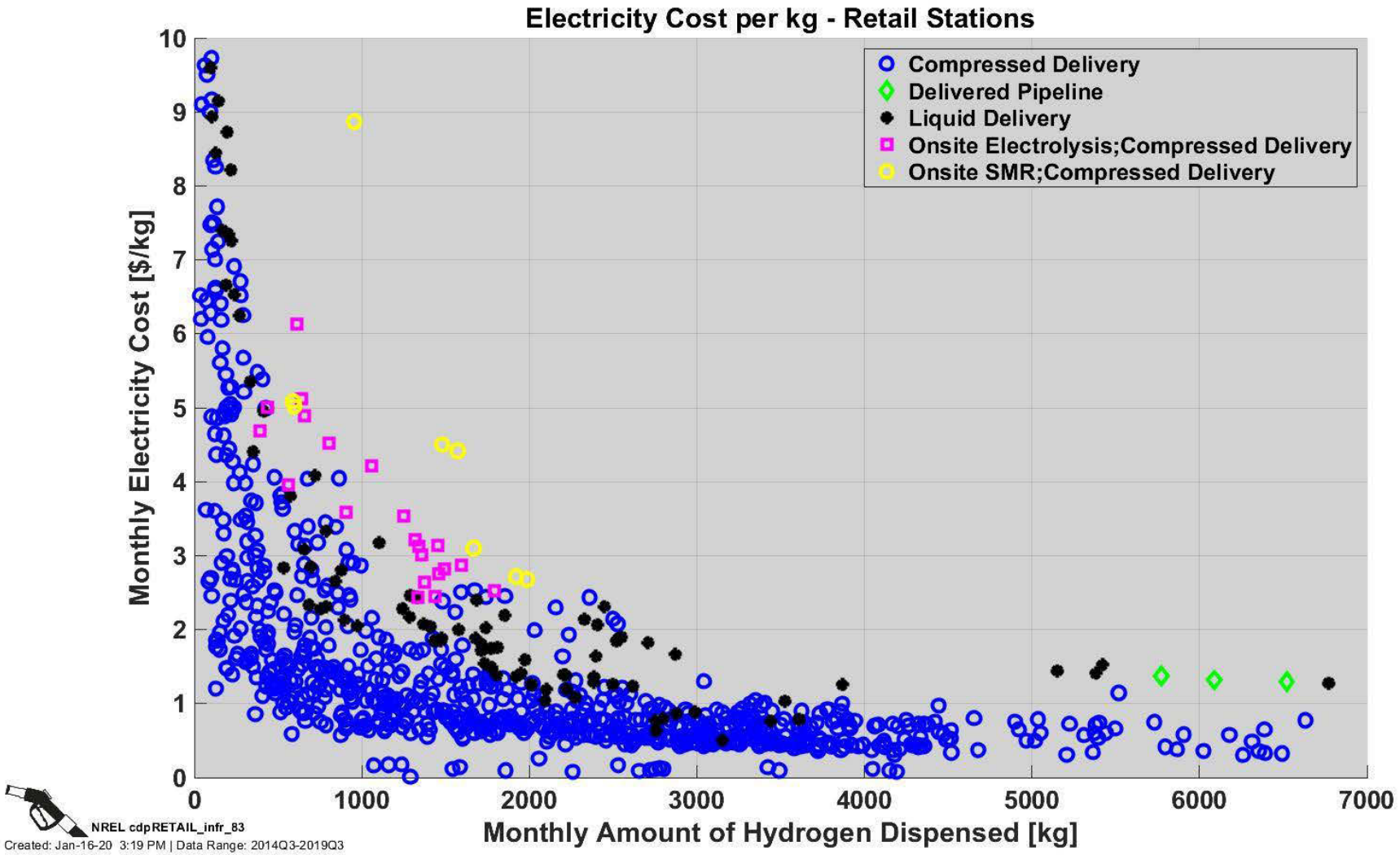
Created: Jan-13-20 10:42 PM | Data Range: 2014Q3-2019Q3

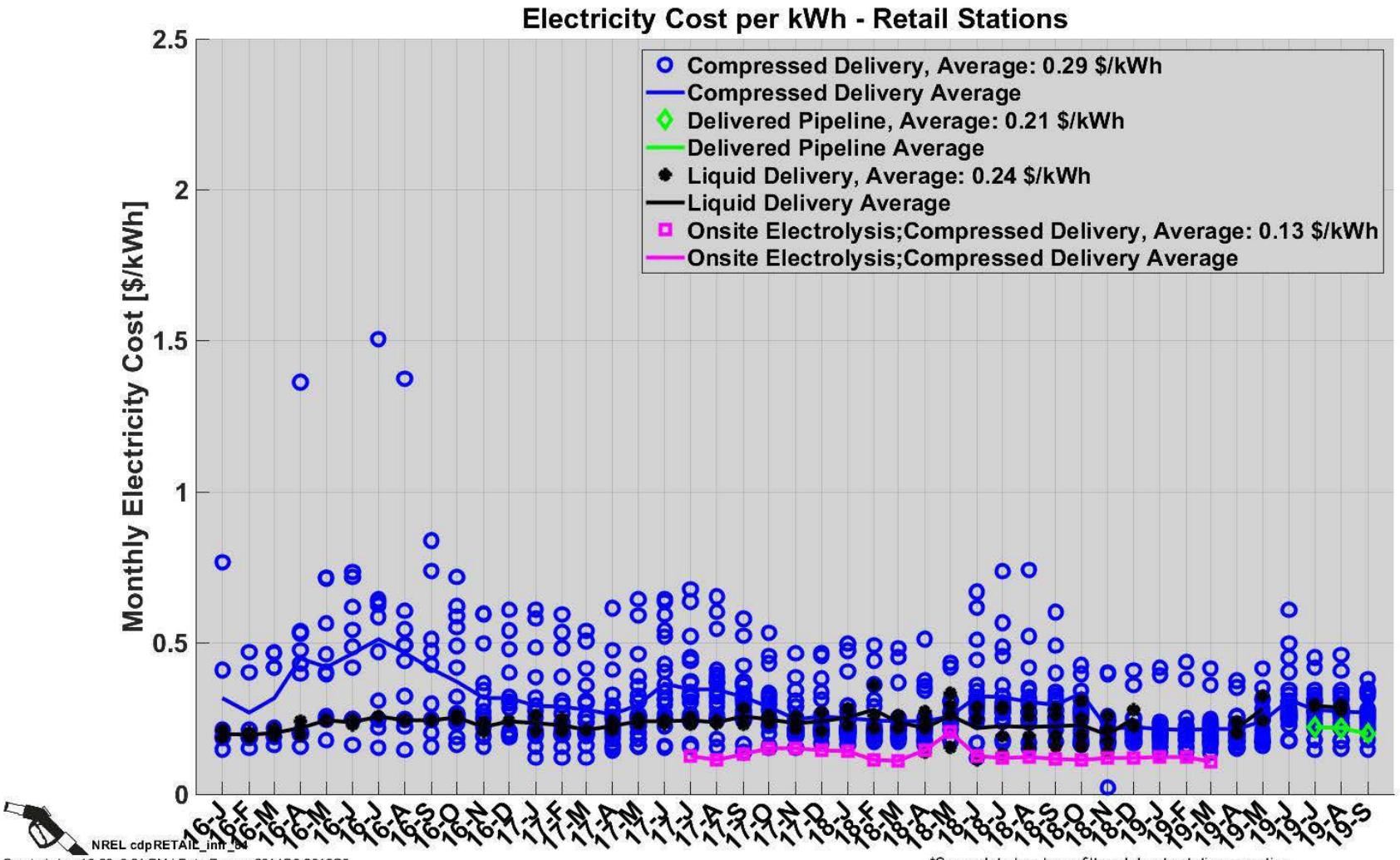
CDP-INFR-78
Station Energy per kg Dispensed



CDP-INFR-83
Station Energy Cost per kg Dispensed



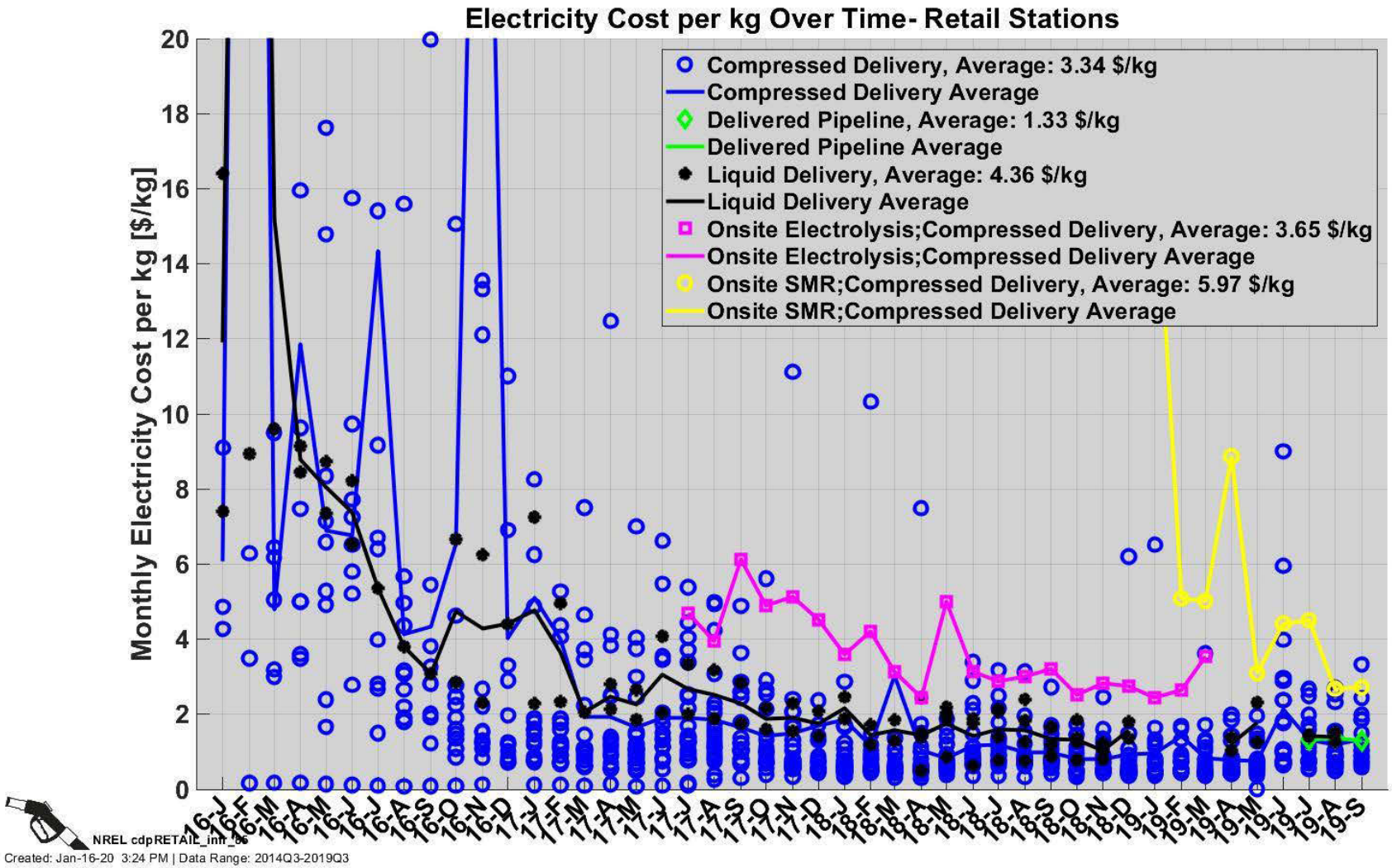
CDP-INFR-84
Station Electricity Cost per kWh



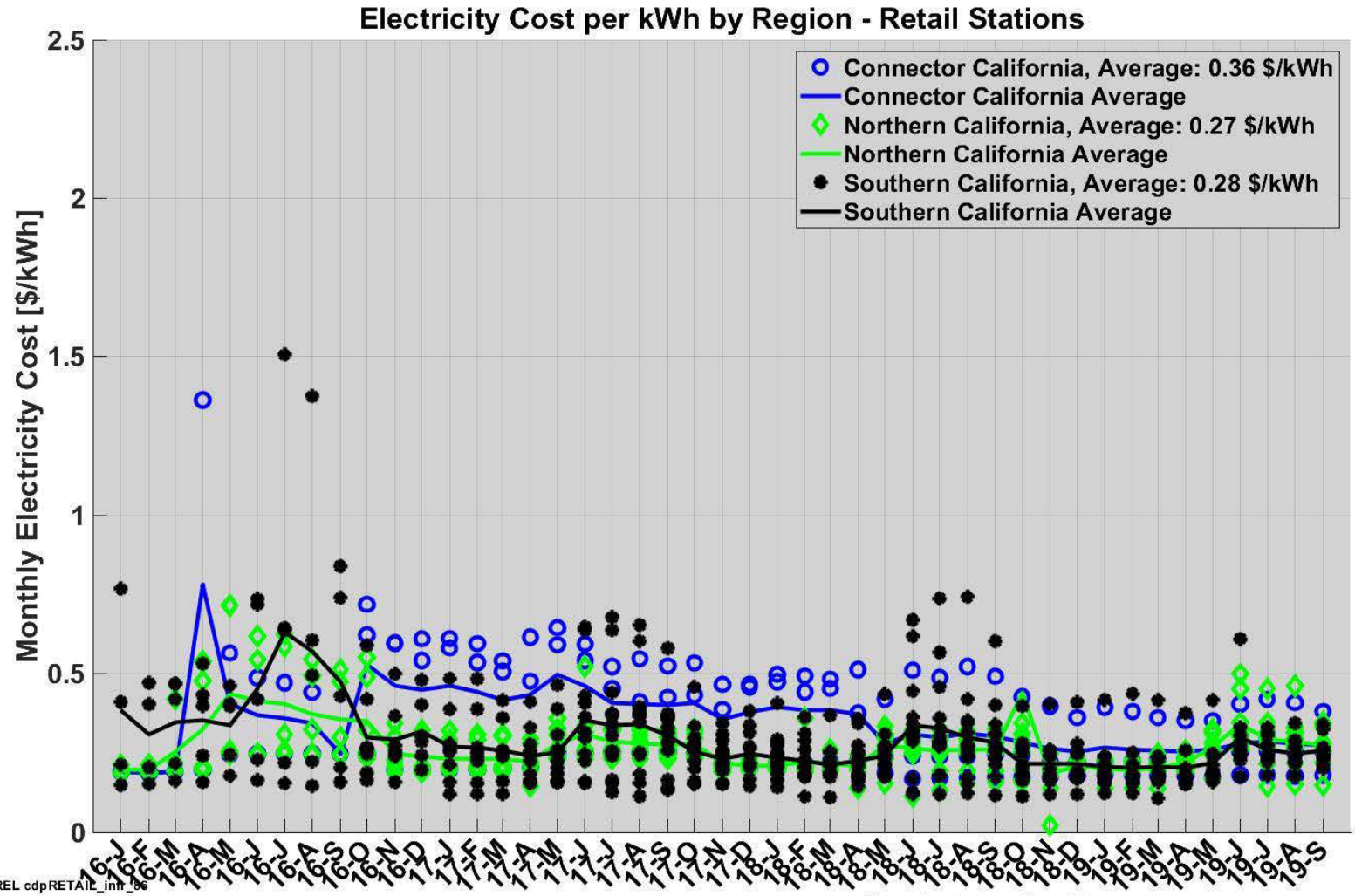
NREL cdpRETAIL_infr_84
Created: Jan-16-20 3:21 PM | Data Range: 2014Q3-2019Q3

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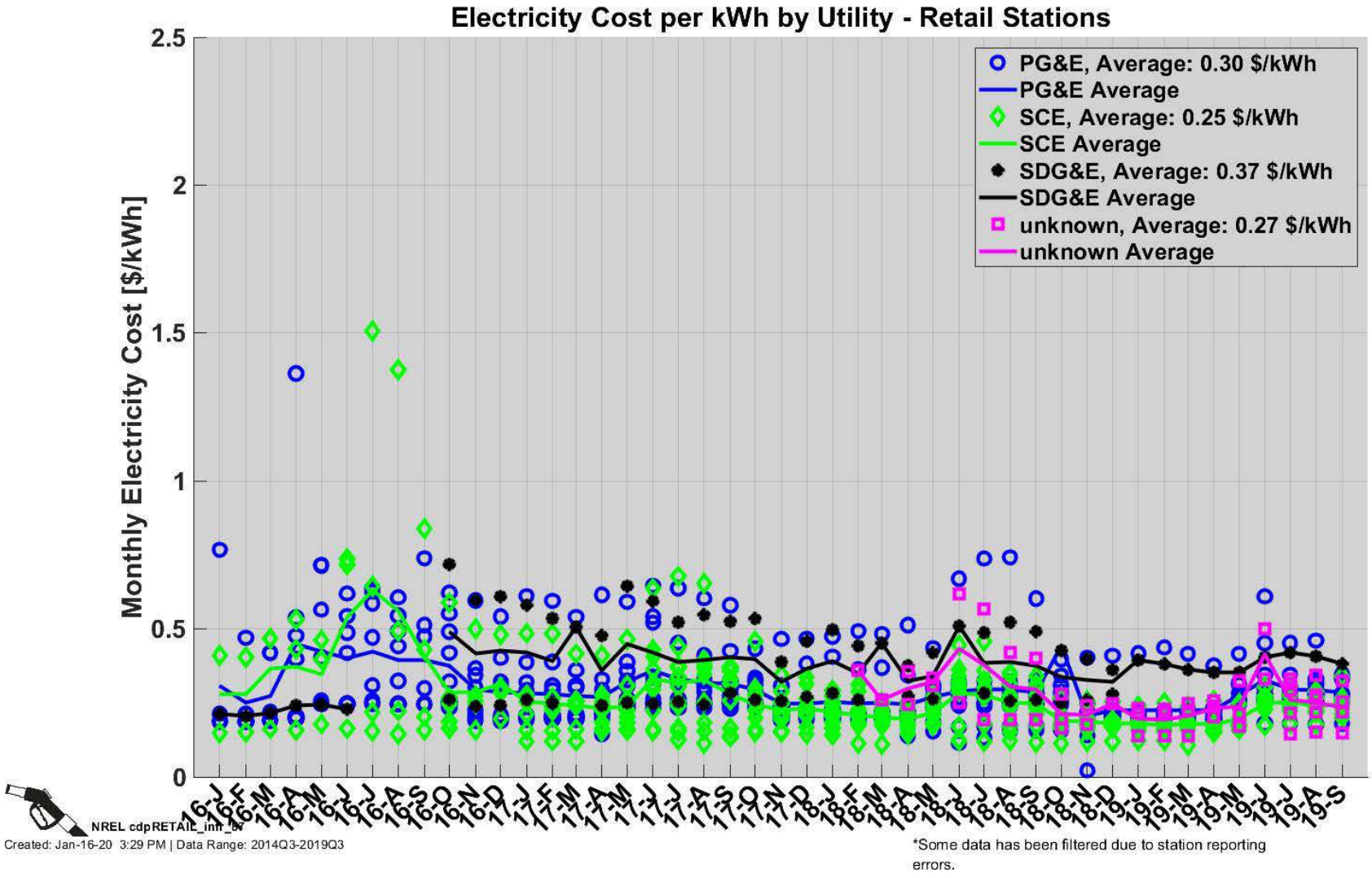
*Some data has been filtered due to station reporting errors.

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



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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.