Fueling Station Component Validation

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H2@Scale Working Group
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Approach: NFCTEC Data/Analysis/Results Handling

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

DDPs

Internal analysis completed quarterly

NREL's National Fuel Cell Technology Evaluation Center

Results

Confidential

Public

CDPs

Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months[1]

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months[2]

1) Data exchange may happen more frequently based on data, analysis, and collaboration
2) Results published via NREL Tech Val website, conferences, and reports

Collaborations

Data Requirements > Data Reporting > Analysis Results > Feedback

STATION PROVIDERS

Air Liquide
Air Products
California State University Los Angeles
Equilon
FirstElement Fuel
H2 Frontier
ITM Power
Iwatani
Linde
Messer
Proton OnSite/NEL
Shell
StratosFuel

STATION FUNDERS

California Energy Commission
California Air Resources Board
SCAQMD

ORGANIZATIONS

California Fuel Cell Partnership
IPHE and HySUT
Gas Technology Institute
CA - CDFA Division of Measurement Standards

Relevance: Evaluating Existing Stations/Equipment

A Developing Market

- 41 retail stations open (39 last AMR)
  - 40 in CA
  - 1 in CT
  - As of April 2020
- Supporting over 8,250* FCEVs
  - 2,006* FCEVs sold in 2019

Air Liquide, Anaheim, CA. Photo: NREL

FirstElement Fuel, Costa Mesa, CA. Photo: NREL

Objectives

- Use existing stations as real-world guide for future innovations
- Identify issues for research
- Have results readily available (both public and private)

** https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates*

Hydrogen Stations Across the U.S.
Light Duty

45 Total Stations

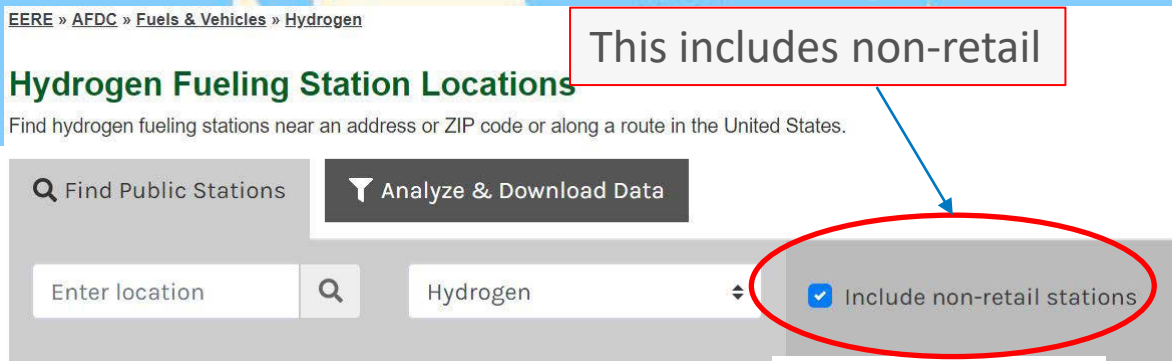
Retail and Non-Retail

43 are Retail - Open

North East
12-25 Retail – Planned
1 Retail Station Open
5 Retail Stations Planned in 2020

California
41 Retail - Open
18 Retail – Planned Awarded

California
200 targeted by 2025
1,000 targeted by 2030

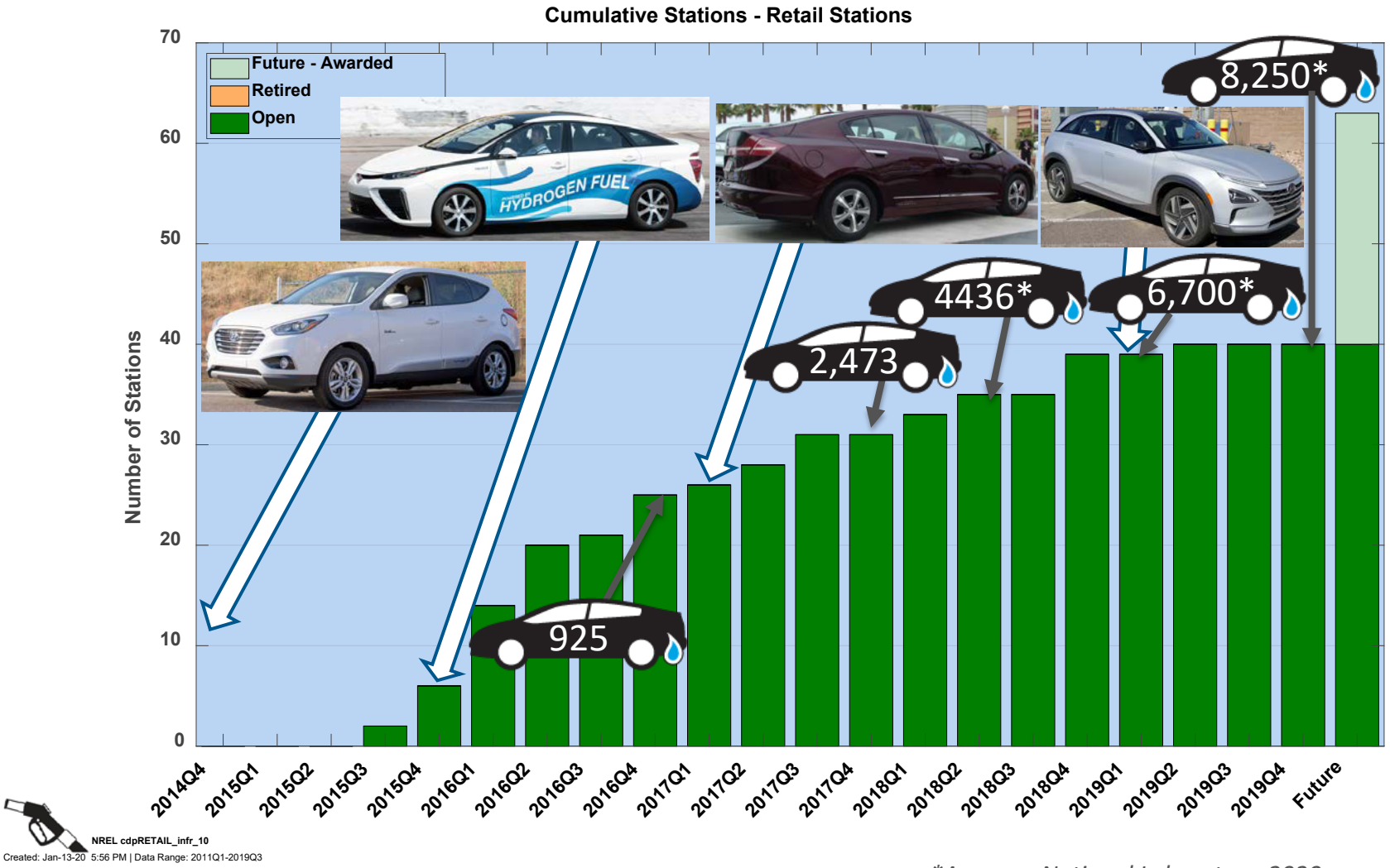


This includes non-retail

www.cafcp.org/sites/default/files/h2_station_list.pdf
www.afdc.energy.gov/fuels/hydrogen_locations.html

As of 4/6/2020

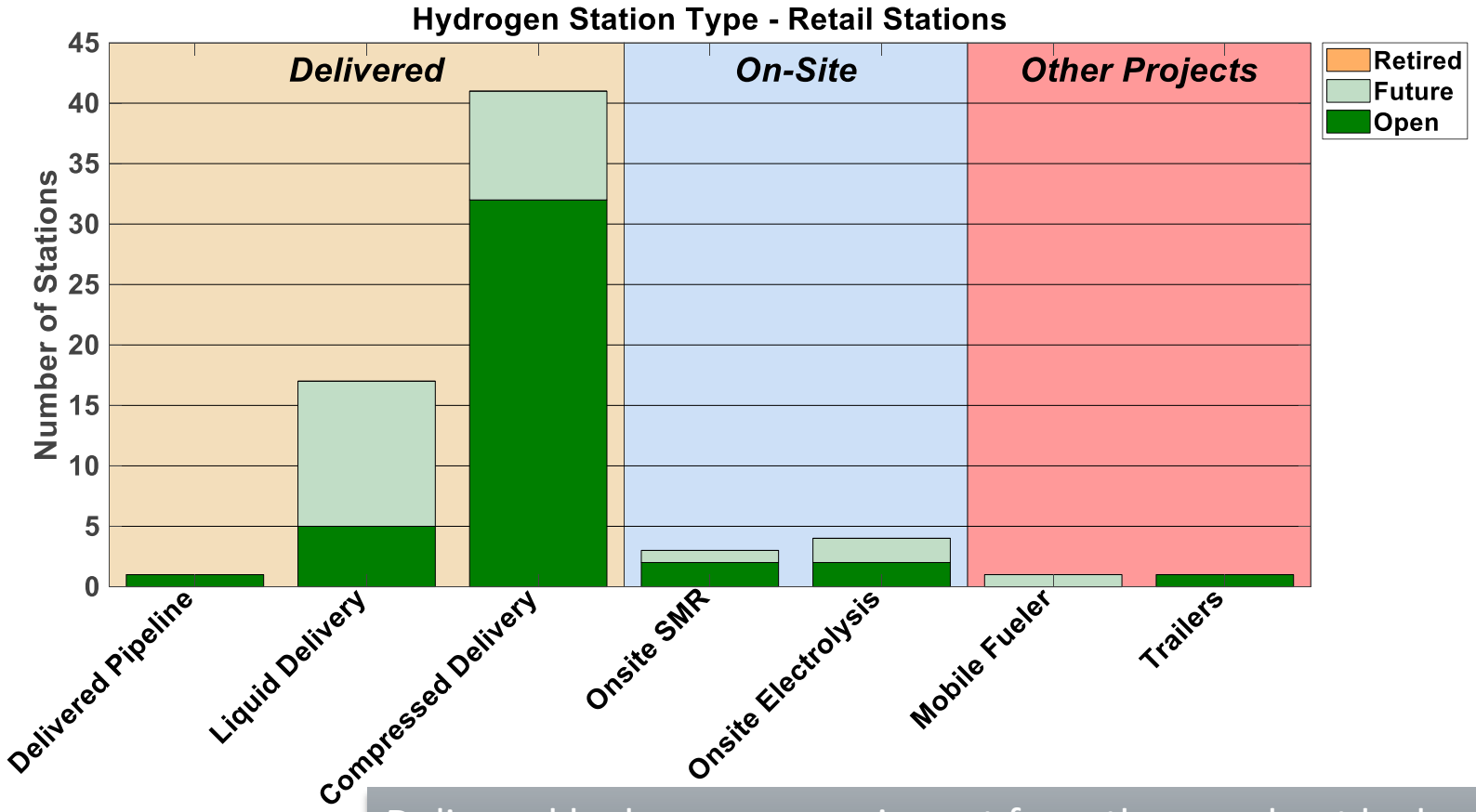
Cumulative Number of Retail Stations



*Argonne National Laboratory, 2020

Next challenge: Medium/heavy duty FC truck refueling

Station Types



NREL cdpRETAIL_infr_11
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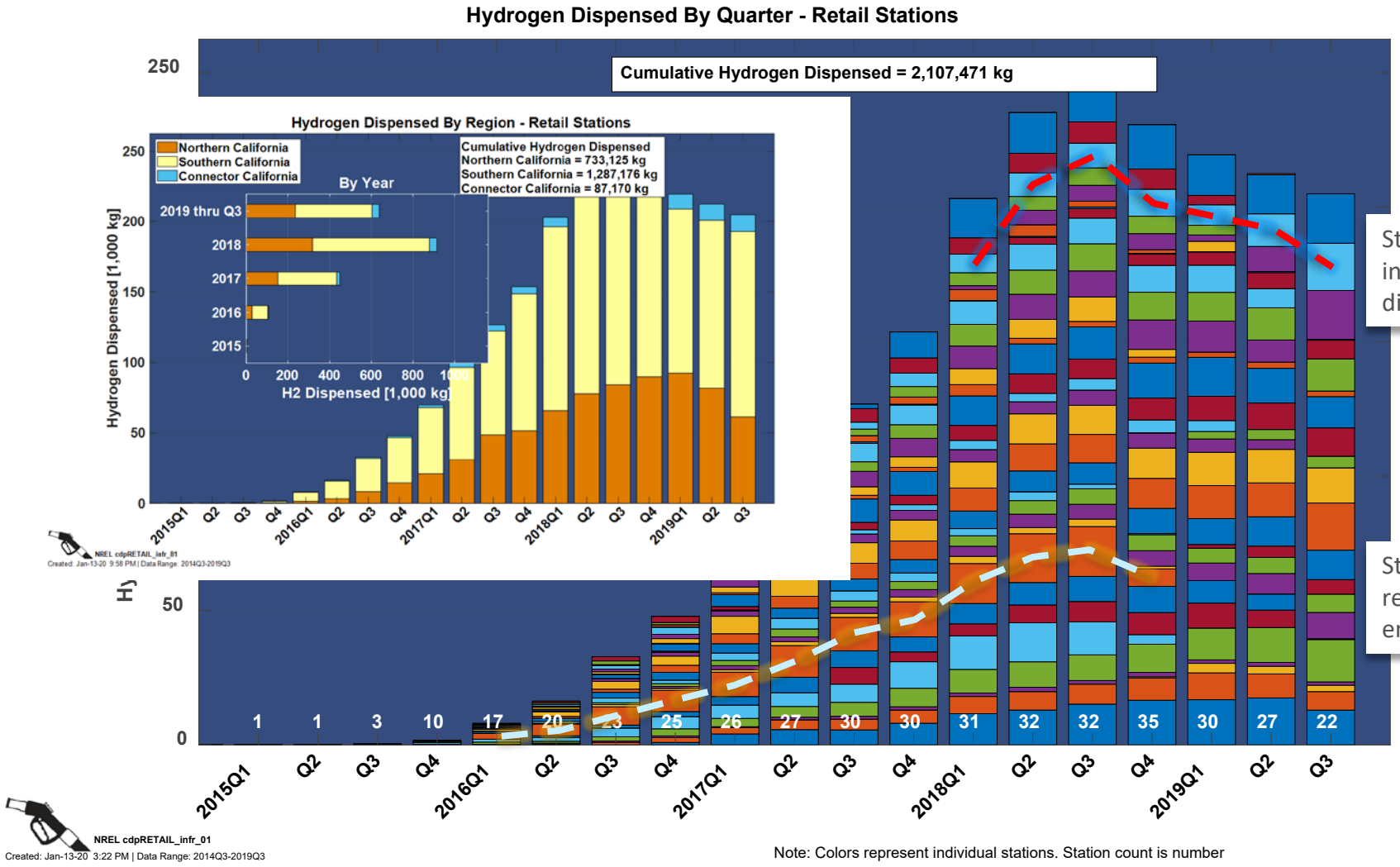
Delivered hydrogen comes in part from the merchant hydrogen chemical market which is about 260 tonnes/day for liquid and 15,000 tonnes/day for gaseous*. The flexibility of this market has decreased recently due to demands by FCEVs and other new markets. California FCEVs accounted for ~2.5 tonne/day in 2018.

** Hydrogen and Fuel Cells for Data Center Applications Project Meeting: Workshop Report.* NREL/TP-5400-75355.

Hydrogen Dispensed by Quarter



Station with increasing H2 dispensed trend

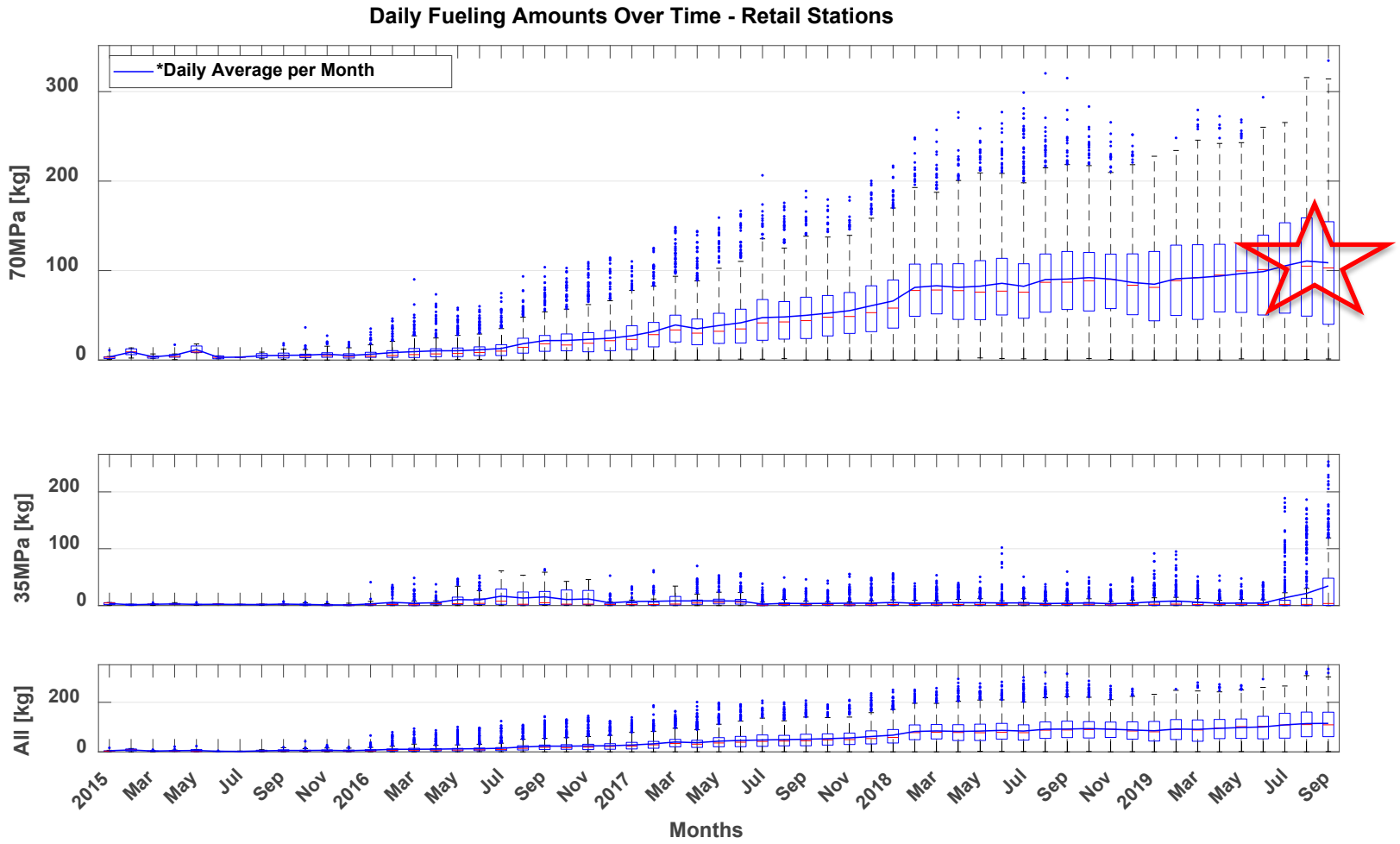
Station whose reporting req. ended

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

Following the color bars, which represent individual stations, one can trace generally increasing H2 dispensed and non-reporting.

Station usage

Daily average per month of 70 Mpa fills now over 100 kg



NREL cdpRETAIL_infr_82

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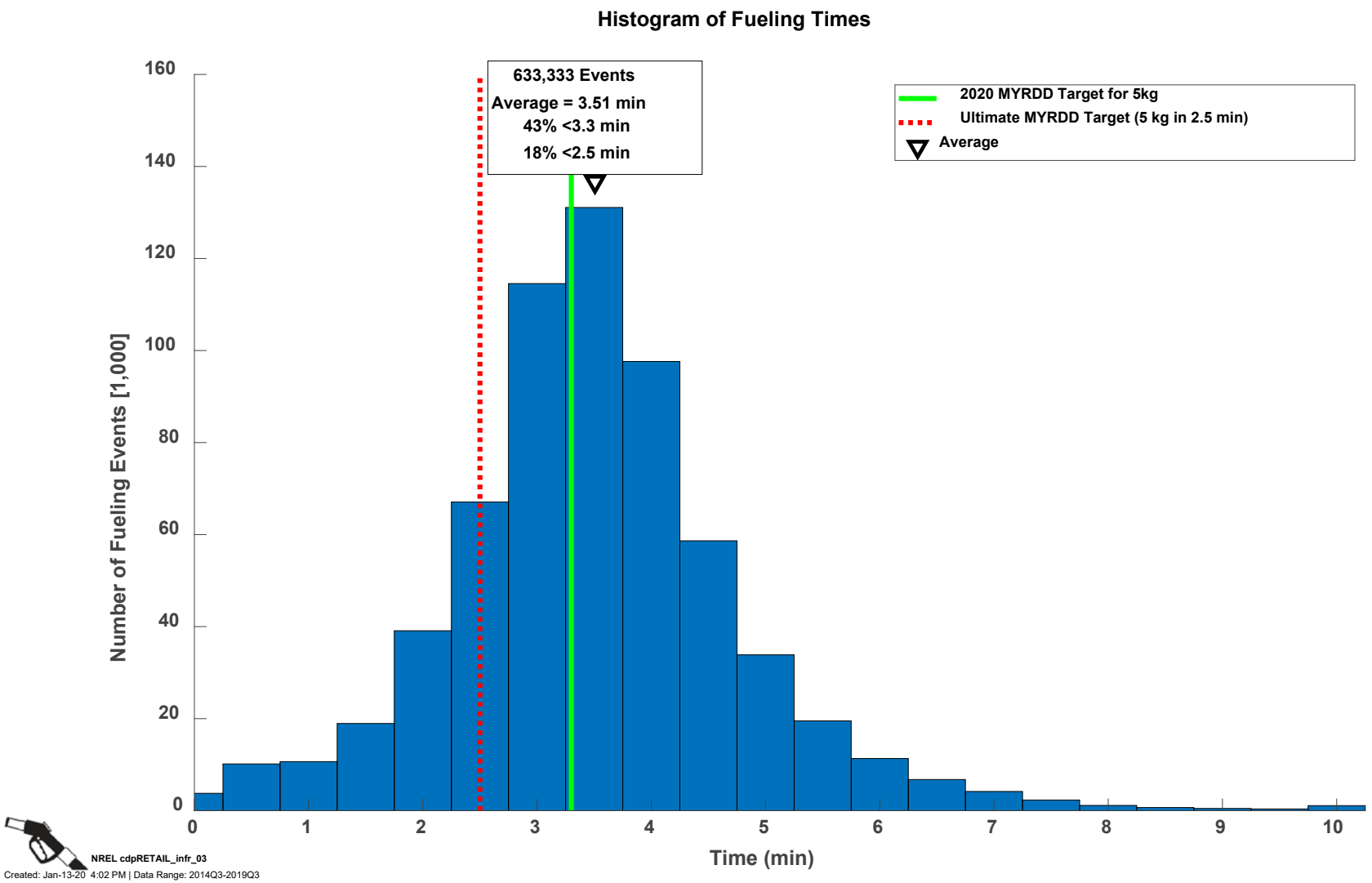
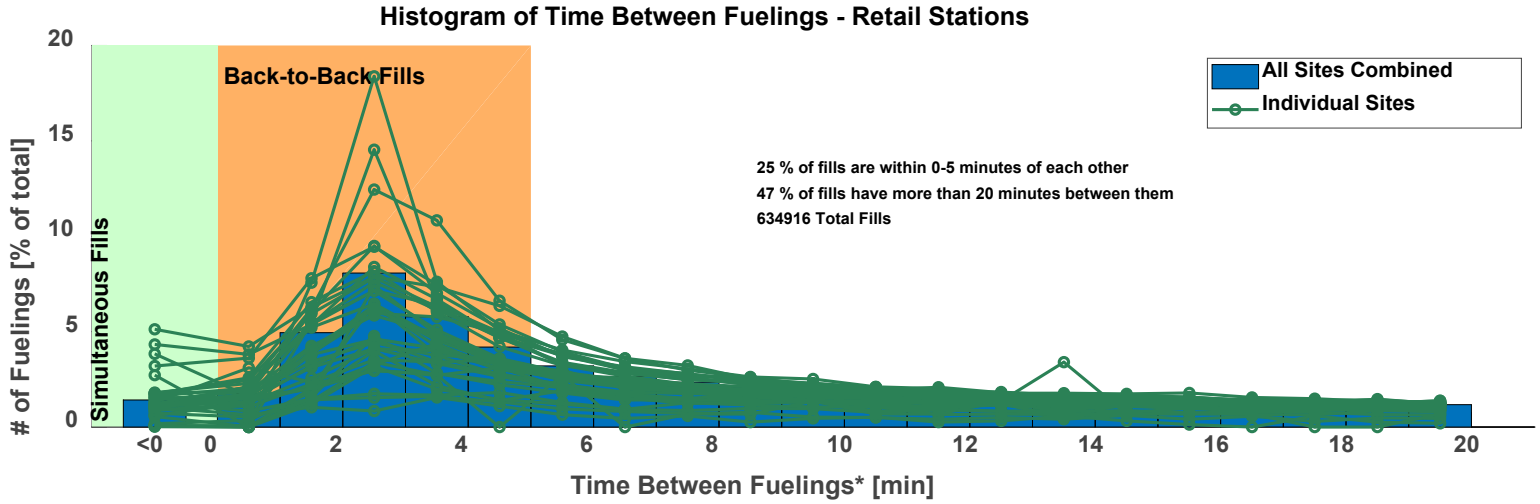
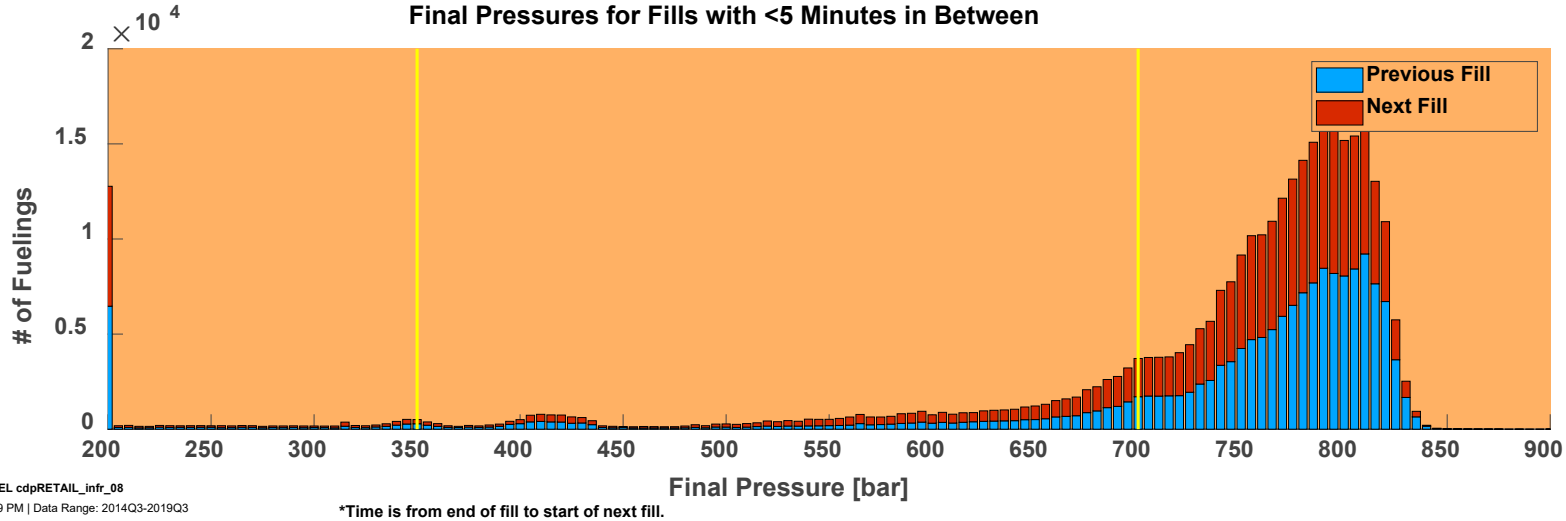
*Daily average only includes days with fills.

Histogram of Fueling Times



Time Between Fueling





NREL cdpRETAIL_infr_08

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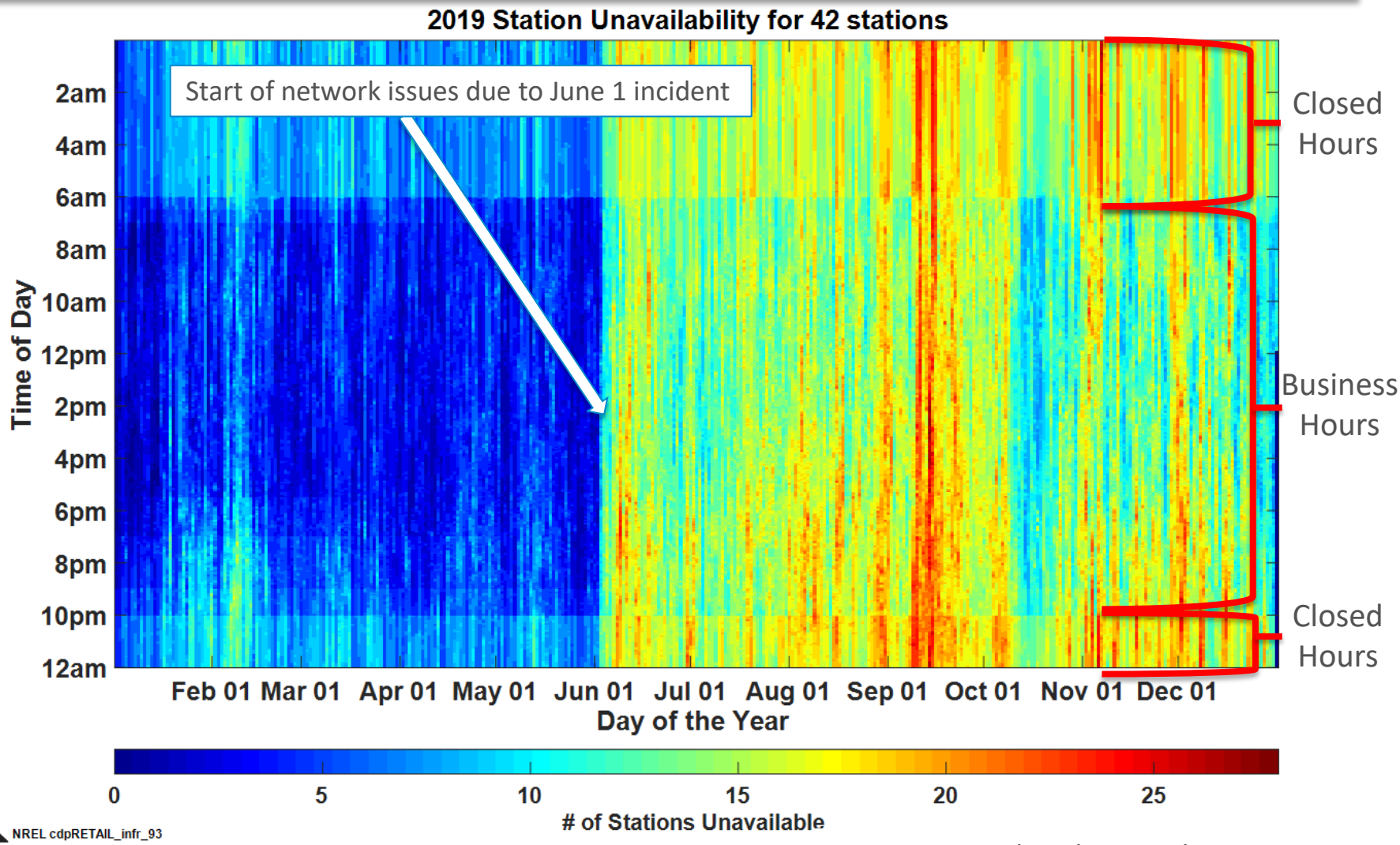
*Time is from end of fill to start of next fill.

Station Unavailability: Number of Stations Unavailable

Based on SOSS "Offline" status for all of 2019.



NREL cdpRETAIL_infr_93
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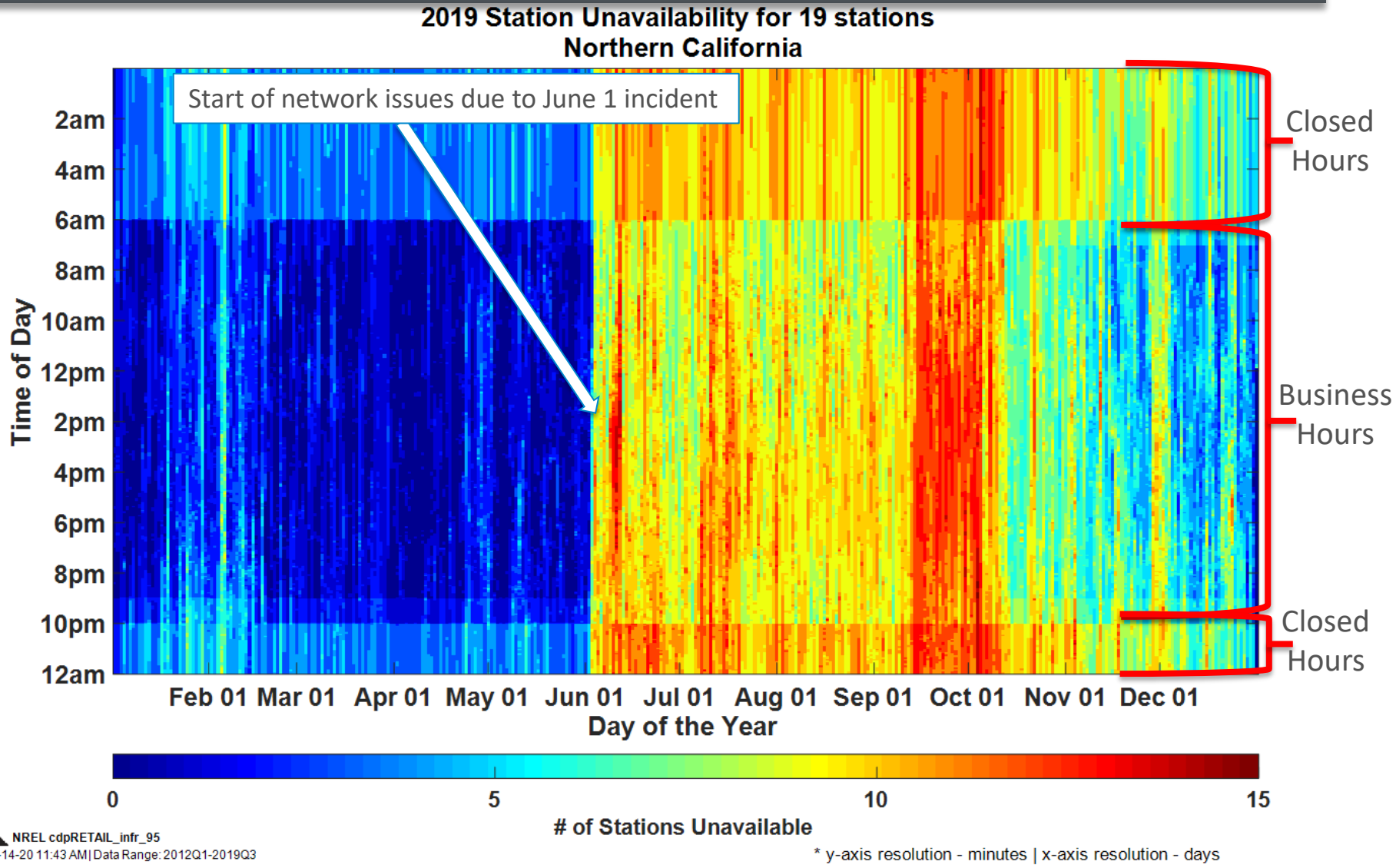
6 stations are closed overnight
36 Stations are open 24/7

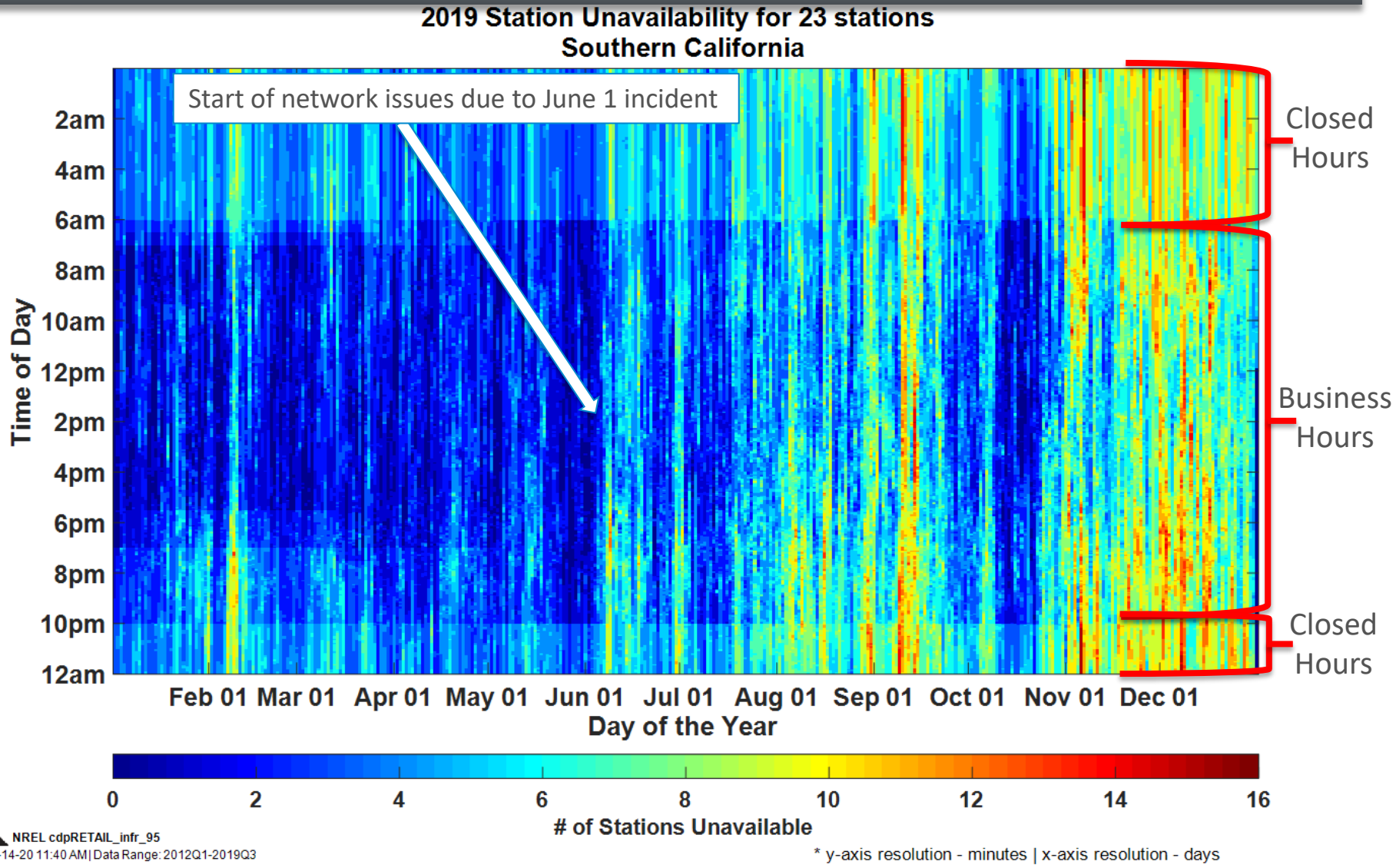
Station Unavailability: Number of Stations Unavailable (Northern California)

Significant network effects to Northern California Retail Stations from June 1 incident



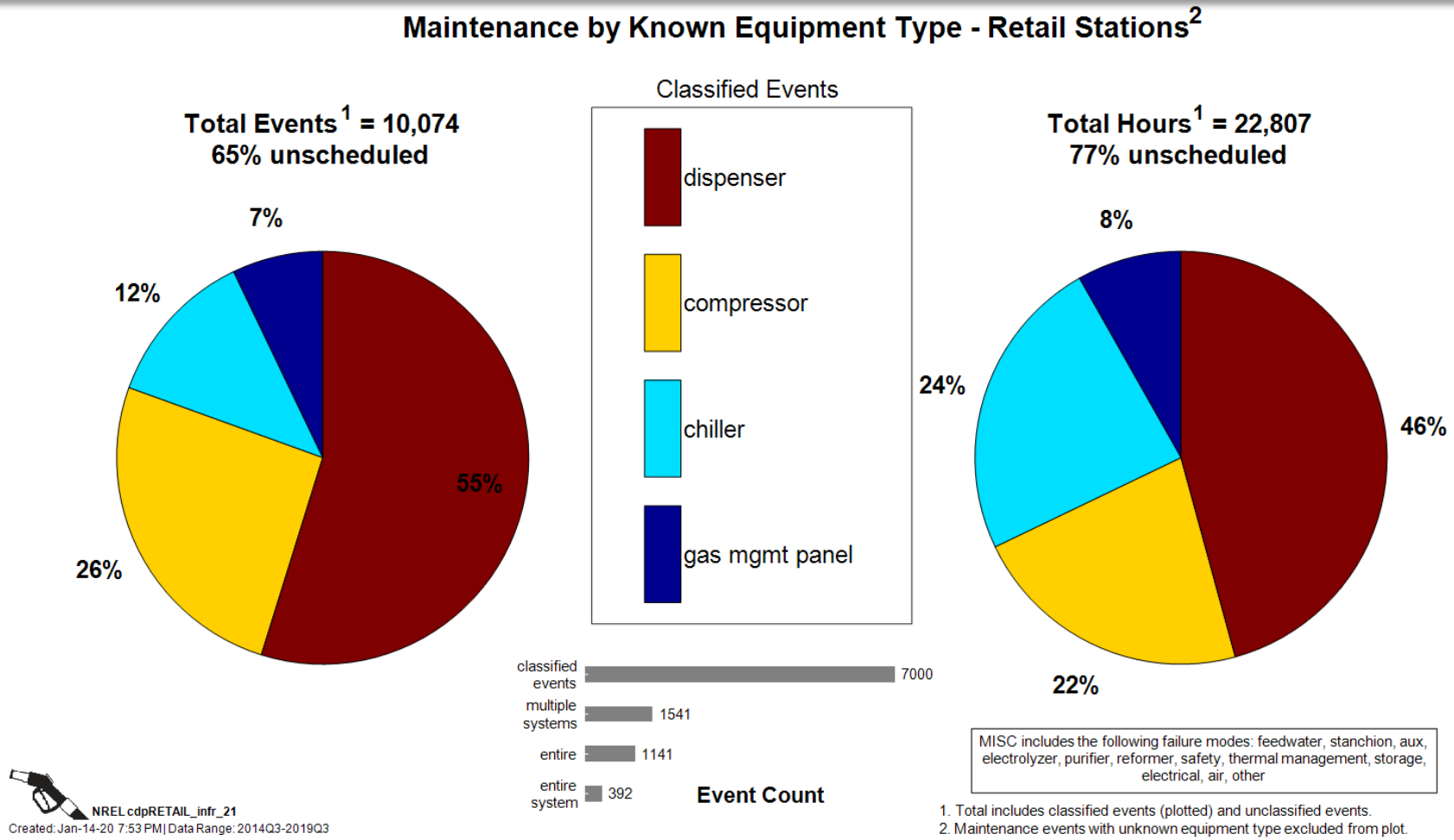
Station Unavailability: Number of Stations Unavailable (Southern California)

Less significant network effects to Southern California Retail Stations from June 1 incident



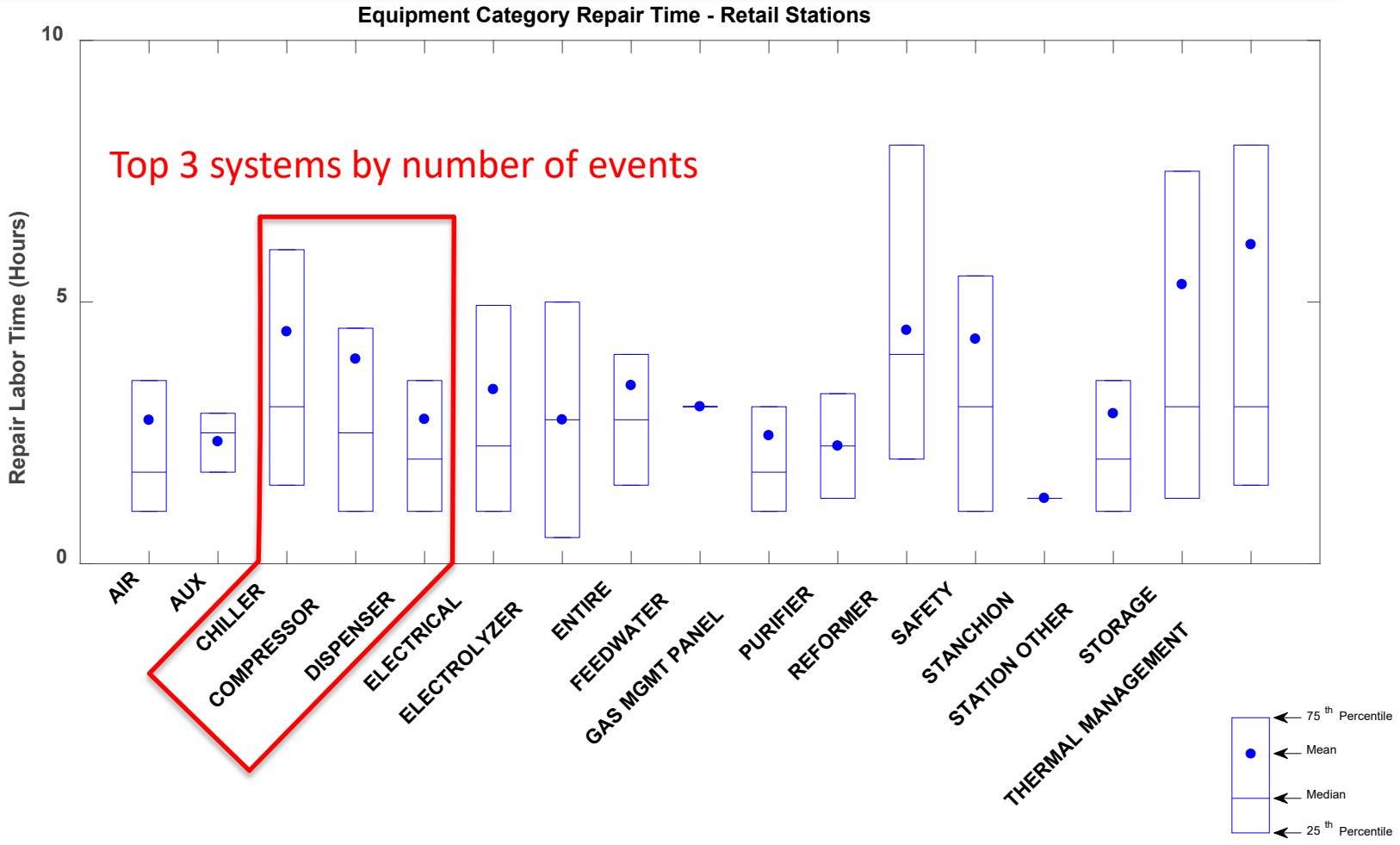
Maintenance by Equipment Type

Most maintenance remains on dispensers, followed by compressors.
Chiller maintenance large portion of events and hours (stations fill at -40 C).



Equipment Maintenance by Time

Of the equipment most identified for repair by event, repair times per event: Chiller ~1-6 hr, Compressor ~0.5-4.5 hr, Dispenser ~0.5-3 hr



NREL cdpRETAIL_infr_23
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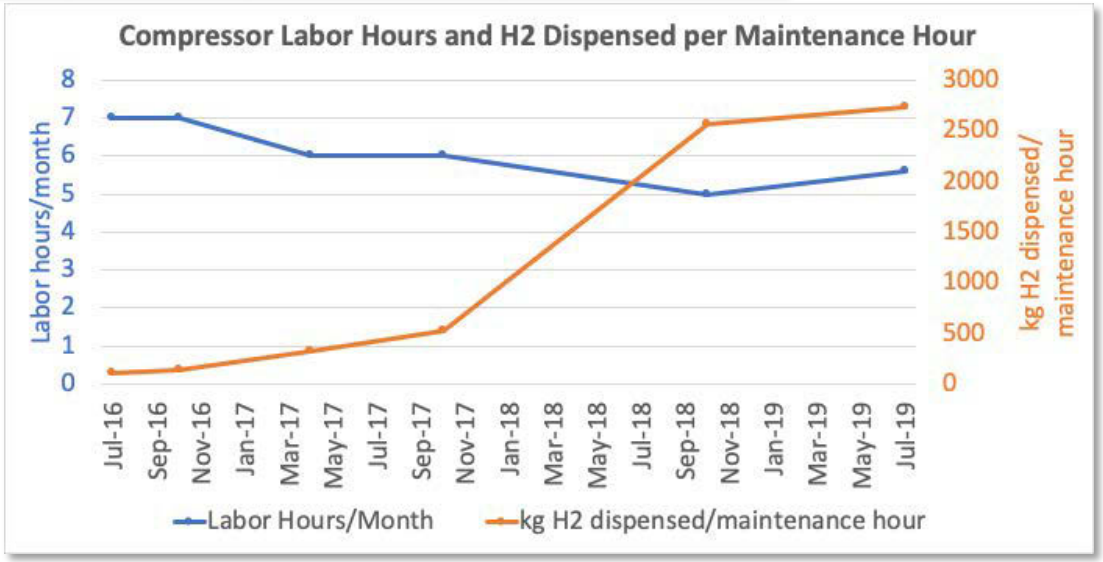
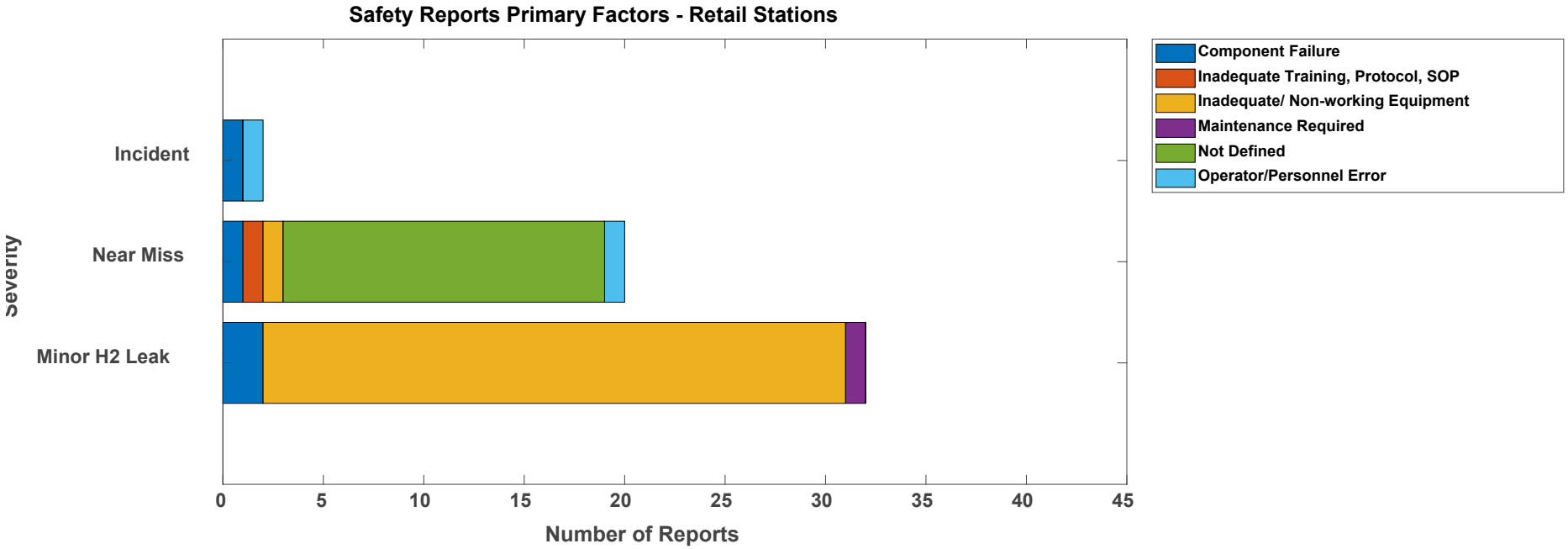
Compressor Deep Dive

Data normalized per station				
Events/ Month	kg H2 dispensed /event	Labor Hours/ Month	kg H2 dispensed/ maint. hour	Data through Quarter
2	N/A	7	105	Q3 2016
2	450	7	140	Q4 2016
3	812	6	328	Q2 2017
3	N/A	6	525	Q4 2017
3	N/A	5	2569	Q4 2018
2.8	2358	5.6	2739	Q3 2019

Labor hours per station per month spent on compressor maintenance has been declining while dispensed hydrogen per station per maintenance hour is increasing.



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

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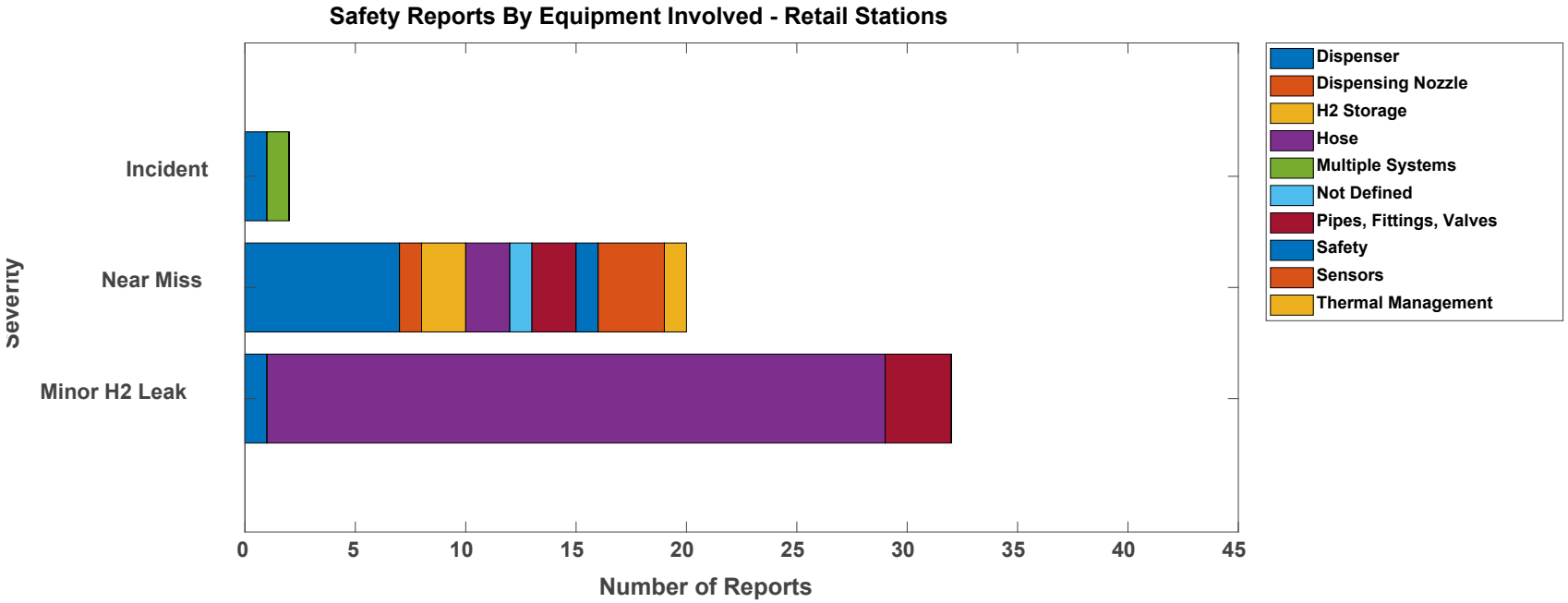
Safety Reports by Equipment Involved



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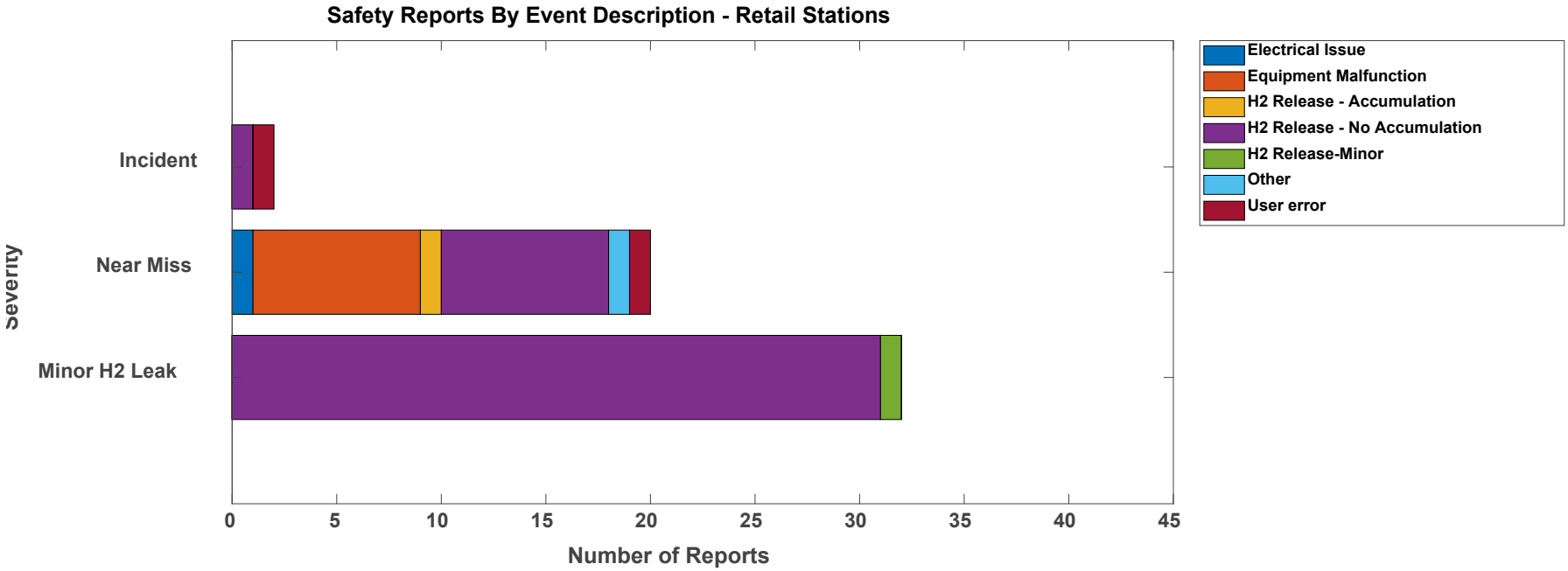
NREL cdpRETAIL_infr_32

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

Safety Reports by Event Description



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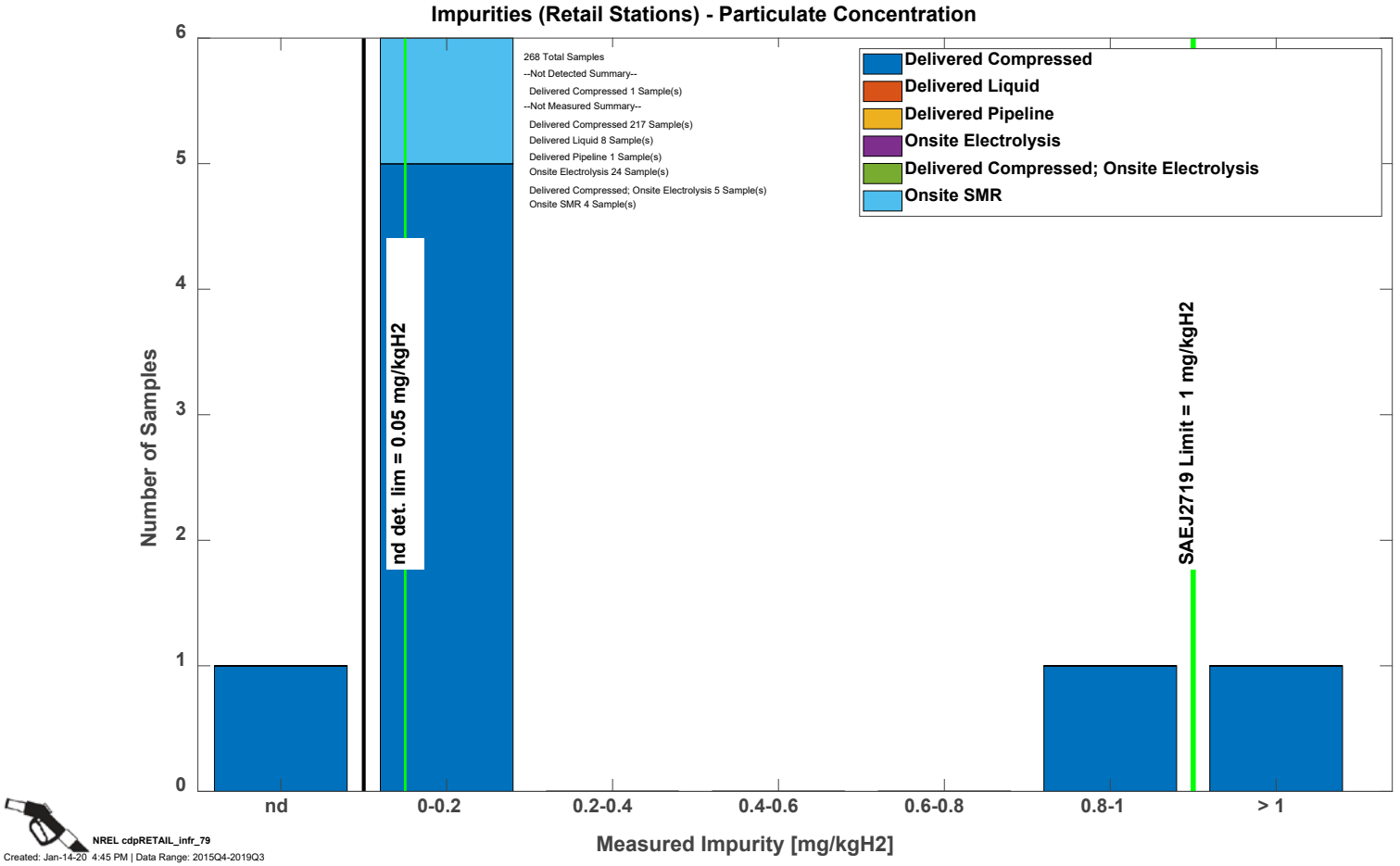
NREL cdpRETAIL_infr_34

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

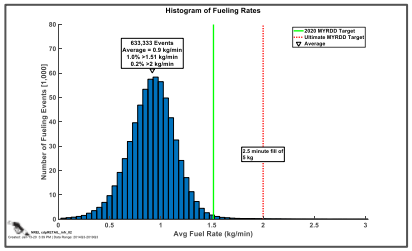
Impurities—Particulate Concentration

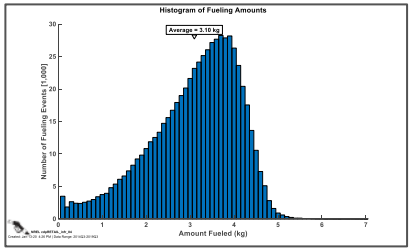


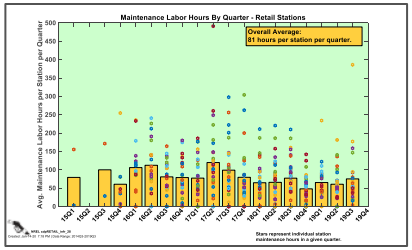
Impurity charts for: ammonia, argon, CO, CO2, formaldehyde, formic acid, helium, nitrogen, oxygen, particulate concentrate, total halogenates, total hydrocarbons, total sulfur, water

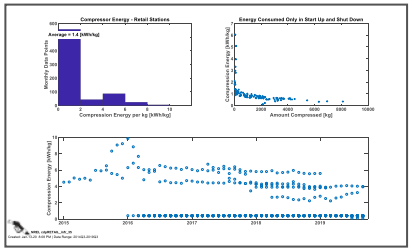
Sampling of Results

- **Station data: 98 Composite Data Products in 8 topic areas publicly available https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html**
- **Expecting data from 3 FY19 awarded MW scale electrolysis projects**

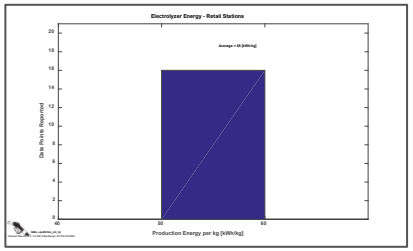


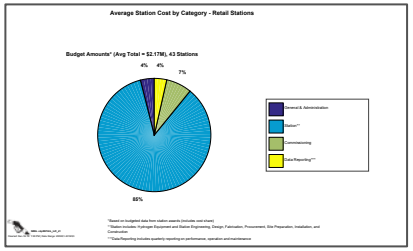


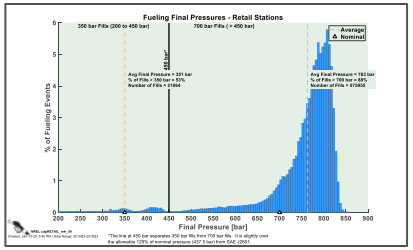


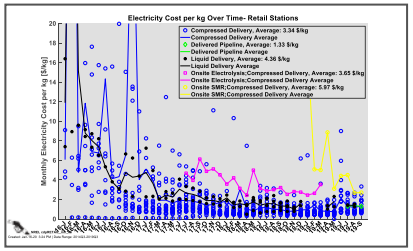


Fueling Rate Average	0.9 kg/min
Fueling Amount Average	3.1 kg
Fueling Time Average	3.51 min
Compressor Energy Average	1.4 kWh/kg
Total Hydrogen Dispensed (35 Stations)	2,107,471 kg 1,470,151 kg - 18Q4
Electrolyzer Energy Average	58 kWh/kg
Maintenance Hours Average	81 hours/Quarter
Fueling Final Pressure Average	763 bar
Average Electricity Cost by Delivery Type 2019Q3	$3.34/kg – Compressed $4.36/kg – Liquid $3.65/kg –Electrolysis









Thank You

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NREL/PR-5400-76846

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