Fueling Station Component Validation

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National Renewable Energy Laboratory

DOE Hydrogen and Fuel Cells Program
2020 Annual Merit Review and Peer Evaluation Meeting

Project ID # IN023

Overview

Timeline and Budget

- Project start date: 10/2011
- FY19 DOE funding (if applicable): $150k
- FY20 planned DOE funding (if applicable): $200k
- Total DOE funds received to date: $1,800k

Barriers

- Lack of current hydrogen refueling infrastructure performance and availability data

Partners

- Industry and agencies listed on collaborations slide

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*

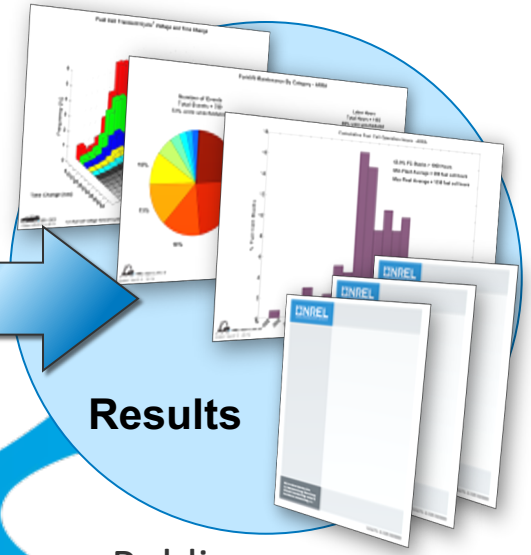
Approach: NFCTEC Data/Analysis/Results Handling

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

Hydrogen Stations Across the U.S.
Light Duty

45 Total Stations

Retail and Non-Retail

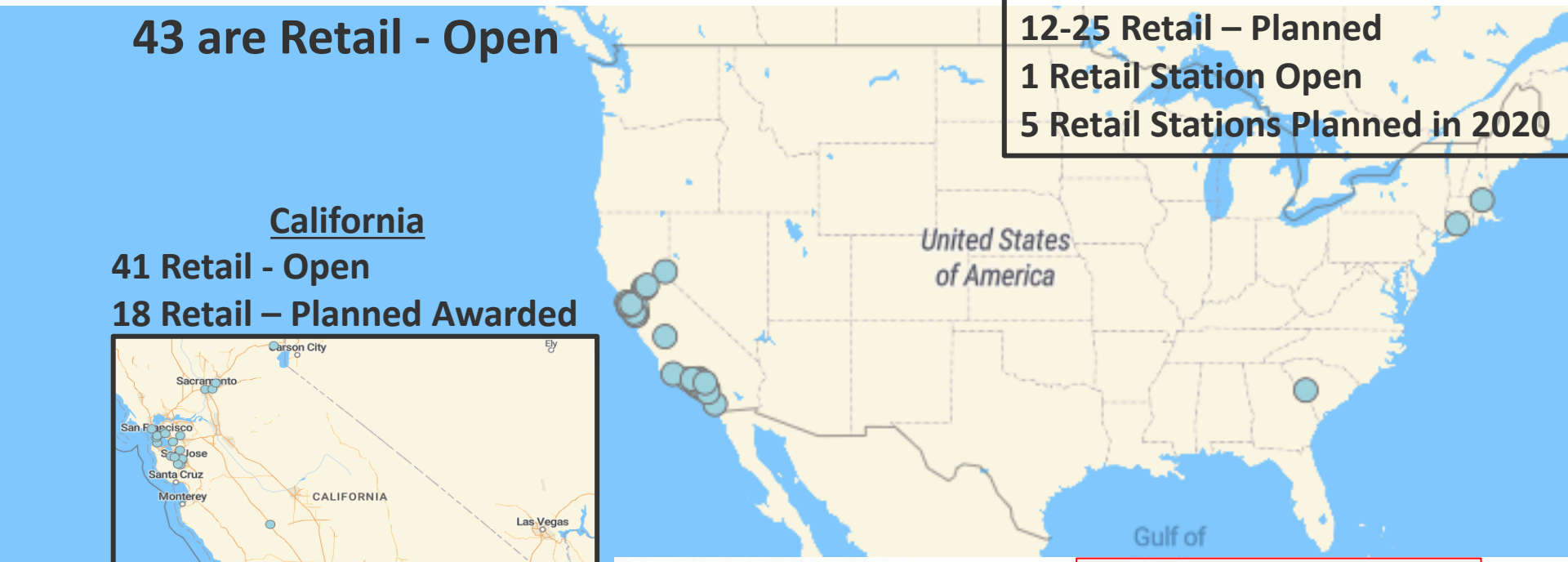
43 are Retail - Open

North East

12-25 Retail – Planned

1 Retail Station Open

5 Retail Stations Planned in 2020



California

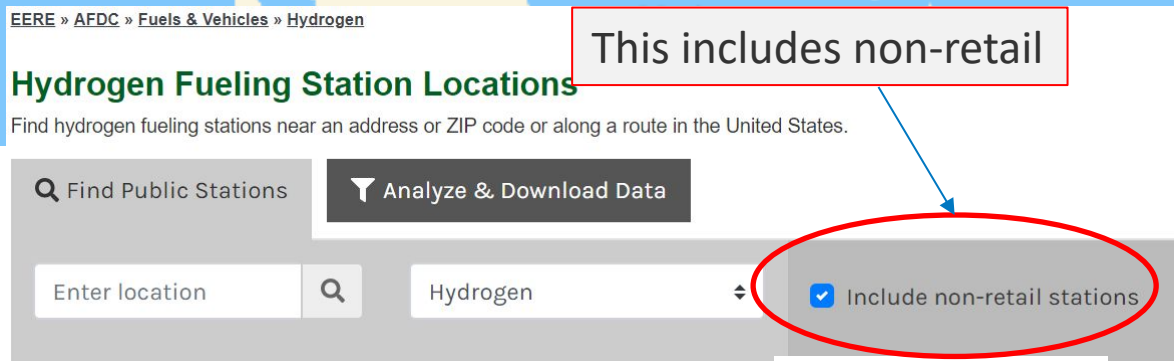
41 Retail - Open

18 Retail – Planned Awarded

California

200 targeted by 2025

1,000 targeted by 2030



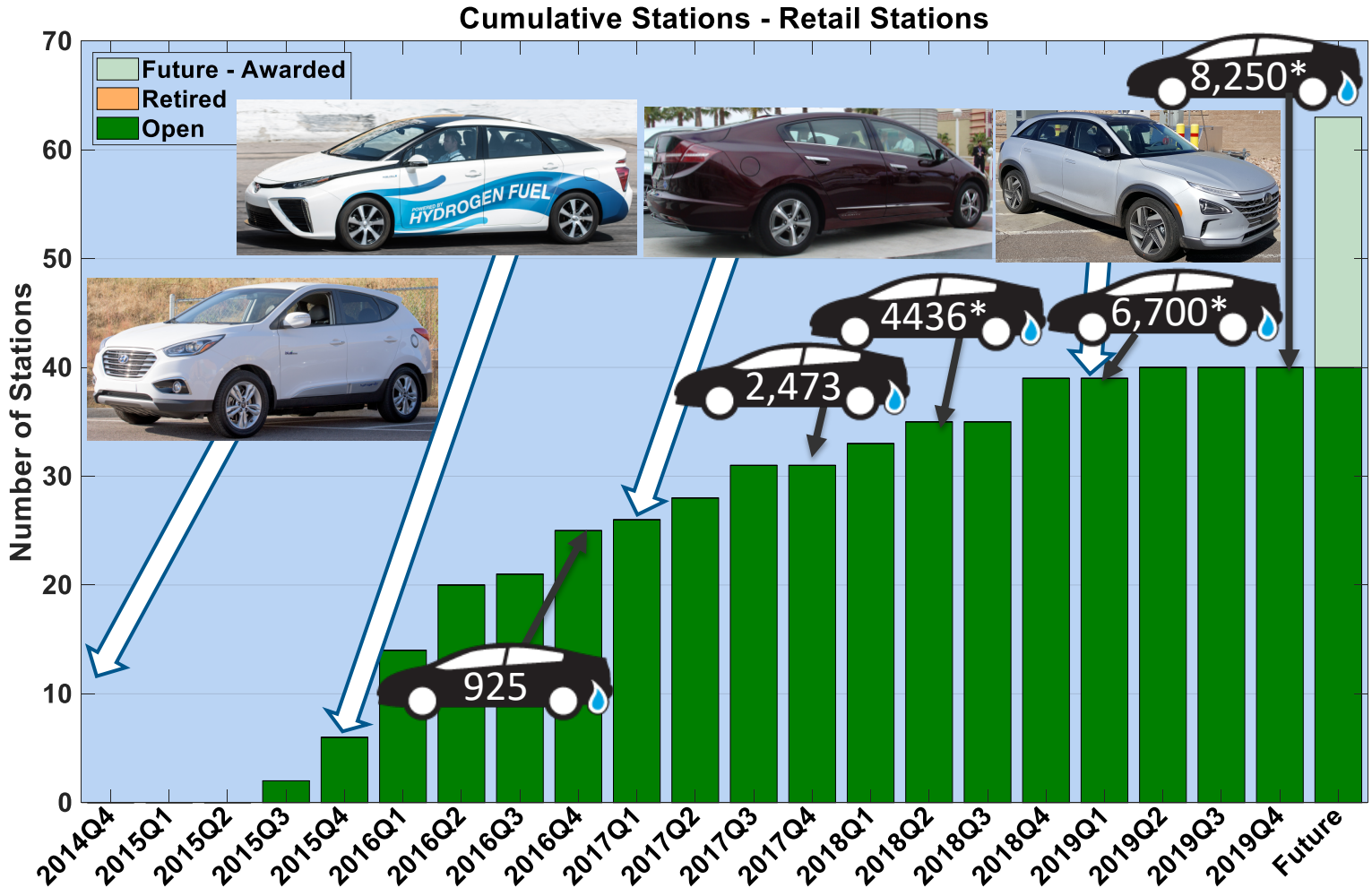
This includes non-retail

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



NREL cdpRETAIL_infr_10
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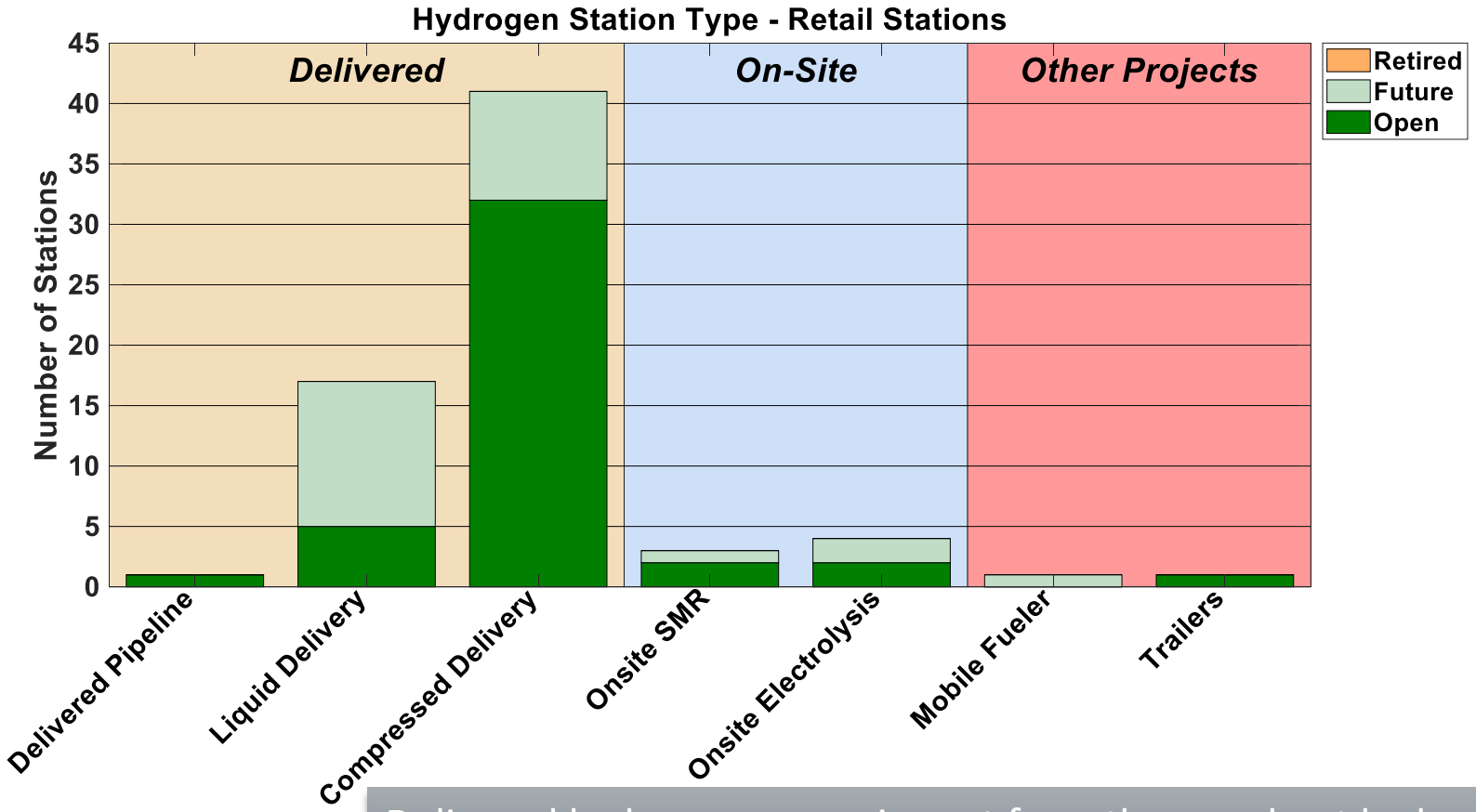
*Argonne National Laboratory, 2020

Next challenge: Medium/heavy duty FC truck refueling

Station Types



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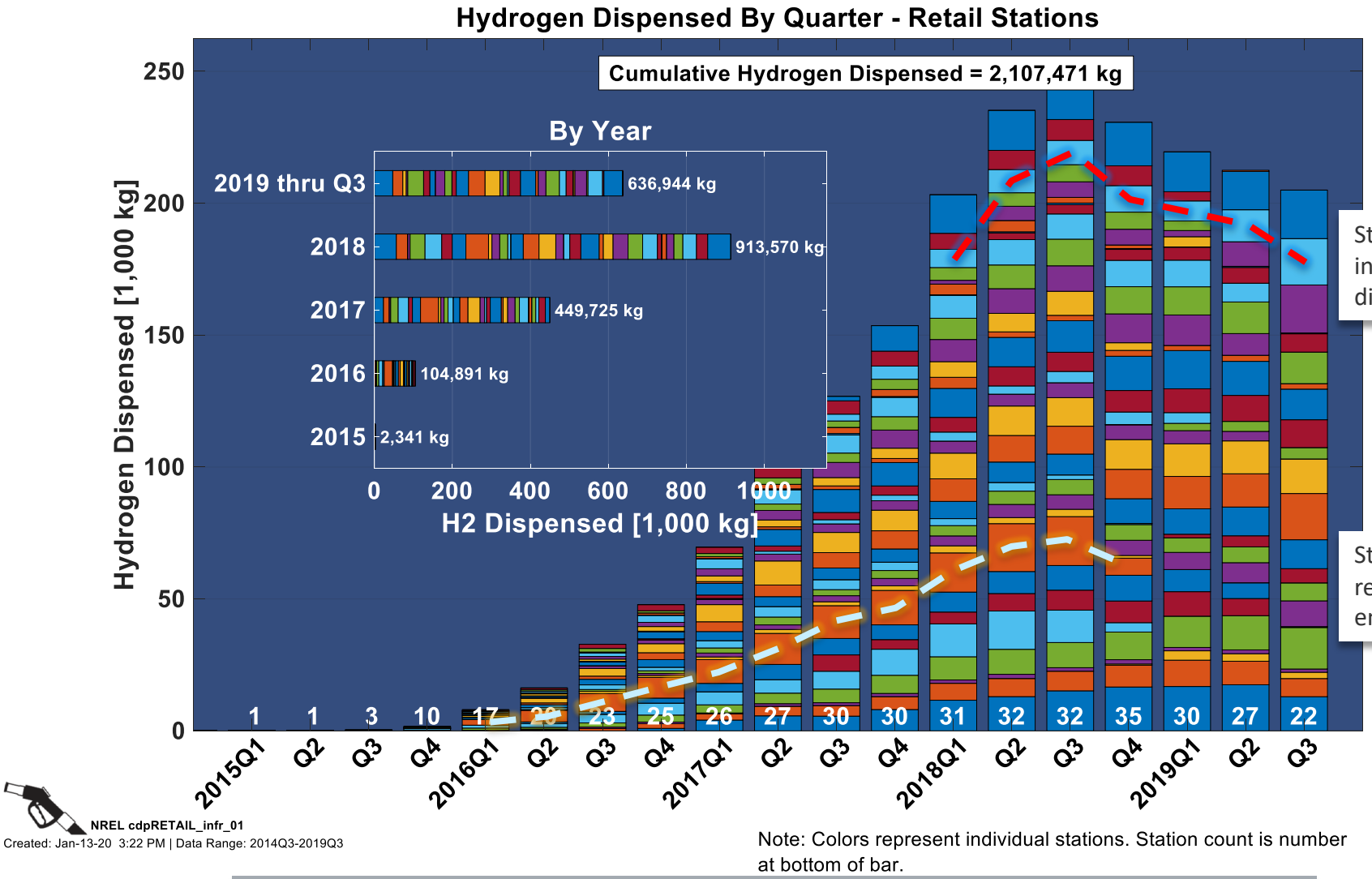
Delivered hydrogen comes in part from the merchant hydrogen chemical market which is about 260 tonnes/day for liquid and 15,000 tonnes/day for gaseous*. The flexibility of this market has decreased recently due to demands by FCEVs and other new markets. California FCEVs accounted for ~2.5 tonne/day in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

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

Accomplishments and Progress:
Hydrogen Dispensed by Quarter



Station with increasing H2 dispensed trend

Station whose reporting req. ended

NREL cdpRETAIL_infr_01
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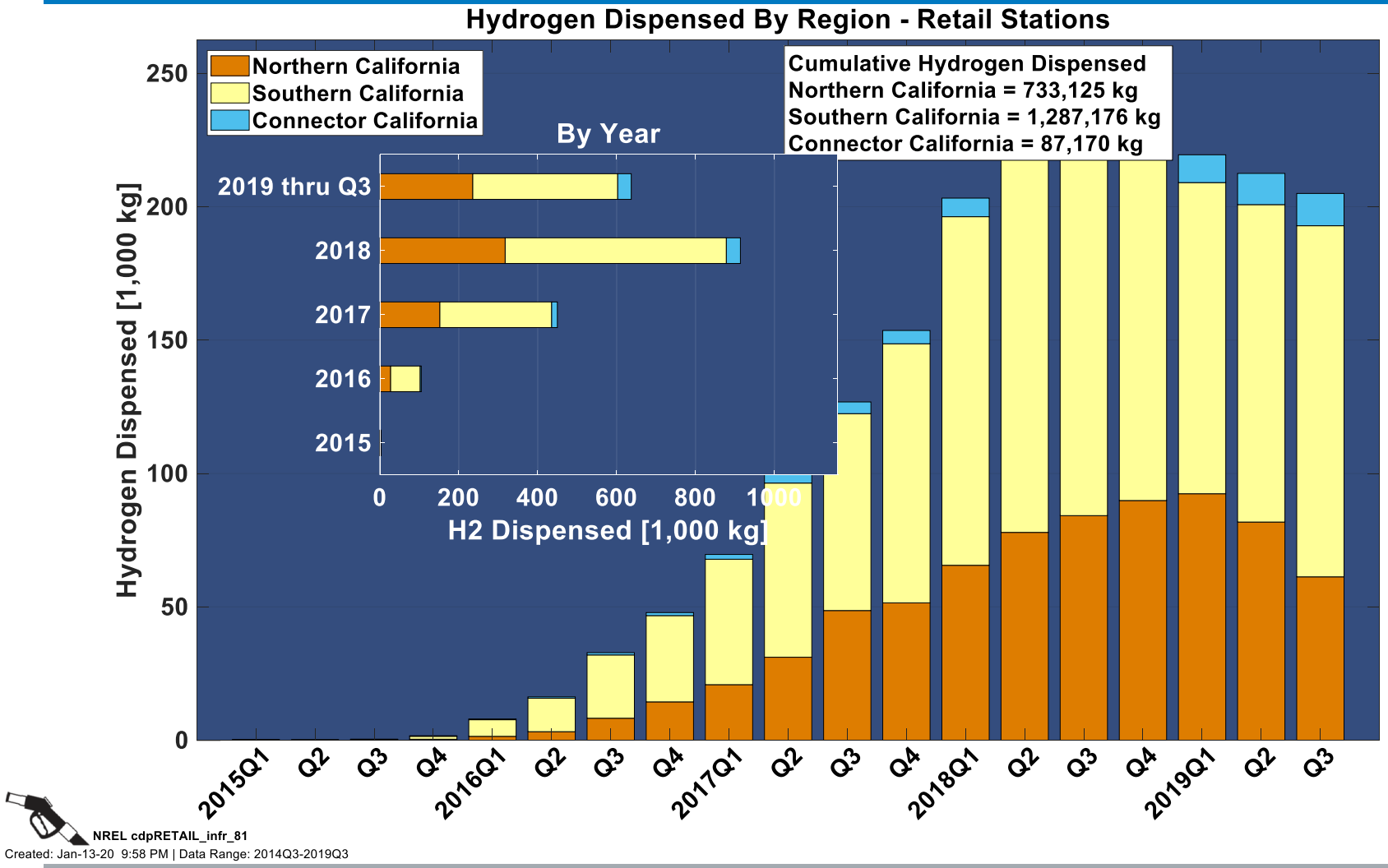
Note: Colors represent individual stations. Station count is number at bottom of bar.

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

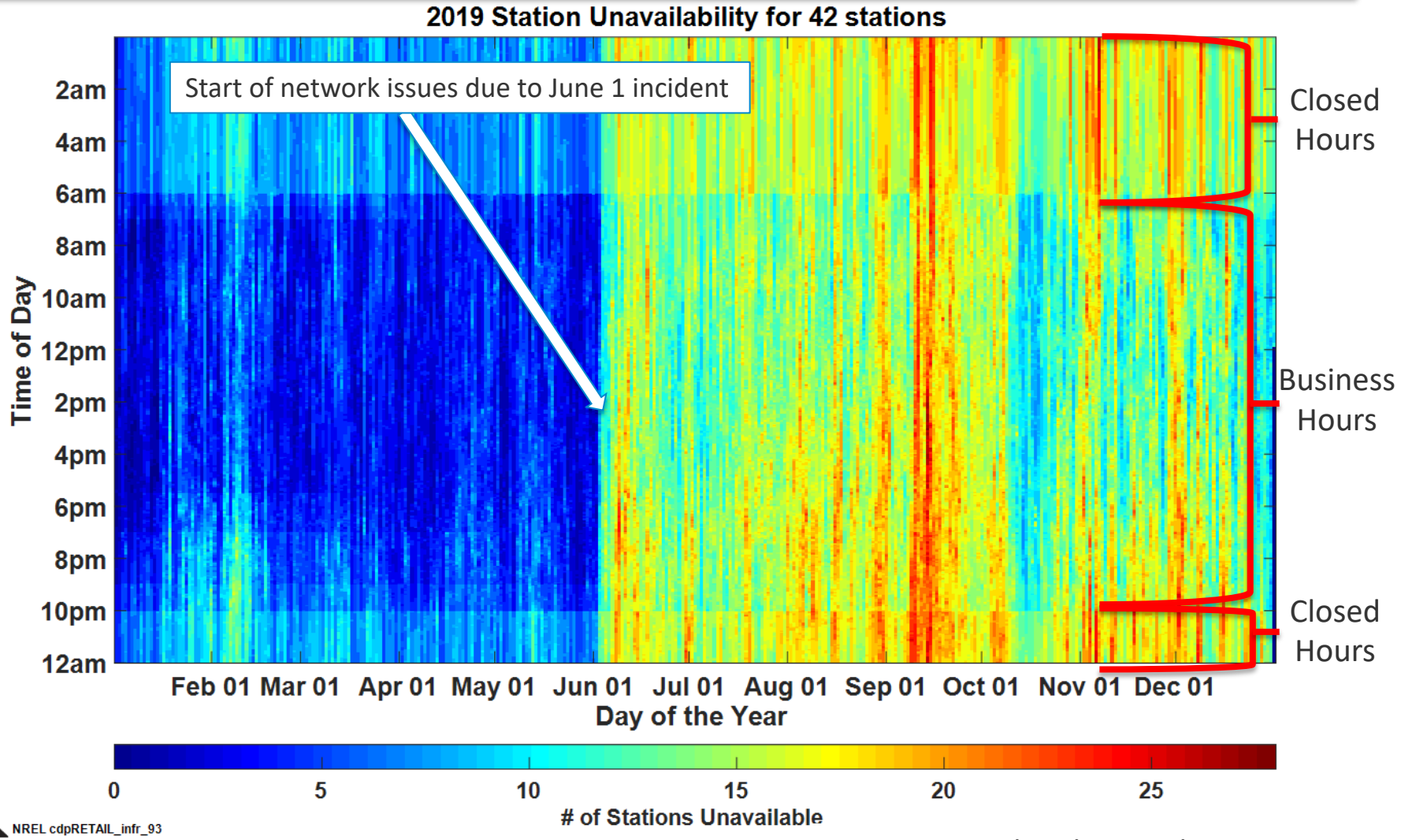
Accomplishment: Hydrogen Dispensed* by Region



* The number of reporting stations has decreased due to the required reporting period expiring starting in 2018Q4. This is not an indication of reduced hydrogen dispensed. Future CDPs will try to visualize the data in different ways.

Accomplishments and Progress:
Station Unavailability: Number of Stations Unavailable

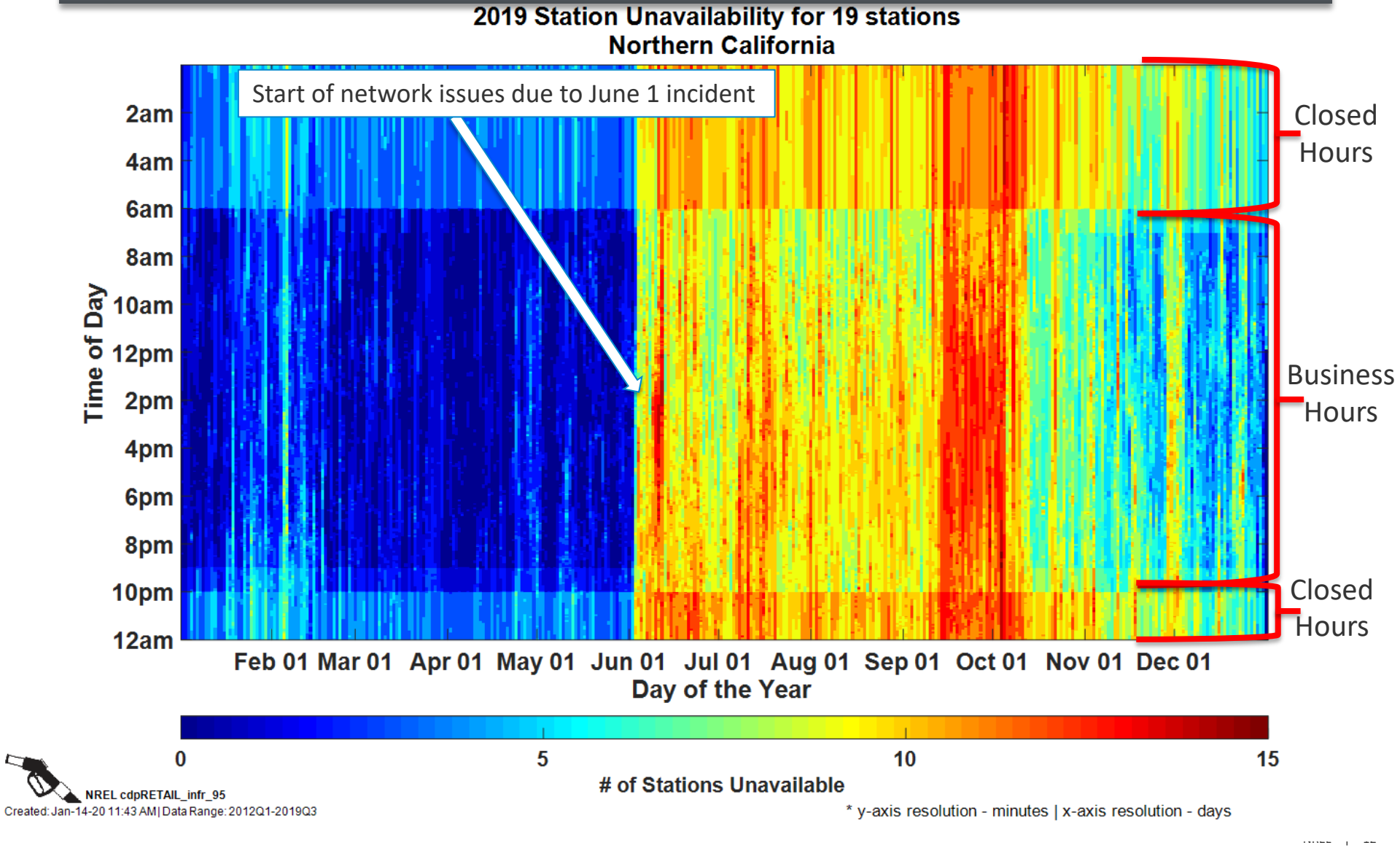
Based on SOSS "Offline" status for all of 2019.



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

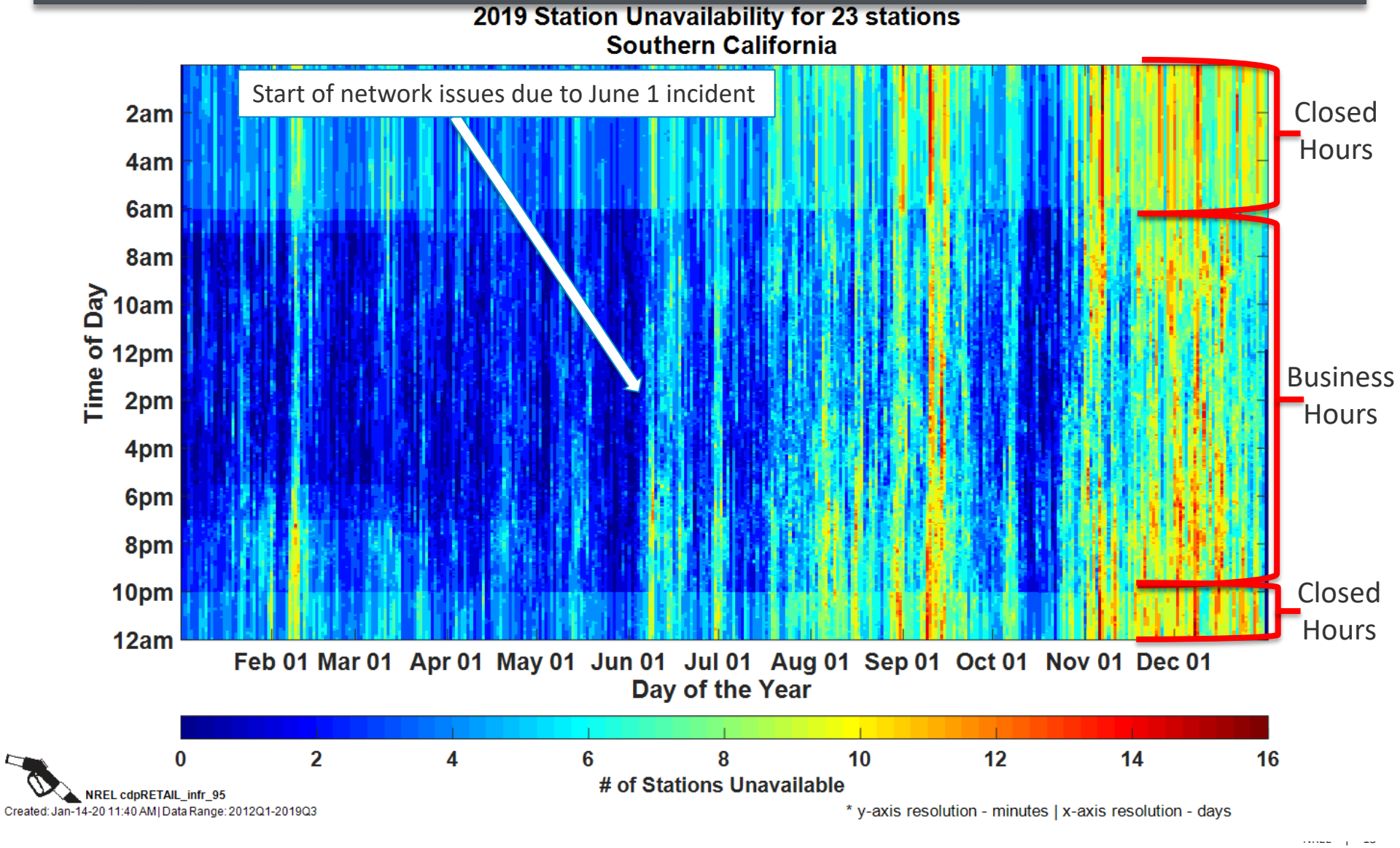
Accomplishments and Progress:
Station Unavailability: Number of Stations Unavailable (Northern California)

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



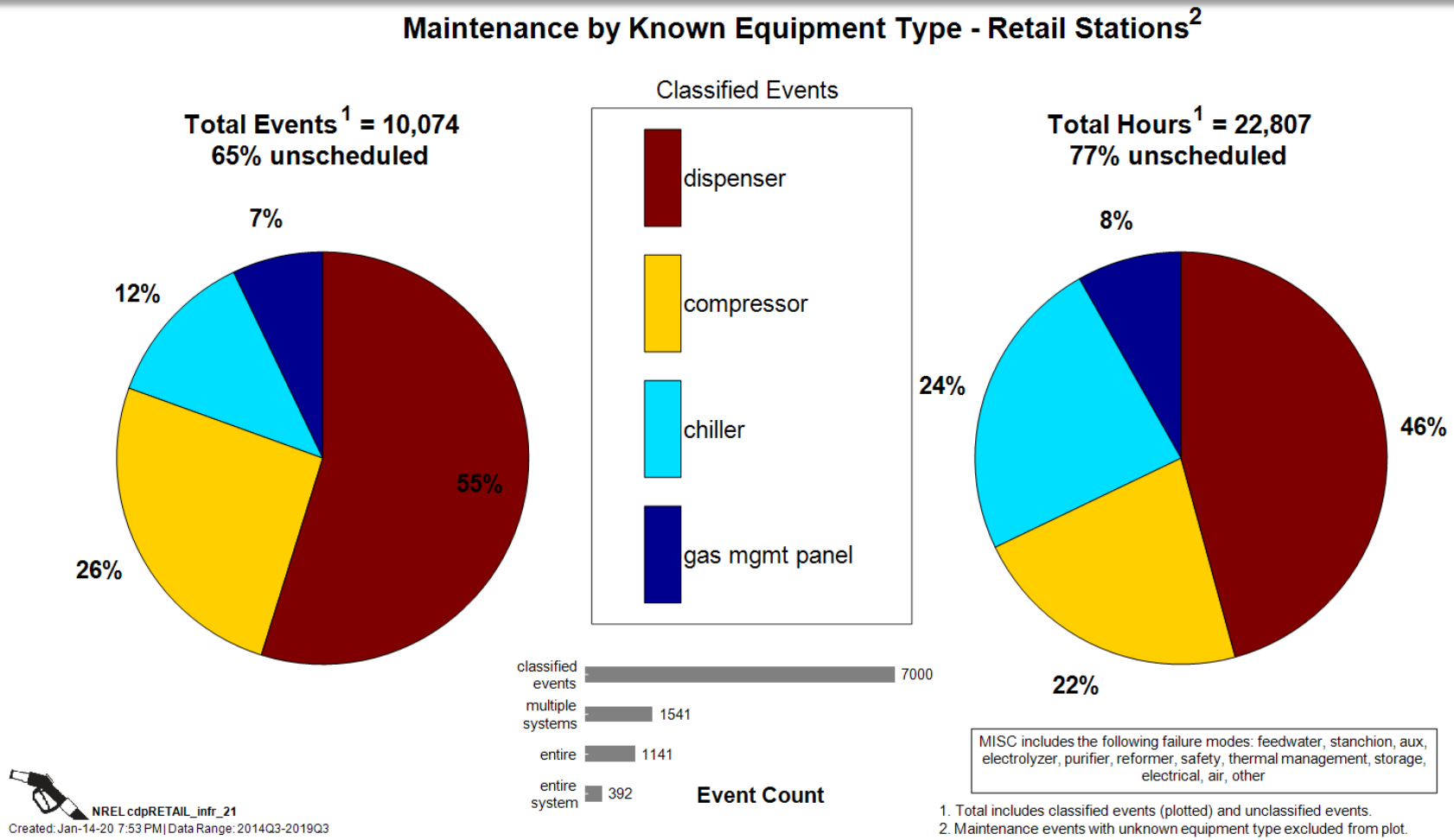
Accomplishments and Progress:
Station Unavailability: Number of Stations Unavailable (Southern California)

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



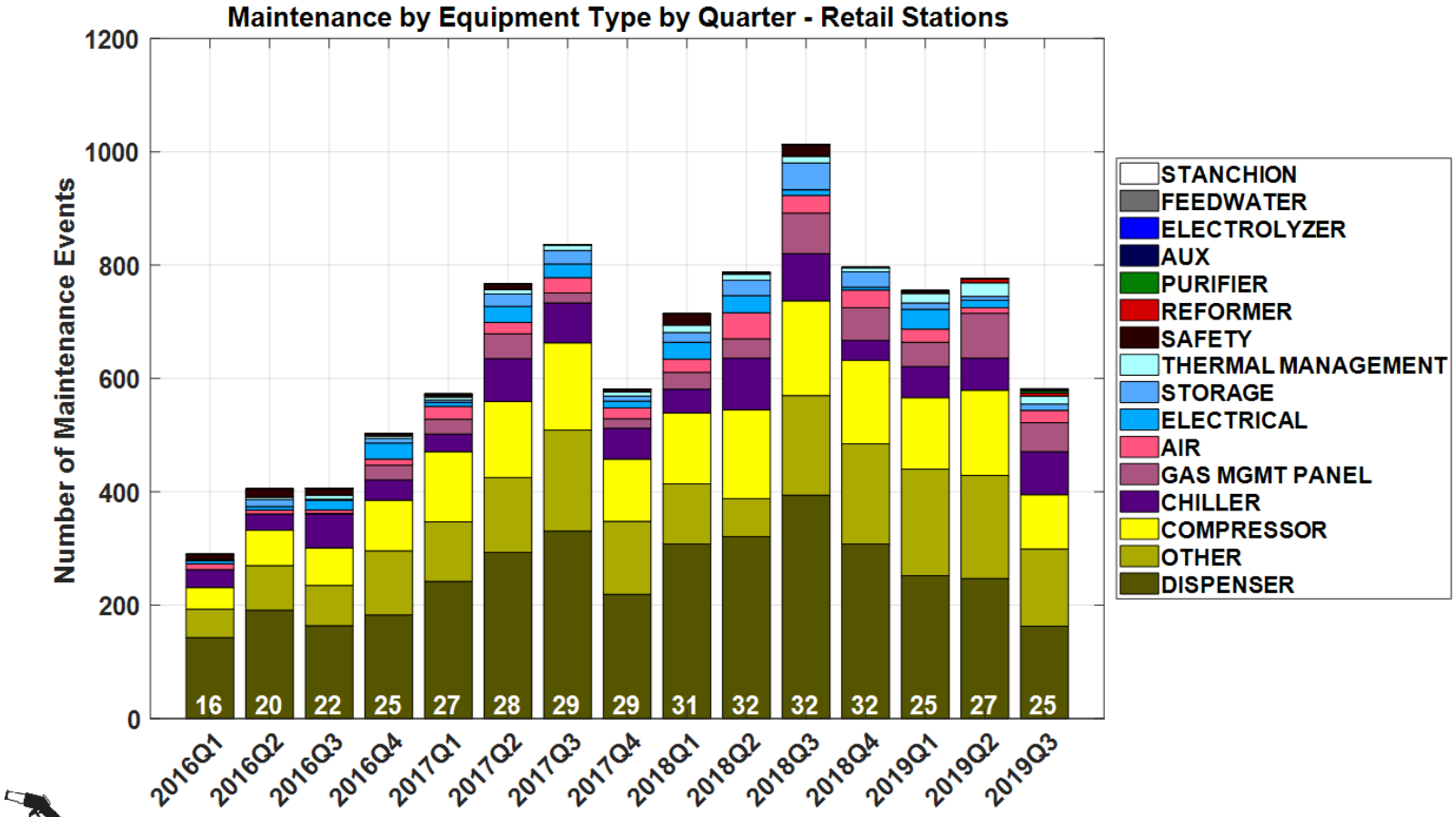
Accomplishments and Progress:
Maintenance by Equipment Type

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



Accomplishments and Progress:
Maintenance by Equipment Type

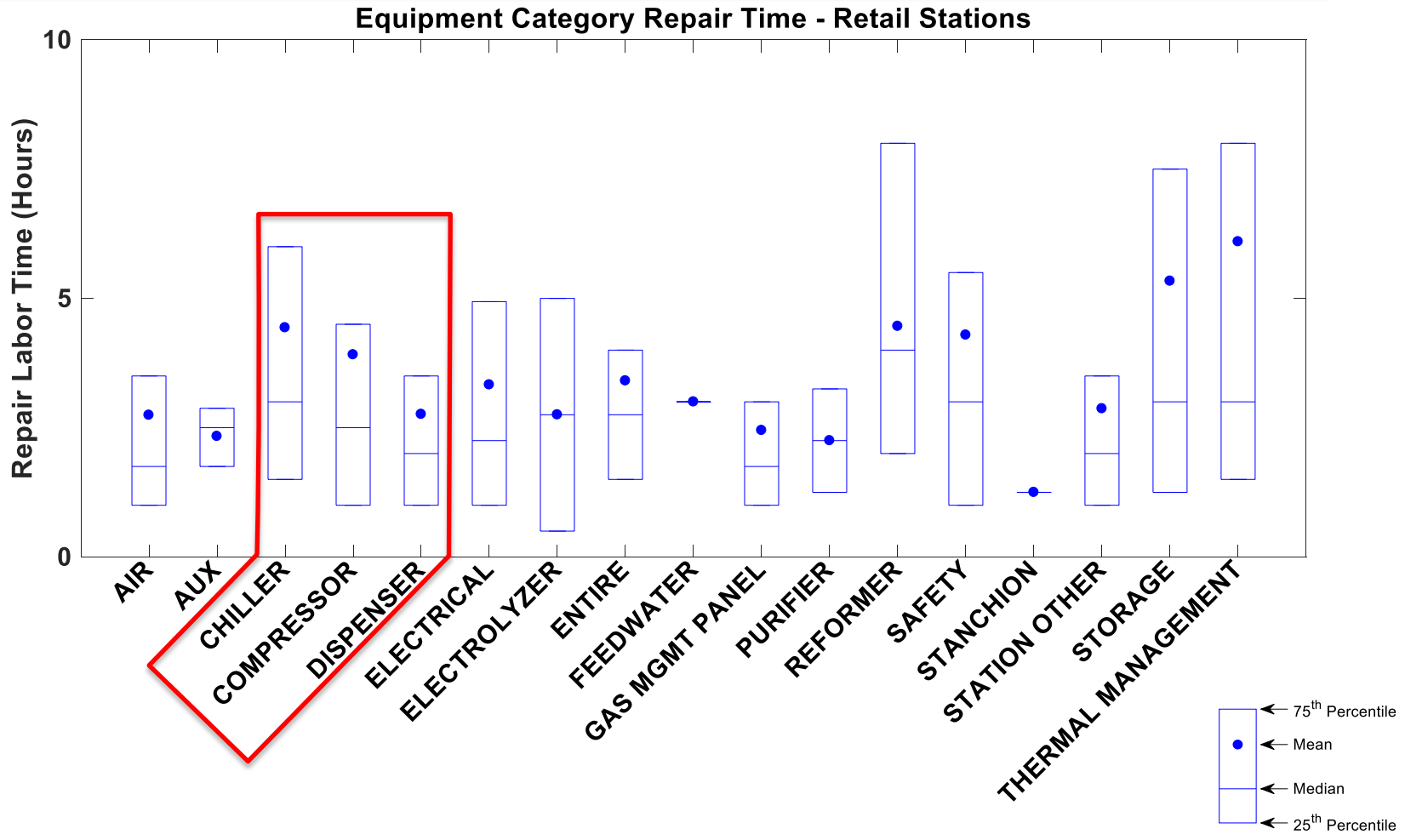
Over time, the distribution of maintenance events by equipment type is similar. Most identified maintenance events are from dispenser, compressor, and chiller.



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.

Accomplishments and Progress:
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



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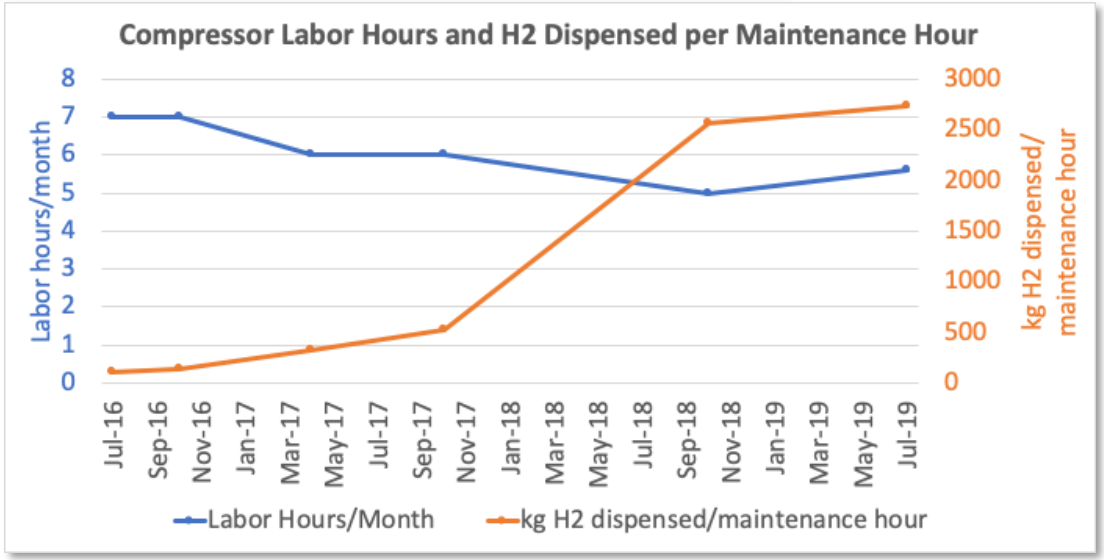
Accomplishments and Progress: Compressor Deep Dive

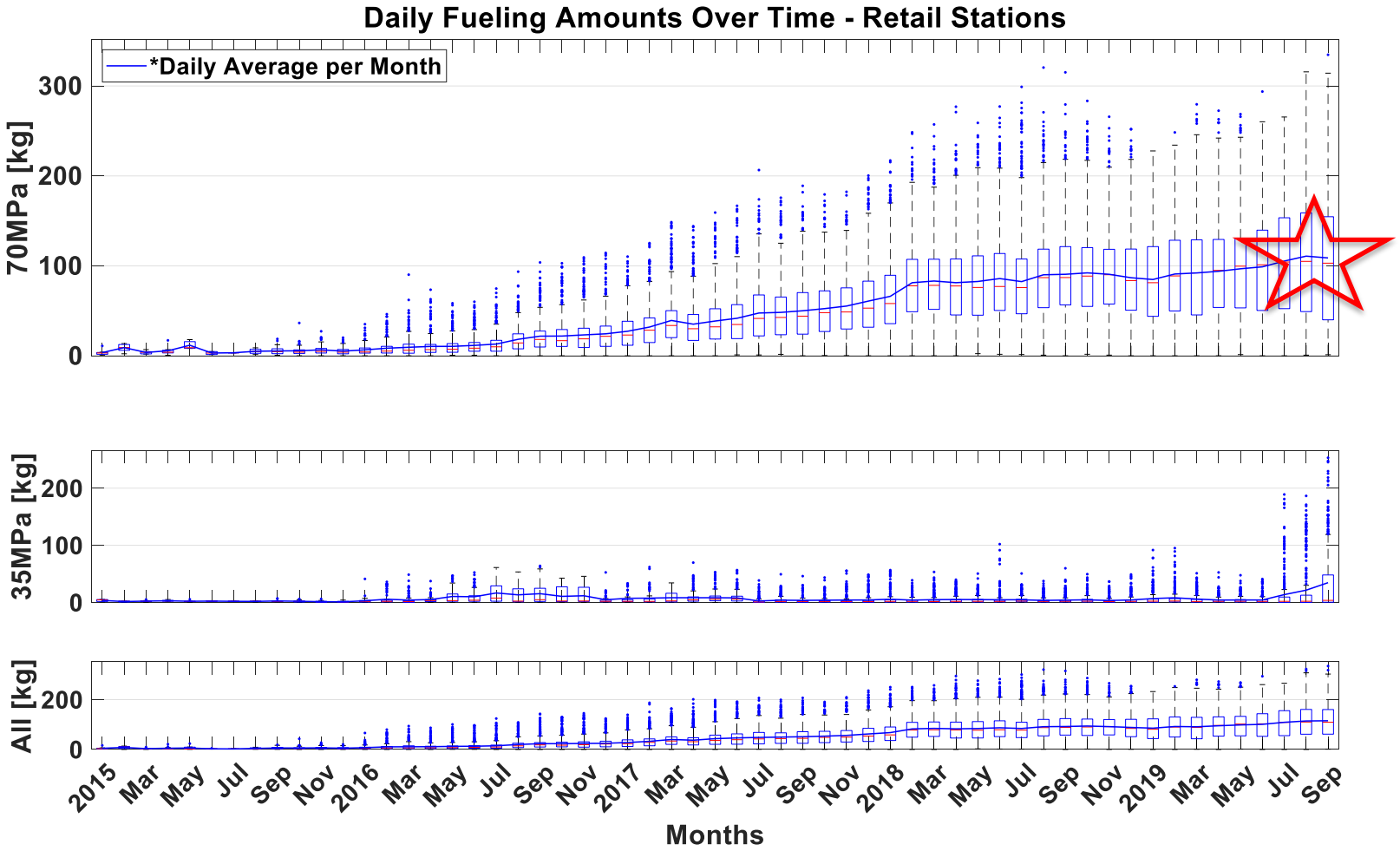
Data normalized per station				
Events/ Month	**kg H2 dispensed /event**	**Labor Hours/ Month**	**kg H2 dispensed/ maint. hour**	**Data through Quarter**
2	N/A	**7**	**105**	**Q3 2016**
2	450	**7**	**140**	**Q4 2016**
3	812	**6**	**328**	**Q2 2017**
3	N/A	**6**	**525**	**Q4 2017**
3	N/A	**5**	**2569**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



Accomplishments and Progress: Station usage

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



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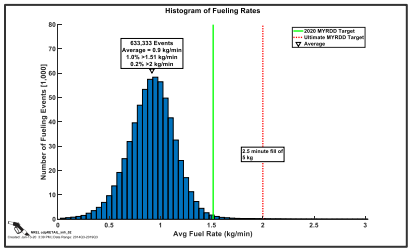
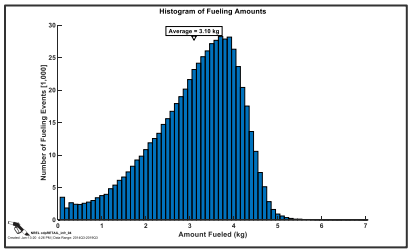
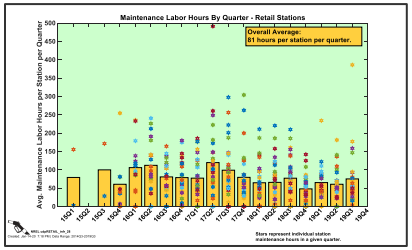
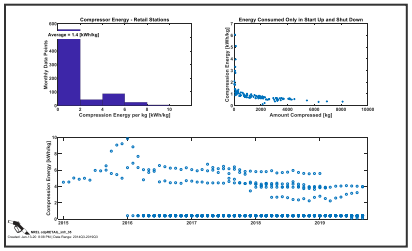
*Daily average only includes days with fills.

Accomplishments and Progress: Sampling of Results

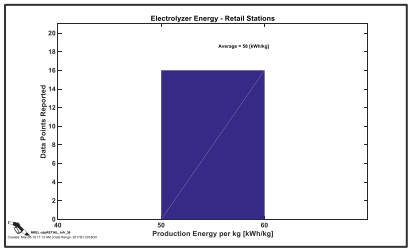


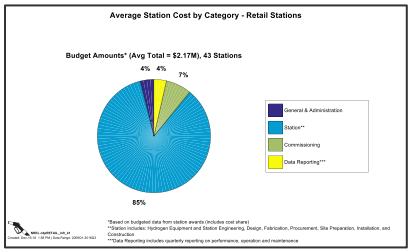


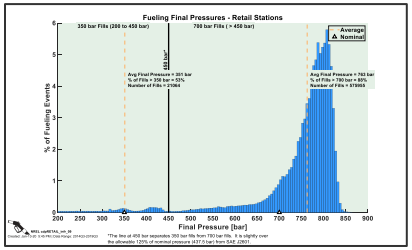


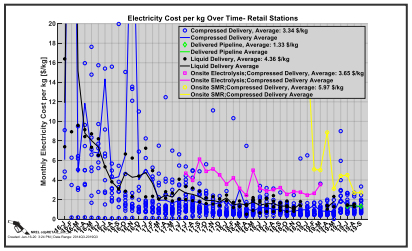


Fueling Rate Average	0.9 kg/min
Fueling Amount Average	3.1 kg
Fueling Time Average	3.51 min
Compressor Energy Average	1.4 kWh/kg
Total Hydrogen Dispensed (35 Stations)	2,107,471 kg 1,470,151 kg - 18Q4
Electrolyzer Energy Average	58 kWh/kg
Maintenance Hours Average	81 hours/Quarter
Fueling Final Pressure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









98 Composite Data Products in 8 topic areas publicly available
https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- For example, it is nice to see, with the reduction in dollars-per-kilogrammaintenance costs, that station design and operation are reaching a certain level of maturity. It was surprising to see the percentage of incidents related to the dispenser versus the compressor; it would be good for the project team to spend time analyzing this in more detail.
  - We are working on developing analysis that can better dive into station maintenance of specific components.
- The purpose of this effort is to use data for future innovations and research, but most of the data is based on existing operational equipment (including HRSs integrated with technology five years old and older), which is several generations behind current technology. It is increasingly unclear how this data is valuable in facilitating future innovation and directing research efforts.
  - The purpose is to assess the state of the technology. However now that there are 5 years worth of retail station data we are exploring how we might better characterize trends to show performance, usage, etc over time.
- The investigators should work with older stations so that the stations will continue to report data even though compulsory reporting is no longer in force.
  - We have plans (if funded) to develop some online data collection in an effort to make the data reporting easier. This would incentivize continued data support after contractual obligations. We are also actively pursuing other opportunities for data such as station roll-out in the northeast.
- (1) to identify additional cost detail that could be useful in state efforts to understand the developing business case for hydrogen stations and (2) to develop a metric for effectiveness of state funding based on the methods used to choose stations to fund and the observed performance.
  - Good suggestions.
- The project should also evaluate whether it currently collects or could easily collect data from fueling events that do not reach full state-of-charge. The evaluation of the data should focus on whether common causes of incomplete fills can be identified. This could help lead to insight on whether the fueling protocols need to be re-evaluated and/or re-tuned, as short fills may be caused by out-of-bounds operation that may not truly need to stop the filling process.
  - That cannot be evaluated with this dataset, however we have separate research proposals that would look into those very questions.

Proposed Future Work

- Analysis and CDP publication
  - Complete data analysis and publish results
    - Summer 2020 with data through 2020 Q2
    - Winter 2021 with data through 2020 Q4
- Update data collection, analysis and feedback
  - Focus new analysis component maintenance results, network health
  - Revise some analysis to look at data trends and normalizing data so that non-reporting stations do not muddle results
  - Pursue all data collection opportunities including in the Northeast corridor
  - Look at online tools for streamlining data collection and providing interactive tools for data visualization

Any proposed future work is subject to change based on funding levels

Summary

- Relevance
  - Independent validation of hydrogen infrastructure
- Approach
  - Collaborate with industry partners and agencies involved in hydrogen infrastructure
  - Continue to develop core NFCTEC analysis capability and tools
  - Leverage years of analysis and experience from hydrogen demonstrations
- Accomplishments and Progress
  - Analyzed performance data from 34 open, retail stations
  - Performed detailed reviews of individual results
  - Published results via CDPs that cover topics of station daily utilization compared to maximum demonstrated capacity, maintenance, fueling performance, operation costs, and efficiencies
- Collaborations
  - Working closely with industry and government partners to validate methodology and with key stakeholders to ensure relevance and accuracy of results
- Future Work
  - Complete analysis of hydrogen infrastructure data and publish every 6 months
  - Identify new opportunities to document hydrogen infrastructure progress and feedback results to researchers

Thank You

www.nrel.gov

Publication Number

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