

# Technology Validation of Hydrogen Refueling Infrastructure

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Fuel Cell Seminar, Long Beach, California

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# Topics of Discussion



NFCTEC



Current Status



FCEV  
Ownership



Cost



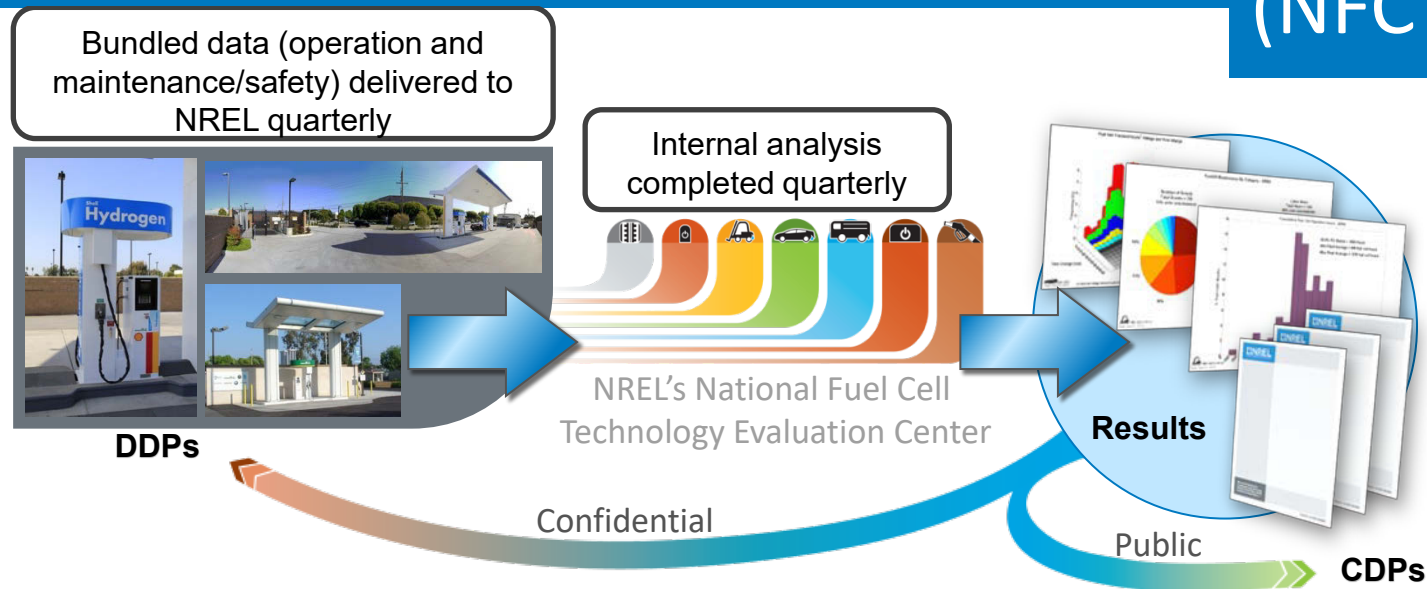
Reliability

# NREL's National Fuel Cell Technology Evaluation Center

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NFCTEC

# National Fuel Cell Technology Evaluation Center (NFCTEC)



## Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months<sup>1</sup>

## Composite Data Products (CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months<sup>2</sup>

1) Data exchange may happen more frequently based on data, analysis, and collaboration

2) Results published via NREL Tech Val website, conferences, and reports

# Evaluating Existing Stations/Equipment

## A Developing Market

- 39 retail stations open (34 last AMR)
  - All in CA (as of April 2019)
- Supporting over 6,000 FCEVs



FirstElement Fuel, Costa Mesa, CA. Photo: NREL



Air Liquide, Anaheim, CA. Photo: NREL

## Objectives

- Use existing stations as real-world guide for future innovations
- Identify issues for research
- Have results readily available

# Collaborations

Data Requirements > Data Reporting > Analysis Results > Feedback

## STATION FUNDERS

California Energy Commission  
California Air Resources Board  
SCAQMD

## STATION PROVIDERS

Air Liquide  
Air Products  
California State University Los Angeles  
FirstElement Fuel  
H2 Frontier  
Linde  
Proton OnSite/NEL  
Shell  
StratosFuel

## ORGANIZATIONS

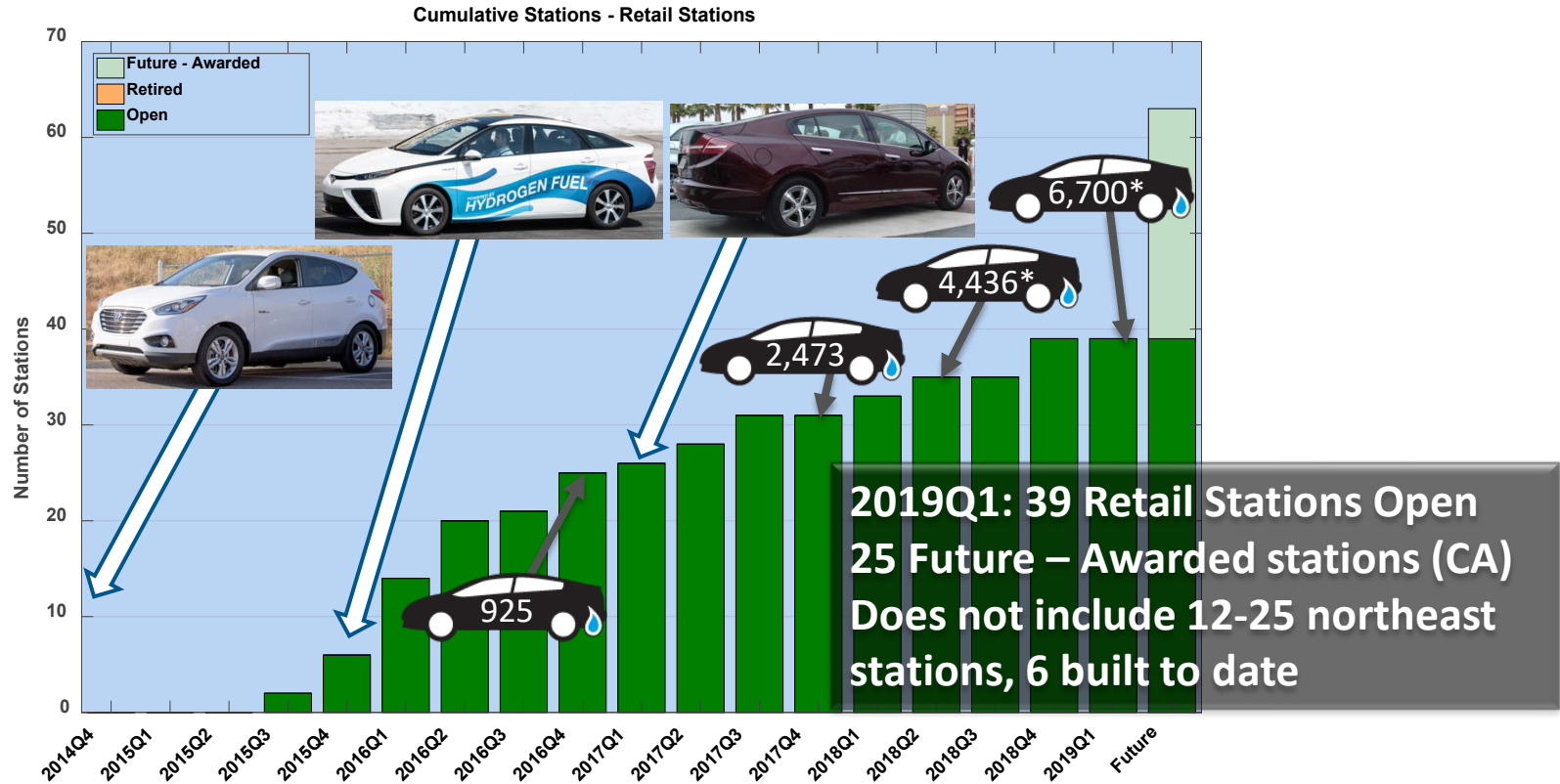
California Fuel Cell Partnership  
IPHE and HySUT  
Gas Technology Institute  
CA - CDFA Division of  
Measurement Standards

# Current Status

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Overview of current retail stations

# Cumulative Number of Retail Stations



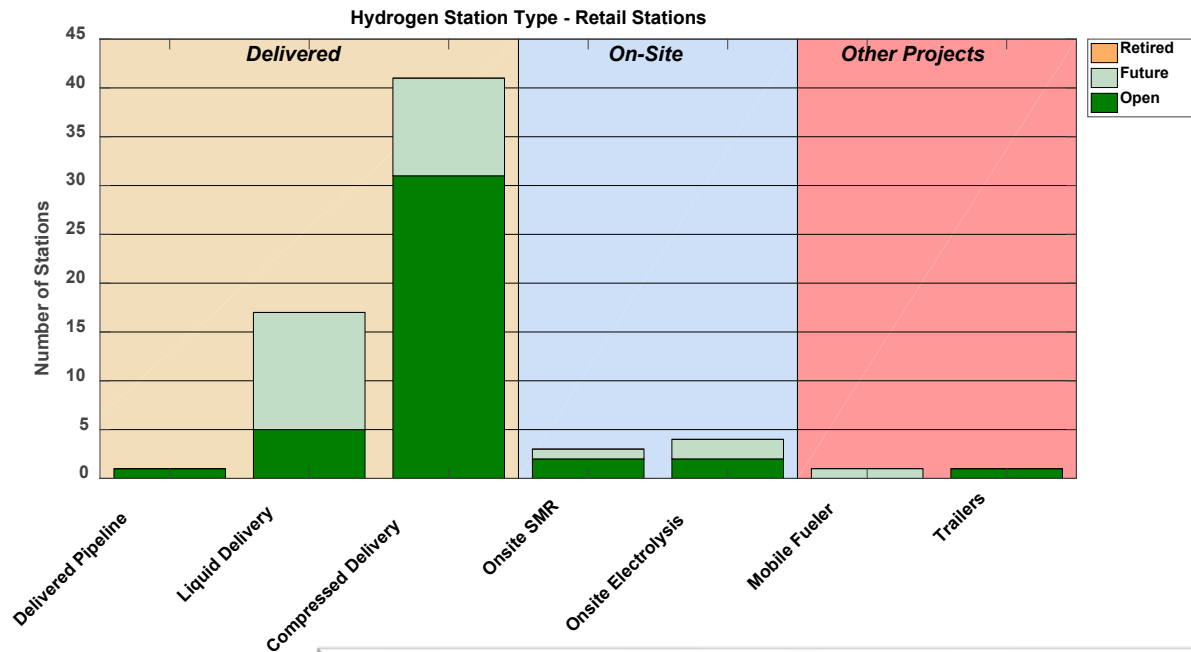
NREL cdpRETAIL\_inf\_10

Created: Mar-15-19 2:56 PM | Data Range: 2011Q1-2018Q4

\*Argonne National Laboratory, 2019



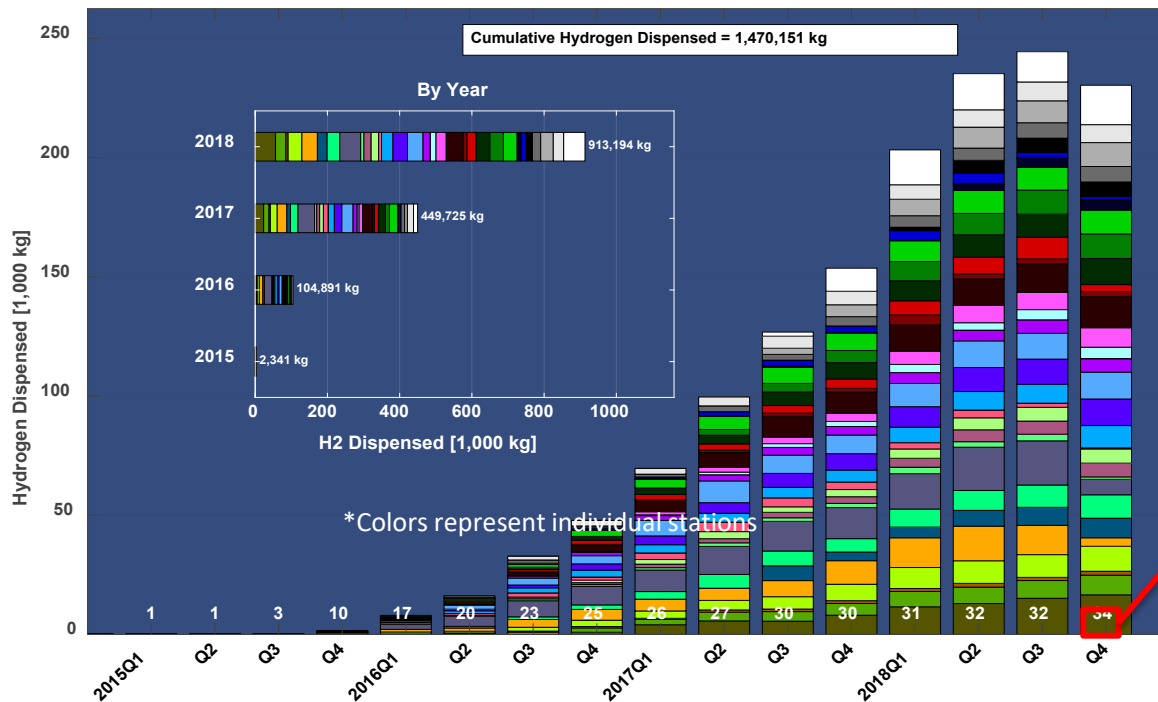
# Station Types



Although most retail stations are compressed H2 delivery, they also include liquid delivery, pipeline, SMR and onsite electrolysis.

# Hydrogen Dispensed by Quarter

Hydrogen Dispensed By Quarter - Retail Stations



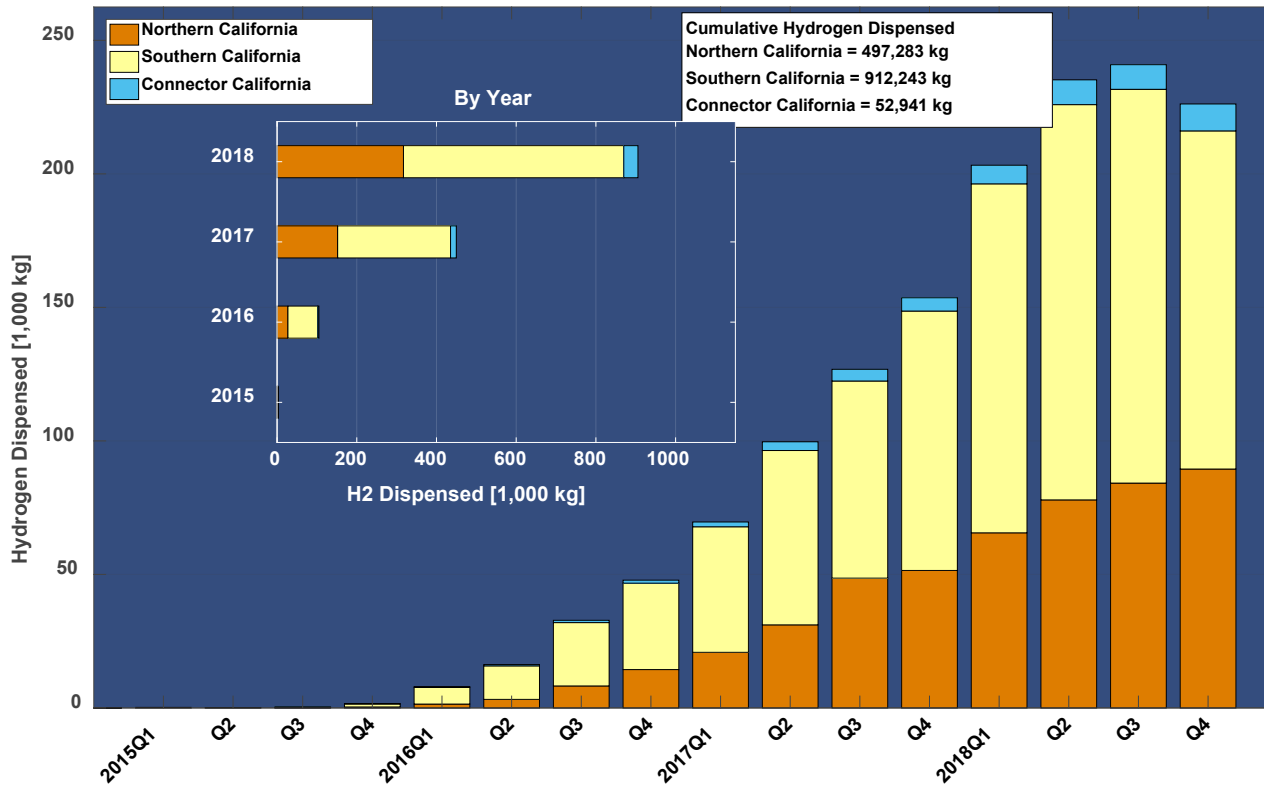
Retail stations dispensing significantly more each quarter. Drop in the final quarter is due to several stations not reporting data after October.

# of Stations Reporting



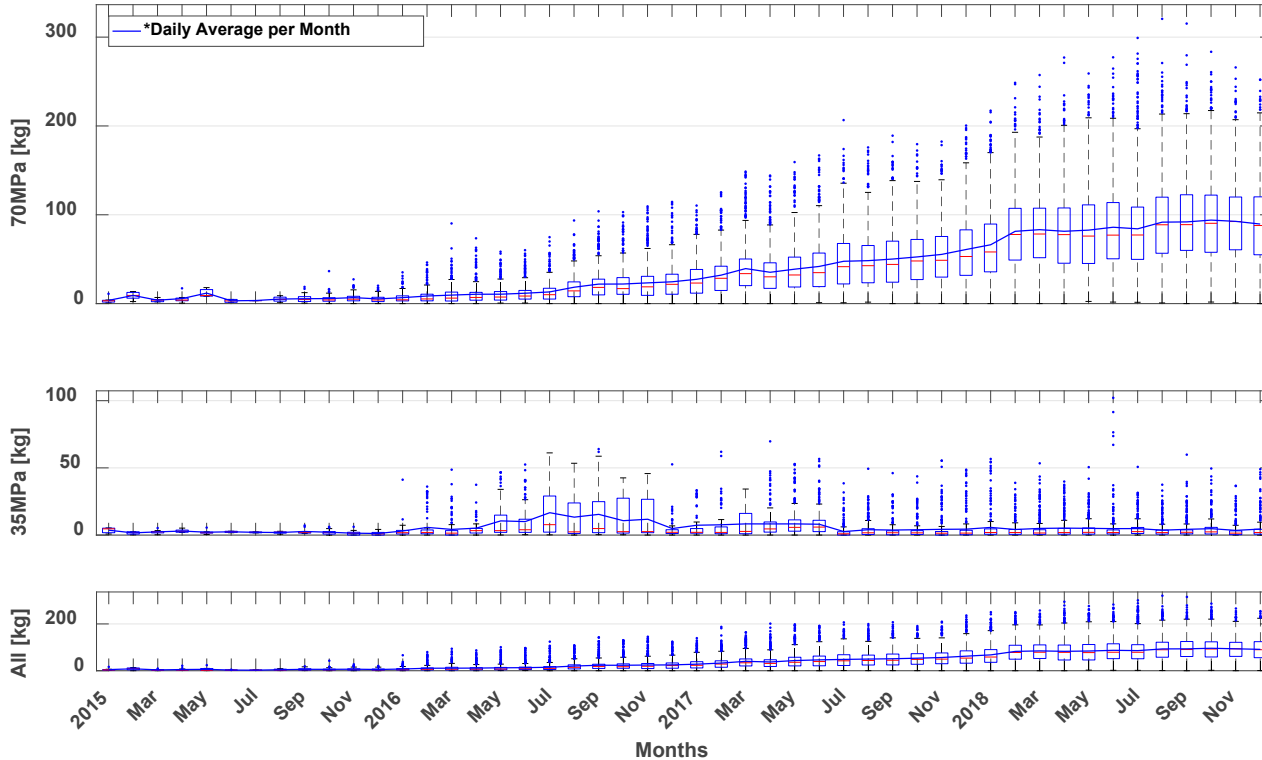
# Hydrogen Dispensed by Region

Hydrogen Dispensed By Region - Retail Stations



# Daily Fueling by Month

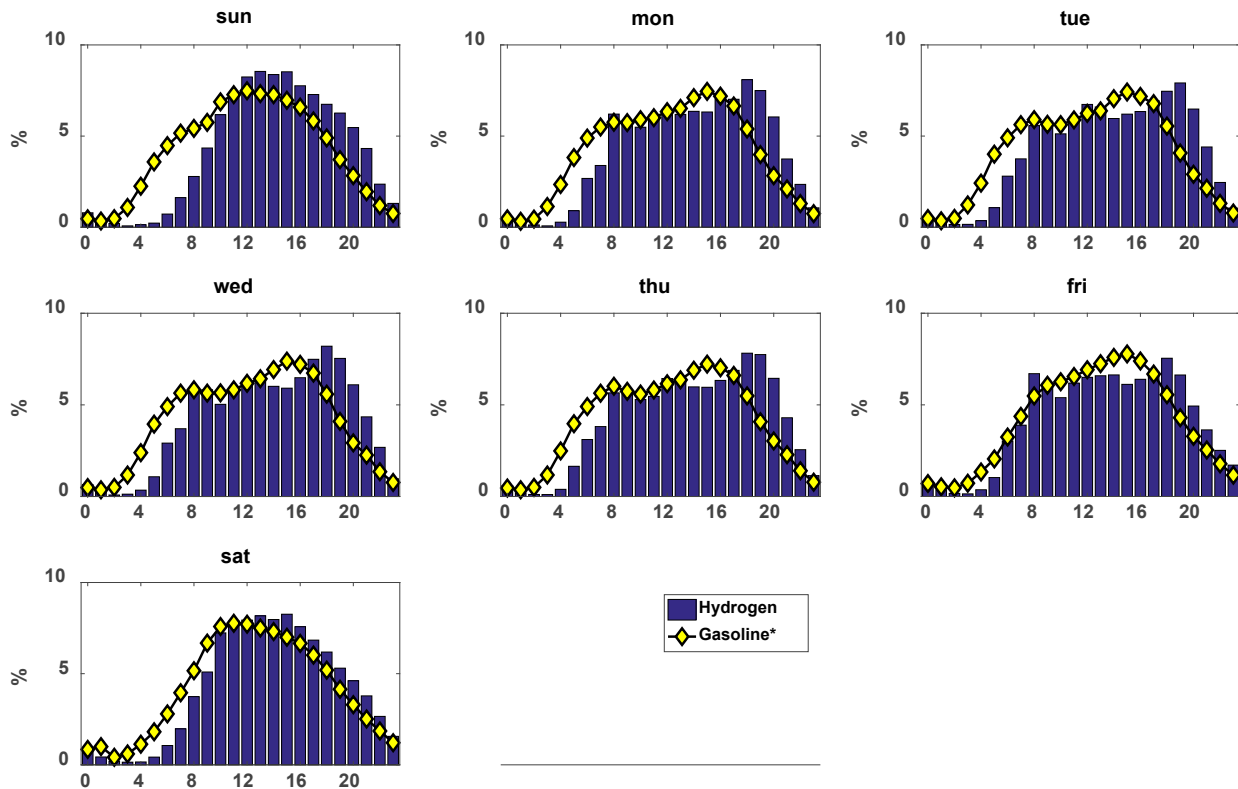
Daily Fueling Amounts Over Time - Retail Stations



- ❖ Average daily is approaching 100 kg/day
- ❖ Several “outlier” days above 200 kg/day

# Hydrogen by Day and Hour – Northern California

Fueling Amounts by Day and Hour - Retail Stations - Northern California



❖ Daily trends approaching those seen in gasoline stations

# Fuel Cell Electric Vehicle Ownership

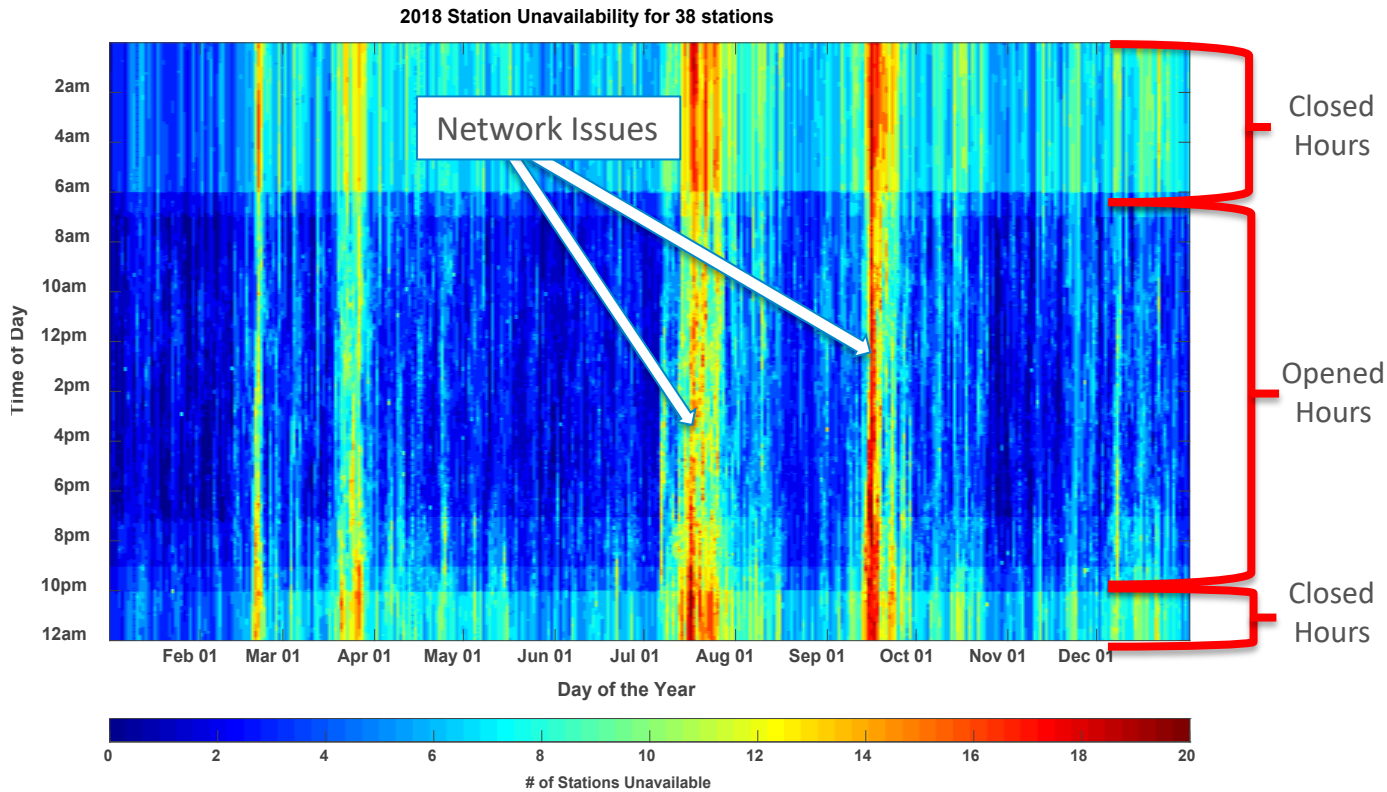
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What to expect

# Station Unavailability: Number of Stations Unavailable in 2018

6 stations are closed overnight

32 Stations are open 24/7

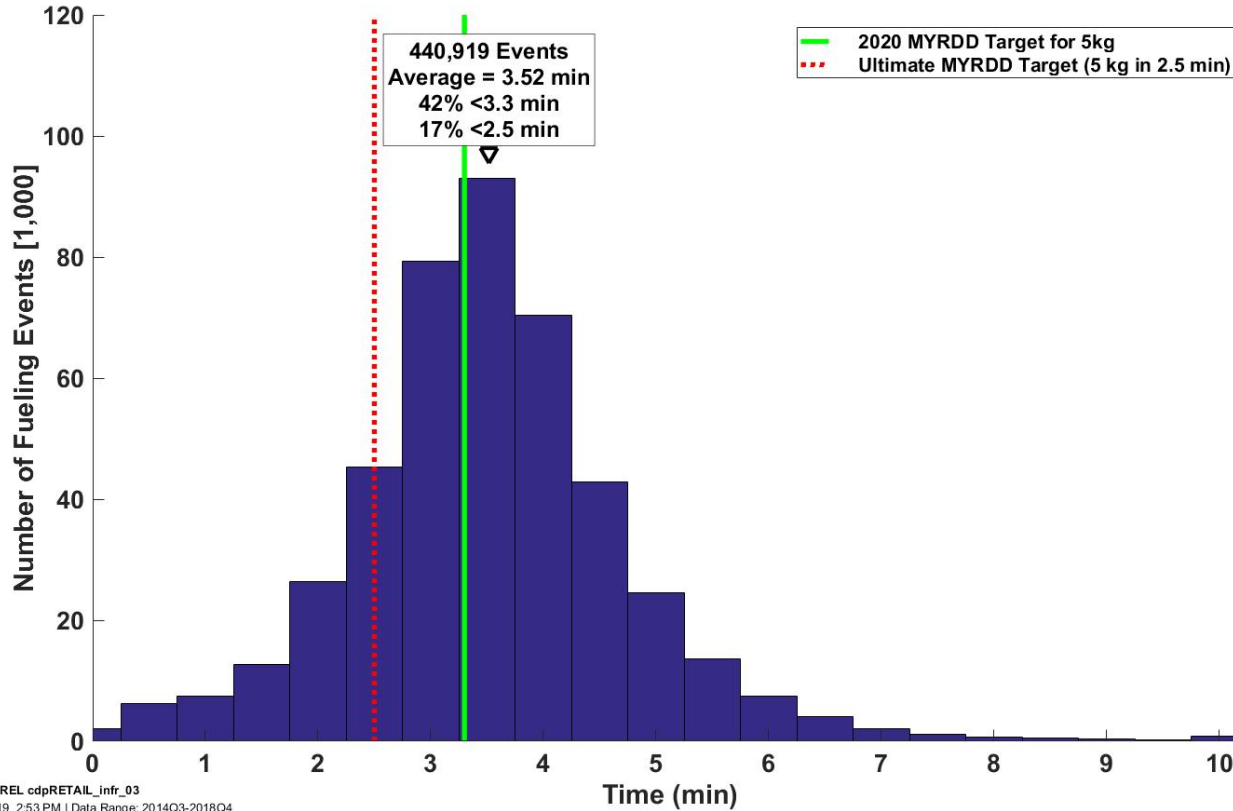


 NREL cdpRETAIL\_intl\_93  
Created: Mar-21-19 1:27 PM | Data Range: 2012Q1-2018Q4

Based on SOSS "Offline" status for all of 2018.

# Fueling Time

## Histogram of Fueling Times





# Queuing at Stations

Fueling times –supplied in NREL templates (covered in CDPs)

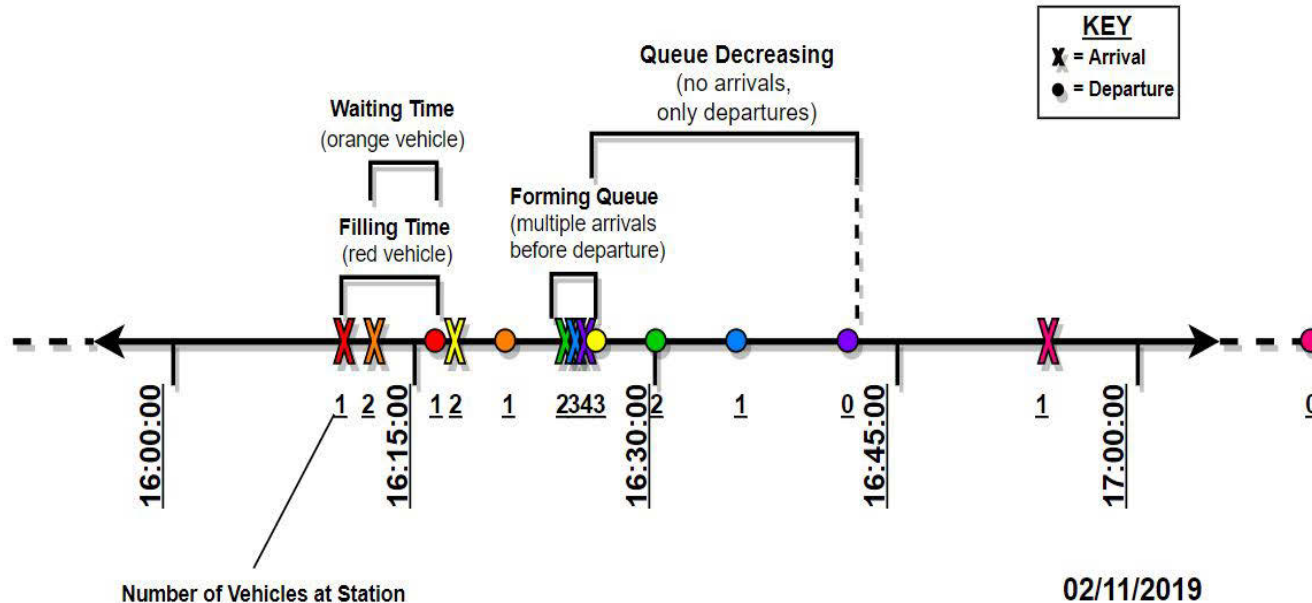
Waiting time/queuing – NREL manually collected 2.5 days of data at FirstElement Fuel using camera footage from 2 stations.



# Queuing at Stations

- Build more accurate queuing models, understand consumer behavior, and provide insight into station needs
- Arrival, waiting, service, departure times, and queuing behavior

## Arrivals and Departures at Hydrogen Fuel Station



# Queuing behavior

Fuel Delivery Truck  
Queuing in opposite direction

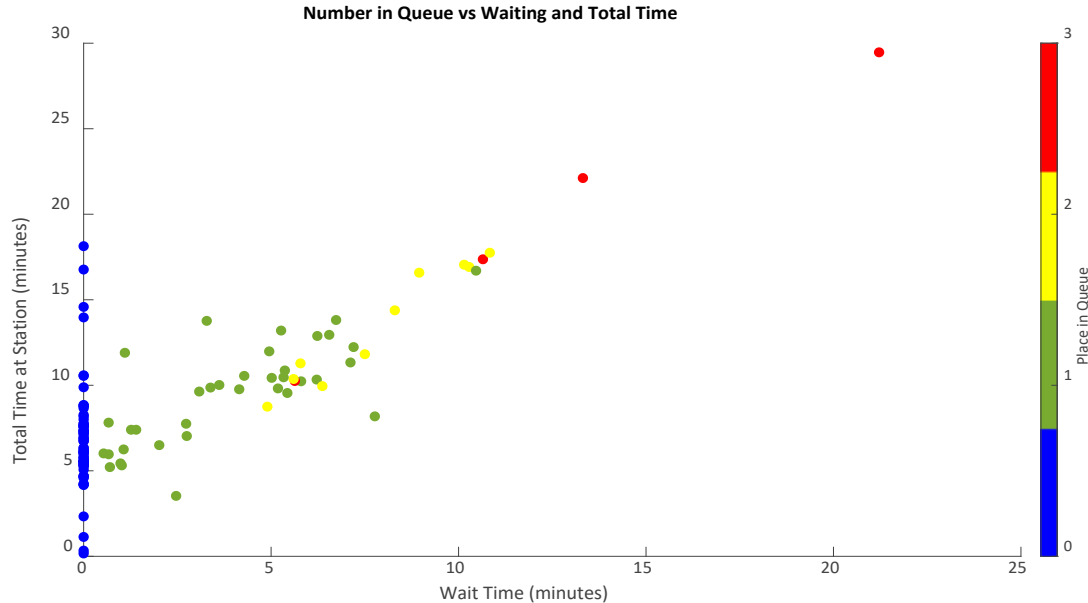


Vehicle dropping out of queue



# Queuing at Stations

- As your place in queue is higher (more vehicles in front of you) your total time at station increases
- Wait times seen over 20 minutes with total time at station near 30 minutes



# Queuing Results Summary

Based on the data:

- A FCEV driver would expect to spend a total of about 7 minutes and 24 seconds at a station (based on the median total time at a station due to skewed data)
- A station would expect about 3 vehicles to arrive each hour but require a current capability of servicing up to at least 12 vehicles per hour

**Total Time at Station**

Max	Median	Min	Grand Mean
30.2 min	7.4 min	0.1 min	8.5 min

**Number of Arrivals per Hour**

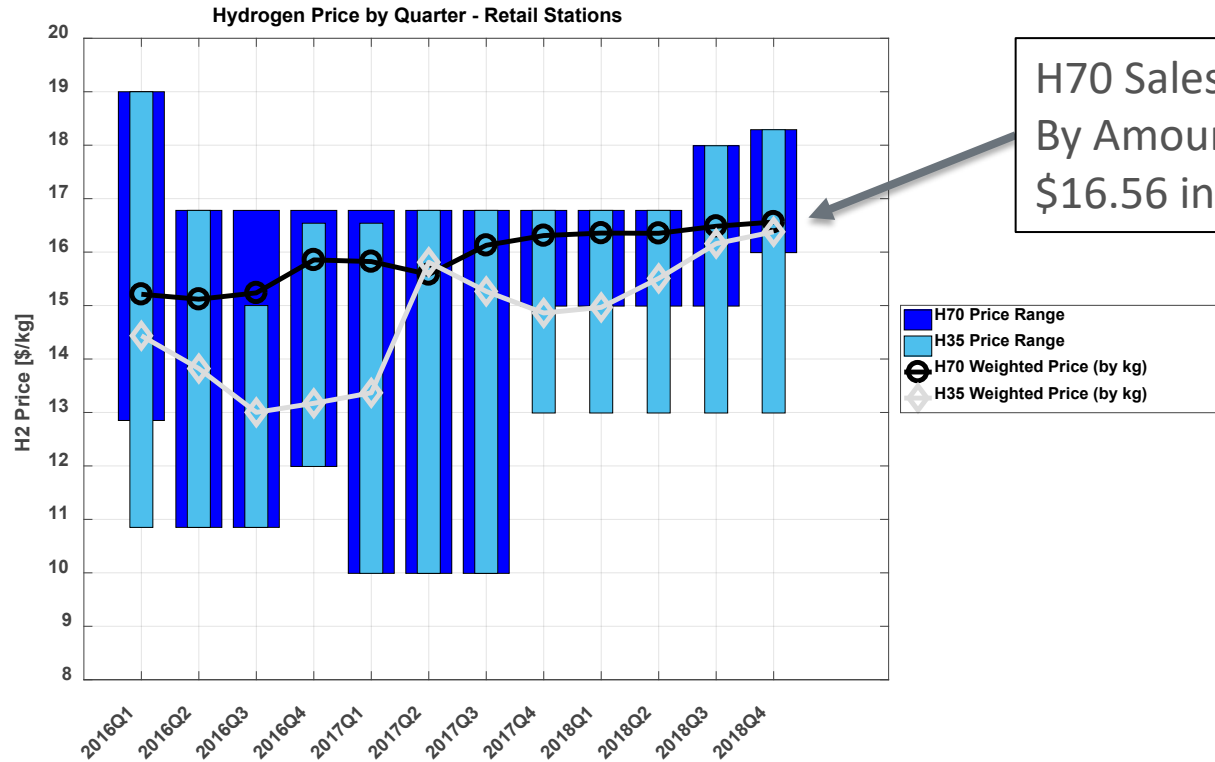
Max	Median	Min	Grand Mean
12	3	0	2.9

# Cost

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Exploring cost to station operators and customers

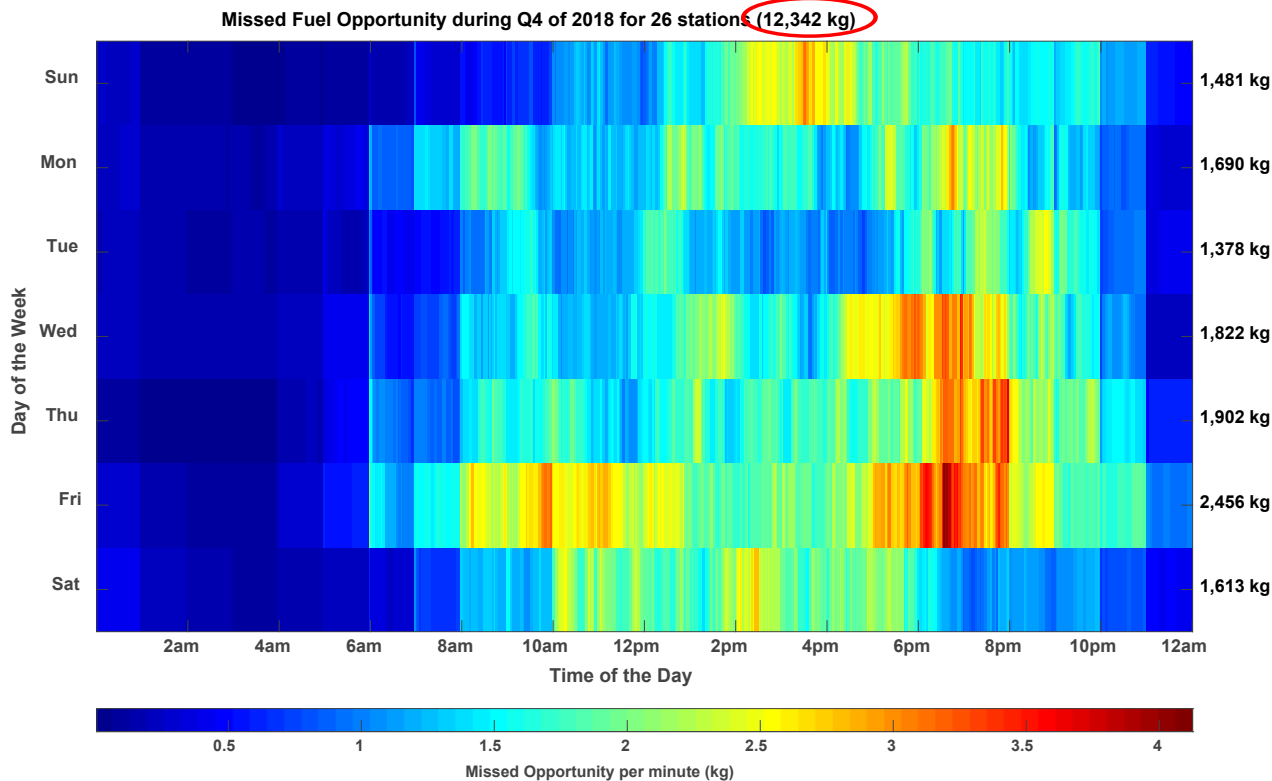
# Hydrogen Price



H70 Sales Price - Weighted Avg  
By Amount Dispensed:  
\$16.56 in 2018Q4



# Missed Opportunity Fueling

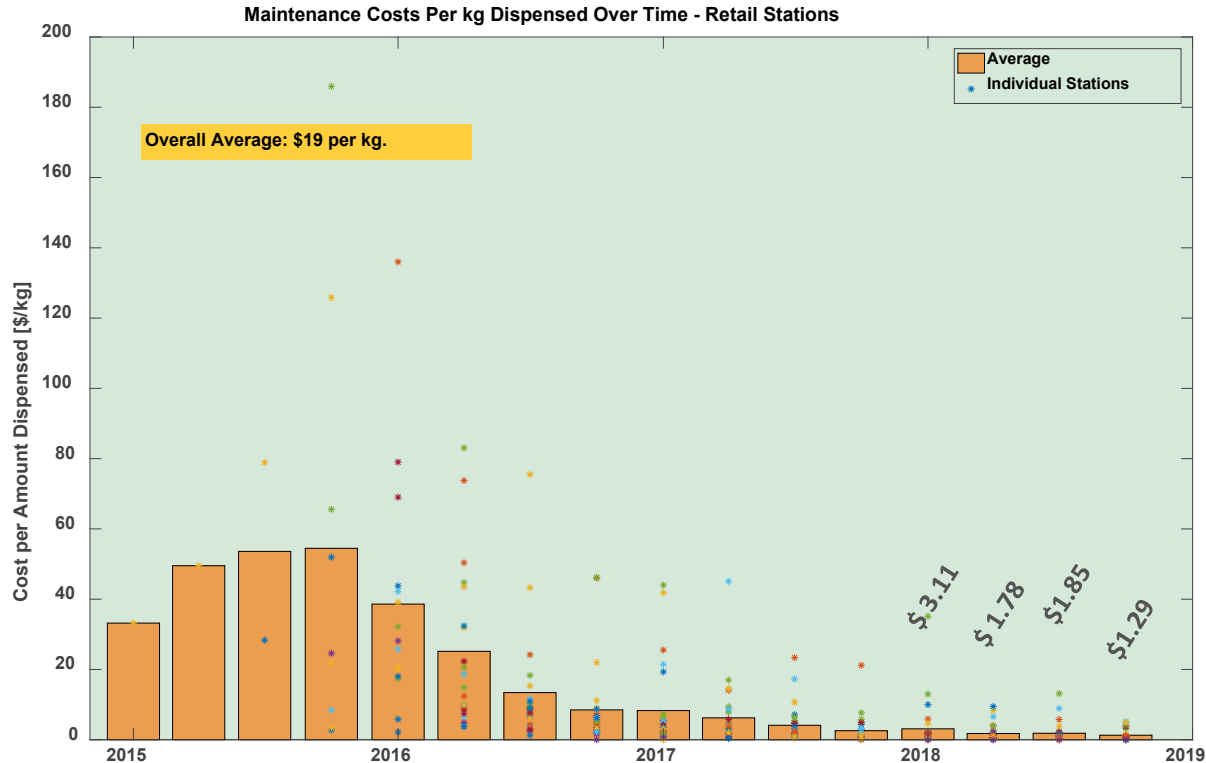


Calculated from average dispensing profiles from each station and their SOSS "Offline" status.

\*The minute fill profile was taken as an average from an hourly total.



# Maintenance Costs per kg Dispensed



Decreasing maintenance cost per kg as more hydrogen dispensed and as stations mature.

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

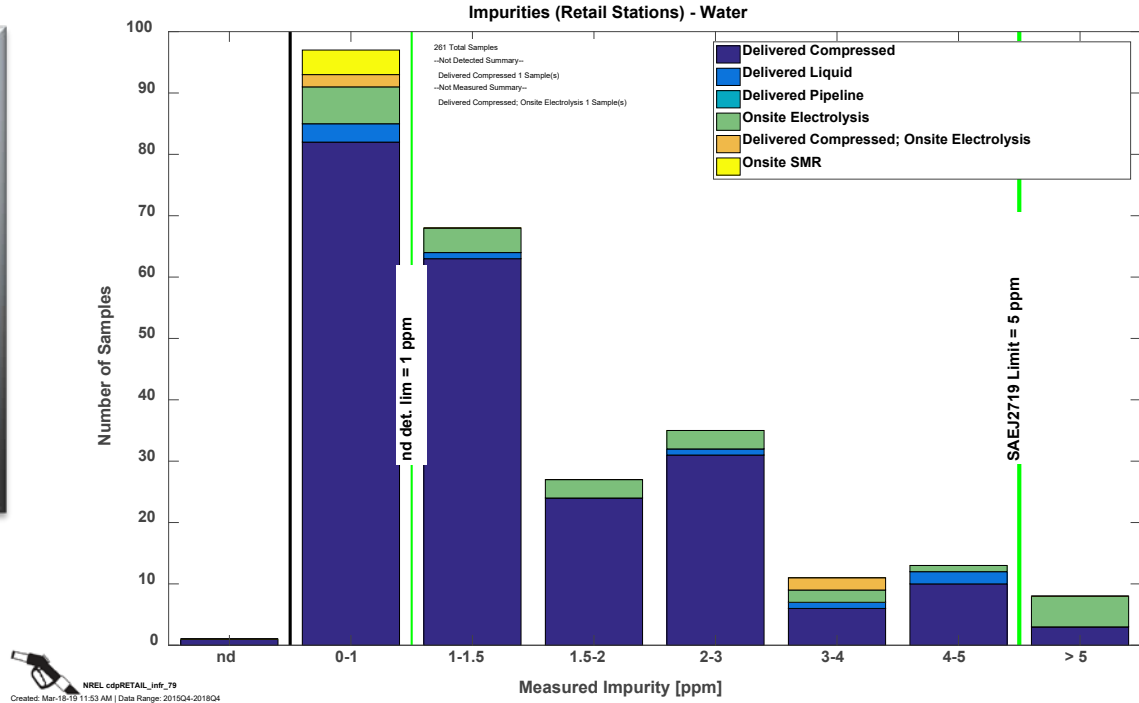
# Reliability

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Looking at what causes station down time and where products can be improved

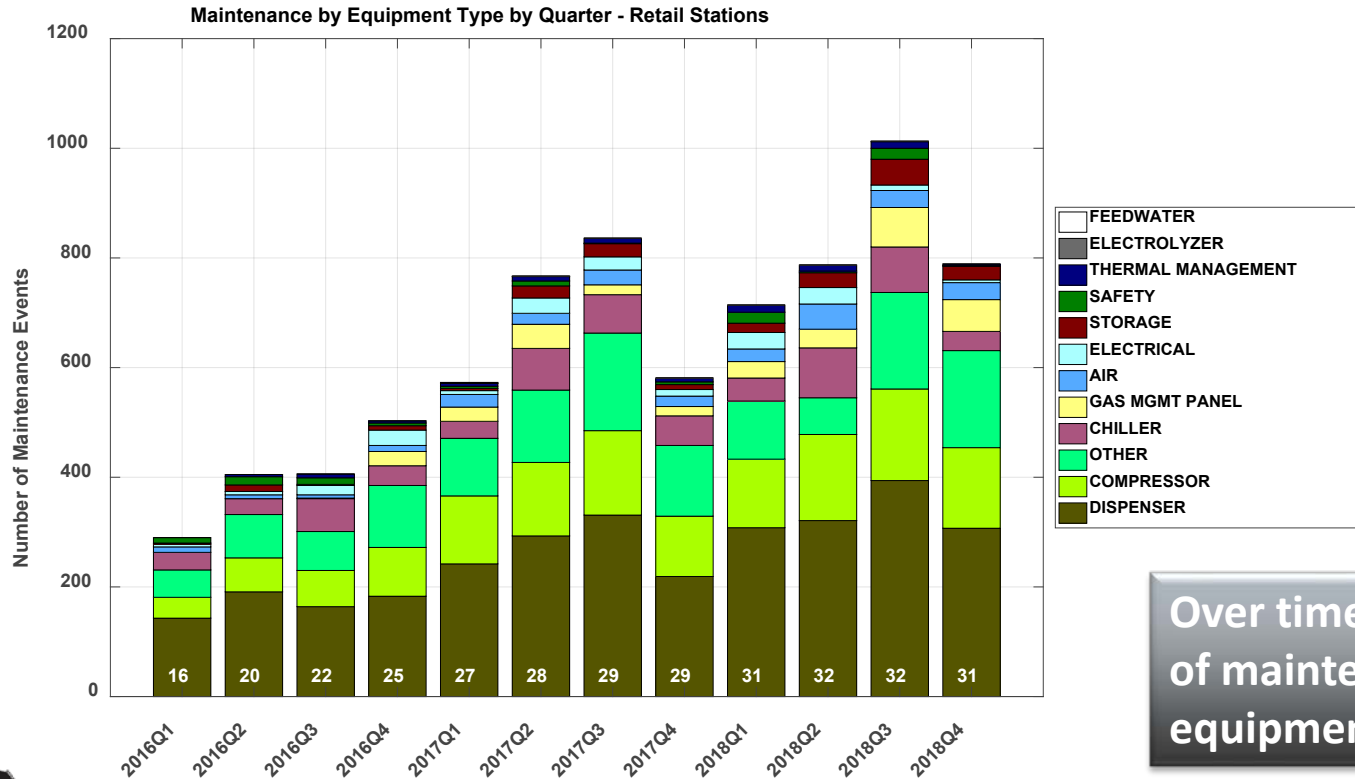
# Impurities - Water

This year, we added large number of data points from CA Department of Food and Agriculture, Division of Measurement Standards. We show H2O here but also publish the other constituents.



8 samples over the limit (water), mostly electrolysis stations

# Maintenance by Equipment Type



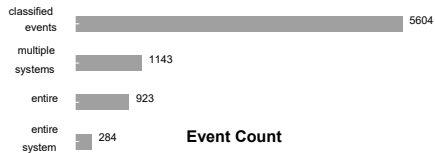
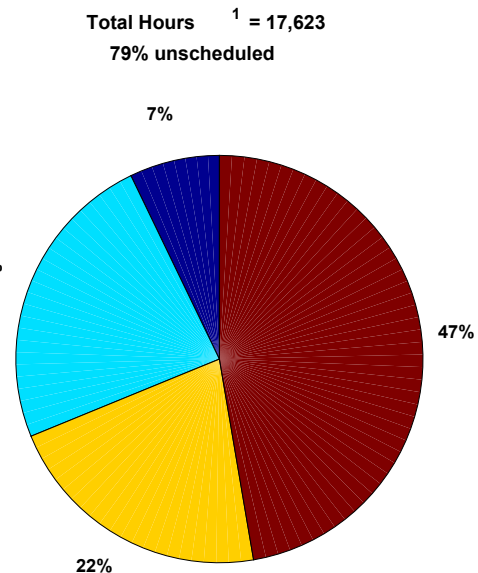
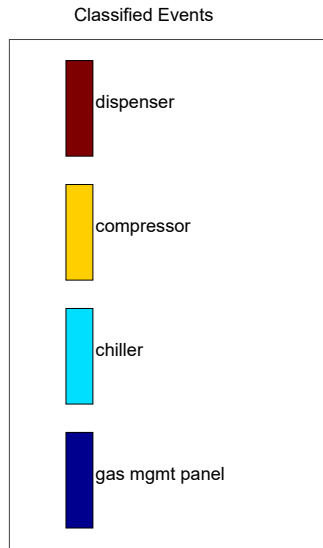
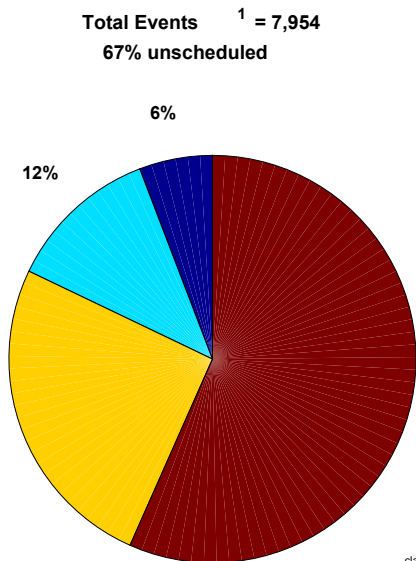
Over time, the distribution of maintenance events by equipment type is similar.



# Maintenance by Equipment Type

Maintenance by Equipment Type - Retail Stations

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



MISC includes the following failure modes: feedwater, electrolyzer, thermal management, safety, storage, electrical, air, other

1. Total includes classified events (plotted) and unclassified events.

# Thank you

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[www.nrel.gov](http://www.nrel.gov)

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