

Next Generation Hydrogen Station Analysis

Genevieve Saur (PI), Spencer Gilleon
National Renewable Energy Laboratory
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DOE Hydrogen Program
2022 Annual Merit Review and Peer Evaluation Meeting

Project ID: TA042

A Developing Market

- 55 retail stations open (52 last AMR)
 - 53 in CA, 1 in HI, 1 in CT
 - As of May 2022
- At least 57 new stations planned
 - 51 CA, 5 Northeast, 1 OH
- Supporting over 13,315* FCEVs
 - 1,033* FCEVs sold in 2022 thru March



Photos: NREL

Project Goal

OBJECTIVE:

Independent analysis of advanced hydrogen and fuel cell technologies operating in real-world conditions for status, benchmarking, technology readiness, value proposition, and research needs.

IMPACT:

- Insight into needed R&D to improve performance and adoption
- Validation of technologies against technical targets
- Regular technology reporting without revealing proprietary information to align industry
- Status and trend of durability, fuel economy, range, and driver behavior

Overview

Timeline and Budget

- Project start date: 10/2011
- FY21 DOE funding (if applicable): \$200k
- FY22 planned DOE funding (if applicable): \$200k
- Total DOE funds received to date*: \$2.2M

* Since the project started

Partners

- Genevieve Saur(PI), Spencer Gilleon, Sam Sprik (NREL)
- Partner organization – see Collaborations slide

Relevance: Evaluating Existing Stations/Equipment

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True Zero, Long Beach, CA. Photo: NREL



Irvine, CA. Photo: NREL

Objectives

- Support deployment of clean energy infrastructure
- 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

CDP

Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months¹

Composite Data Products (CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months²

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

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

CDPs published with data through 2020Q4 (2021Q2 coming Spring 2022)

<https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html>

Collaborations

Data Requirements > Data Reporting > Analysis Results > Feedback

STATION FUNDERS

California Energy Commission
California Air Resources
Board
SCAQMD

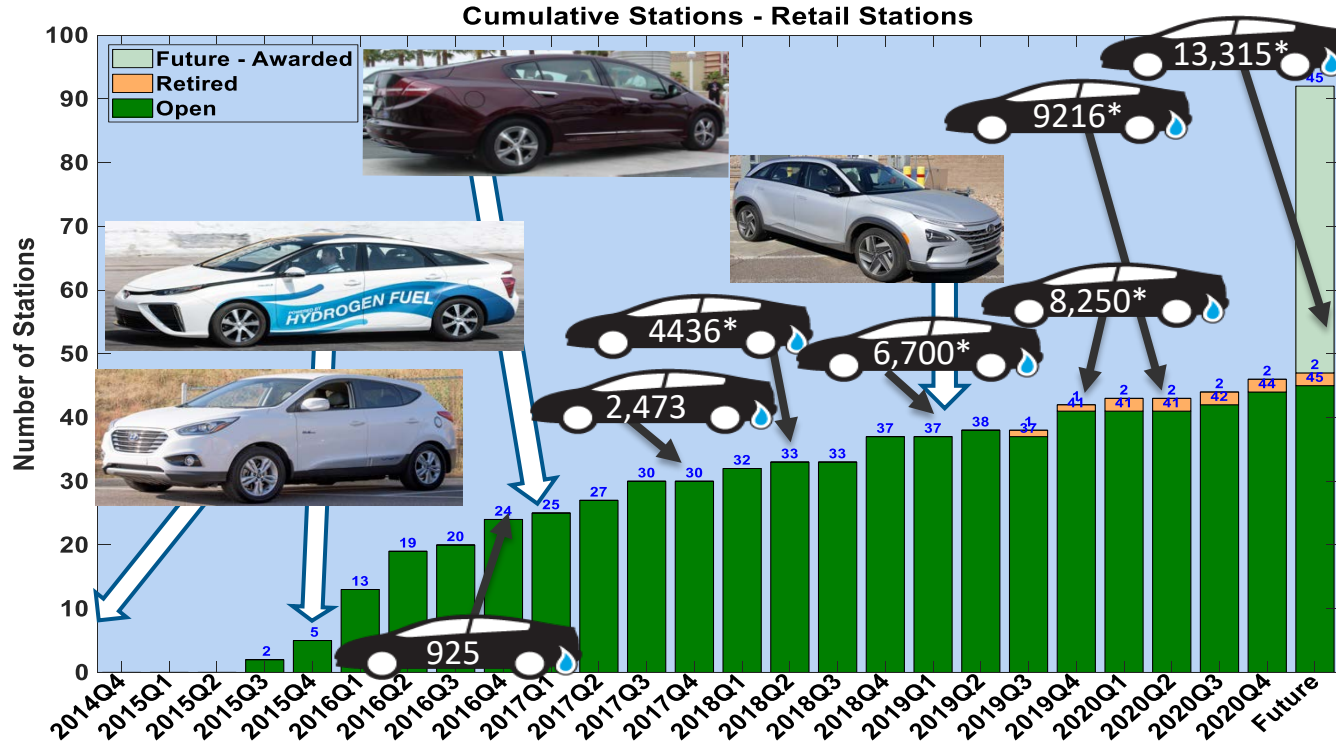
ORGANIZATIONS

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

STATION PROVIDERS

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

Accomplishments and Progress: Cumulative Number of Retail Stations



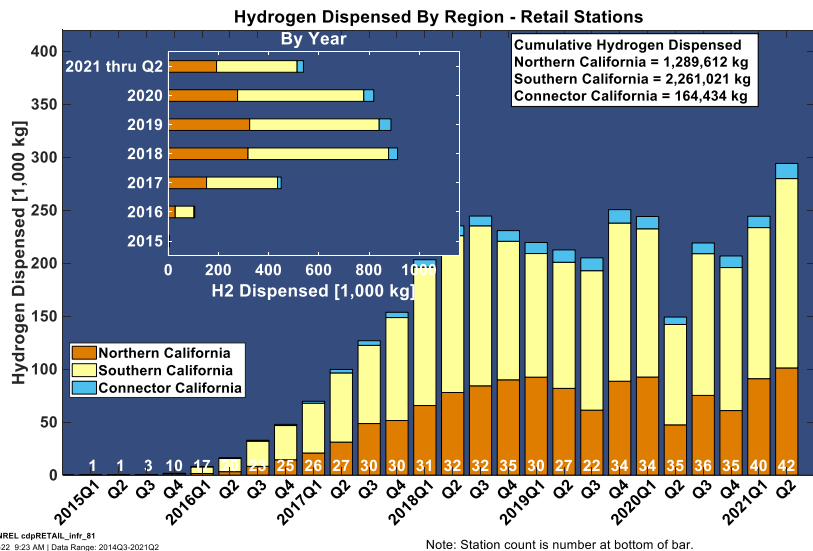
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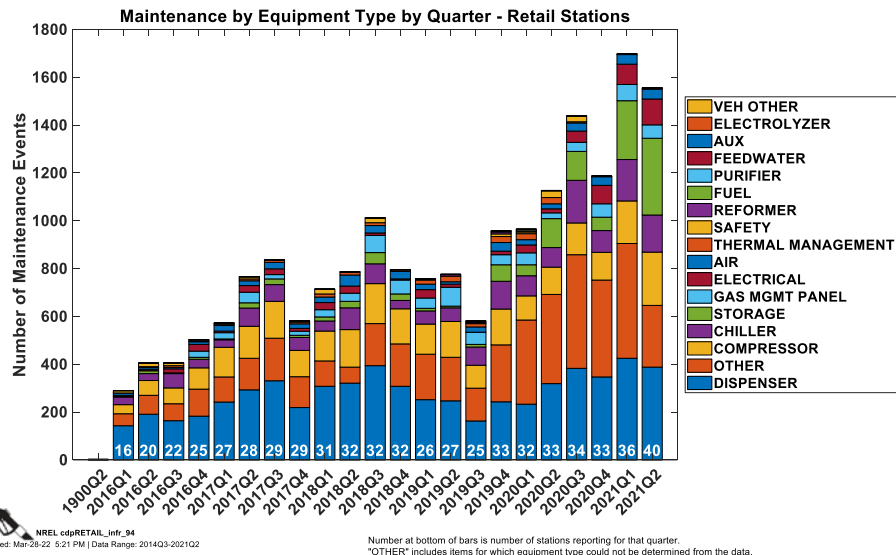
*Argonne National Laboratory, 2022

Next challenge: Medium/heavy duty FC truck refueling

Accomplishments and Progress: H2 Dispensed and Maintenance by Quarter



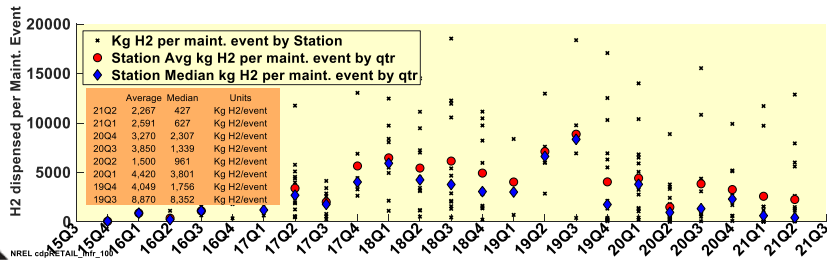
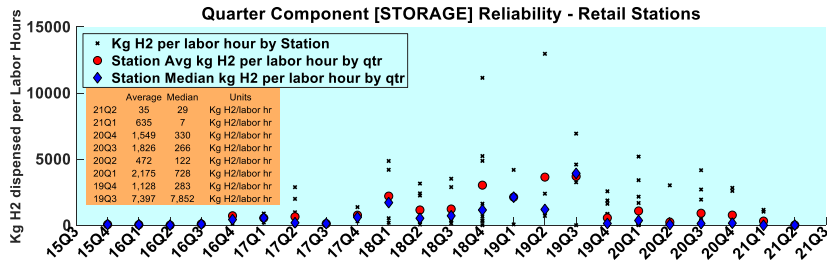
After a decrease in usage in 2020, 2021 has seen a resurgence of usage beyond previous levels. This is seen in both amount of H2 dispensed and the related maintenance.



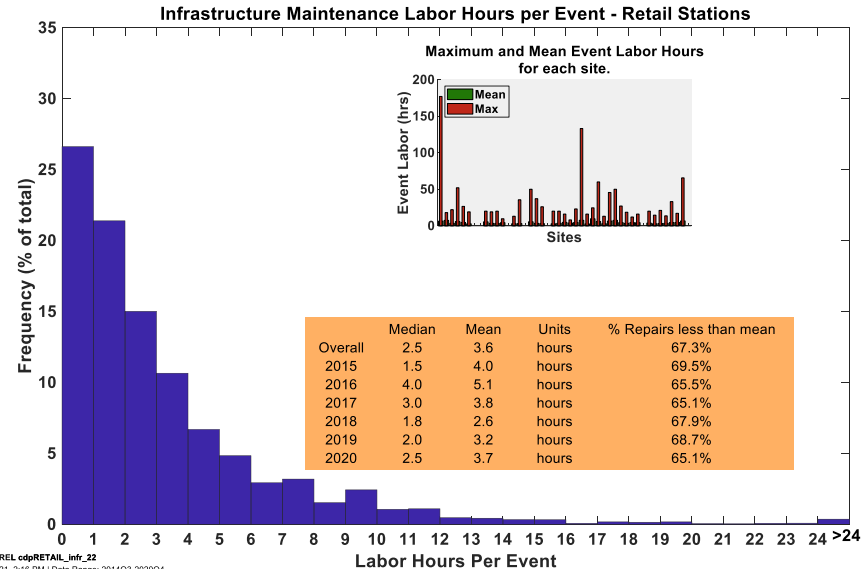
Since 2015 retail H2 station tracking:

- Cumulative H2 dispensed since project inception: 3.72 M kg H2
- Number of Filling events: 1.38 M fueling events

Accomplishments and Progress: Maintenance Dive



Maintenance labor hours will no longer be reported due to a change in the reporting template. Historical data will remain available at the website.

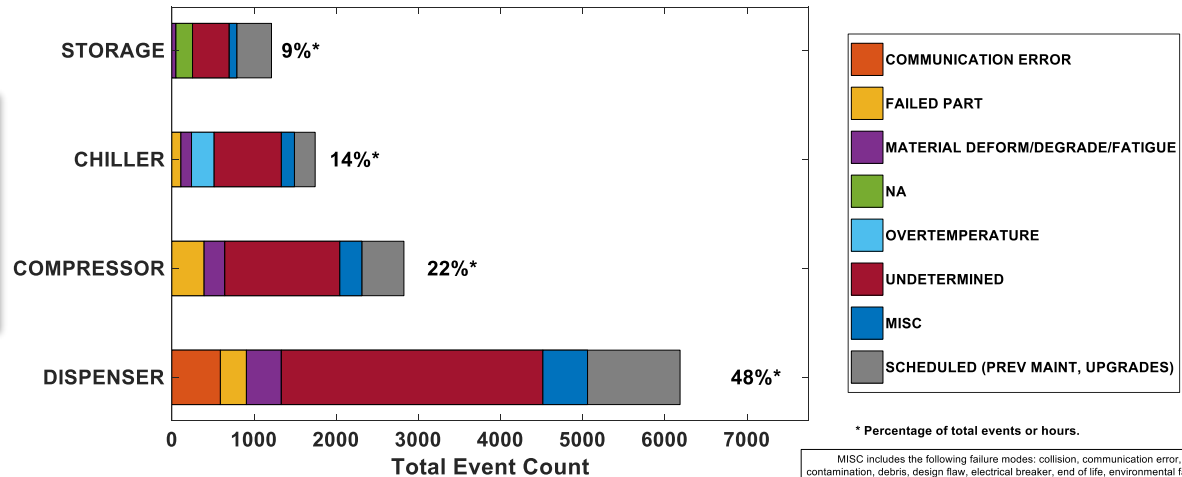


Maintenance related to storage has increased the last few quarters. The impact of maintenance events per kg dispensed is low, but the number of hours required per event is high.

Accomplishments and Progress: Risk Assessment

This project is working with the H2 safety team at NREL and initiated informal collaboration with University of Maryland to utilize maintenance and safety to increase value of data.

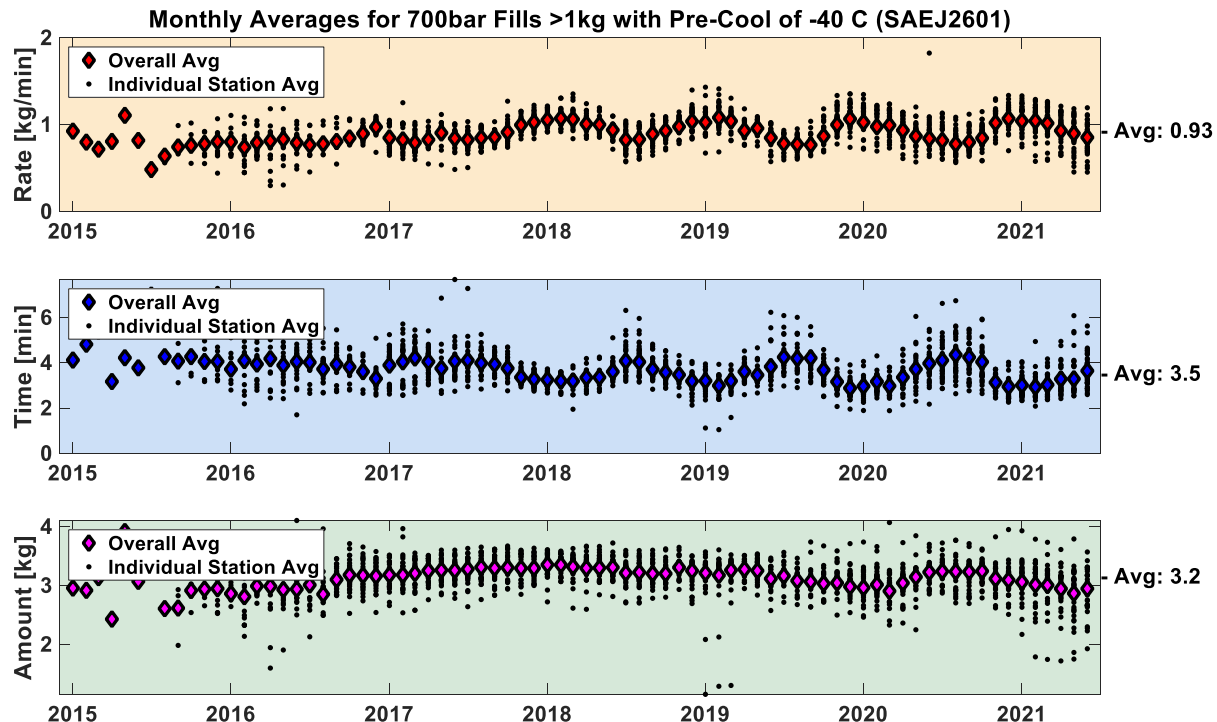
Failure Modes for Top Equipment Categories - Retail Stations



Accomplishments and Progress: Light duty refueling station performance

Light duty H2 refueling station performance:

- H2 refueling rates for LD stations have remained consistently at around 0.93 kg/min for several years.
- A distinct seasonal variation can be seen in the quarterly data.
- MD/HD station are looking to meet 10 kg/min rate, a 10x increase from today



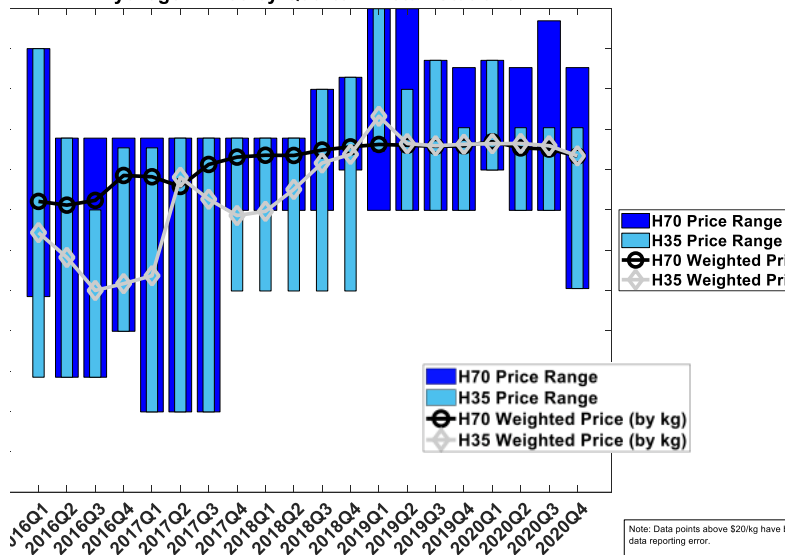
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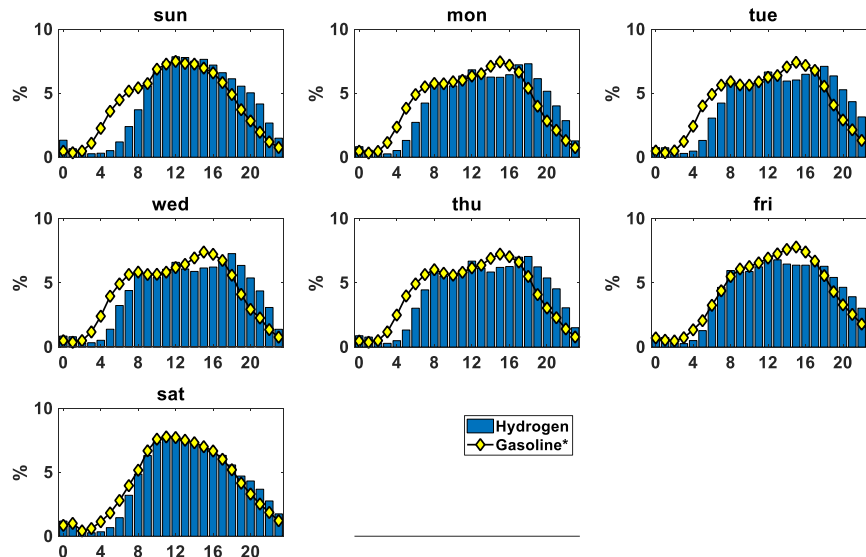
Accomplishments and Progress: H2 refueling stations profiles

- The cost of H2 is decreasing, but further data is needed to understand the trend.
- H2 refueling stations are seeing usage profiles similar to gasoline stations

Hydrogen Price by Quarter - Retail Stations



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

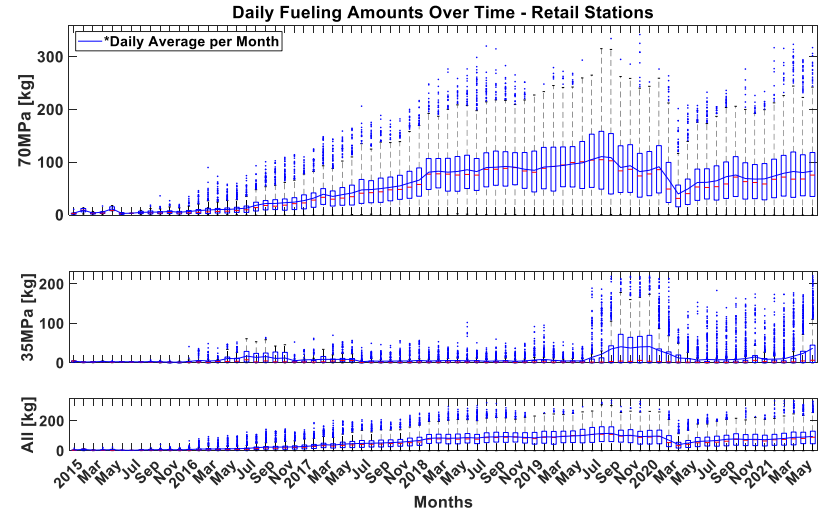
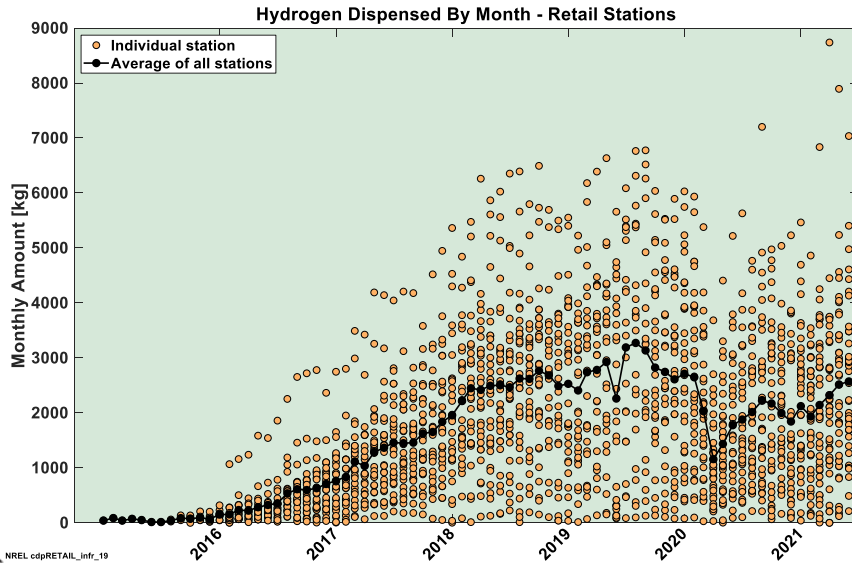


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*Chevron gasoline profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen, 2008.

Accomplishments and Progress: H2 Demand

- Daily fueling amounts are again closing in on a 100 kg H2/day average.
- Some stations are reaching 300 kg H2/day.
- Demand is recovering from 2020.

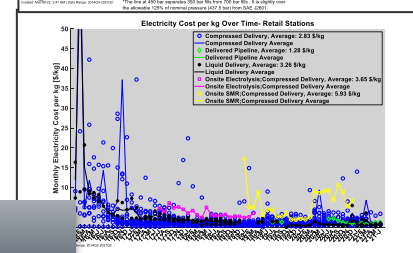
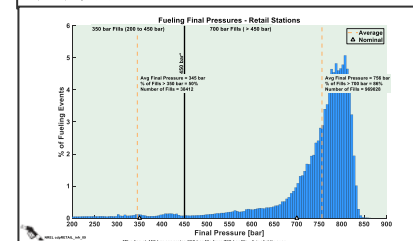
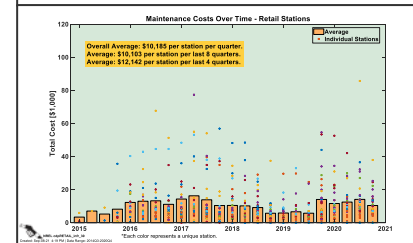
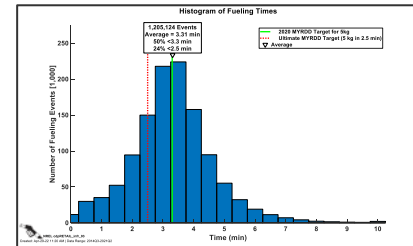
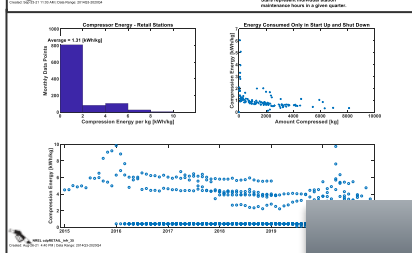
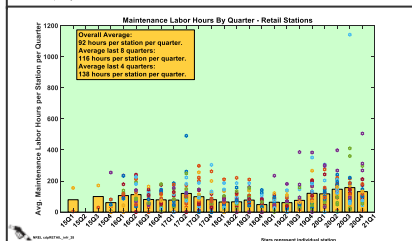
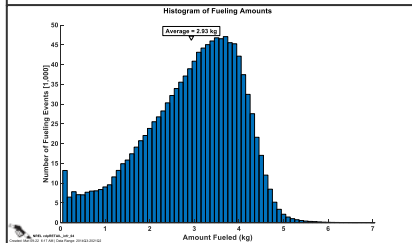
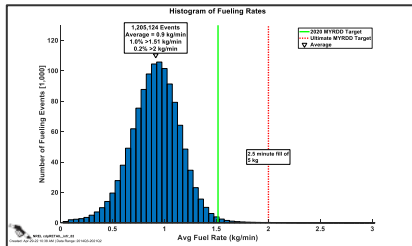


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*Daily average only includes days with fills. Outliers more than 3 standard deviations are not shown.

Accomplishments and Progress: Sampling of Results

Fueling Rate Average	0.9 kg/min
Fueling Amount Average	2.93 kg
Fueling Time Average	3.31 min
Compressor Energy Average	1.29 kWh/kg
Total Hydrogen Dispensed (42 Stations)	3,715,067 kg 2,751,081 kg - 19Q3
Maintenance Cost per Station per Quarter Average	\$10,185 per station-quarter \$10,103 (last 8 quarters)
Maintenance Hours Average	92 hours/Quarter 116 hrs/Qtr (last 8 quarters)
Fueling Final Pressure Average	756 bar
Average Electricity Cost by Delivery Type 2020Q2	\$2.83/kg – Compressed \$3.26/kg – Liquid \$3.65/kg –Electrolysis



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

Accomplishments and Progress: Response to Previous Year Reviewers' Comments

- Additional data cleaning and investigation of outliers would be helpful, though it is understood that the input data and communication with the station operators are limited.
 - *Agreed. Some of the suggestions may be incorporated into future projects and may not be possible within the contractual limitations we have here.*
- The project could benefit from shifting from light-duty (LD) vehicles and an LD infrastructure focus to heavy-duty (HD) vehicles and an HD infrastructure focus, where more transparency of equipment performance and durability is needed because of the expected rapid transition from conventional technology to zero-emissions technology.
 - *We expect future projects to cover this area as well as other H2 infrastructure like large-scale electrolysis and hybrid systems.*
- The consistent updating of the CDPs is of great value to the community in identifying where improvements for stations are needed the most, though better analysis of how downtime and other unplanned events affect costs would be even better.
 - *This is a good suggestion and we will evaluate how to better integrate with cost analysis.*
- The current project objectives appear outdated compared to the state of technology and the rate of technology development by industry. NREL is delivering on the set objectives, but it is recommended that the project shift focus and re-align to provide cutting-edge value.
 - *The project is limited by contractual data and we are evaluating if there are ways to provide analysis more nimbly.*

Remaining Challenges and Barriers

- Quality reporting especially around maintenance events is an ongoing challenge
- A template change has made some CDPs impossible to update further.
- Providing relevant data products that address needs of a diverse set of stakeholders is a challenge in terms of number of requests and time to develop the analyses

Proposed Future Work

- Analysis and CDP publication
 - Complete data analysis and publish results
 - Spring 2022 with data through 2021Q2
 - Fall 2022 with data through 2021Q4
- Update data collection, analysis and feedback
 - Implementing strategies for improving maintenance data reporting
 - Focus new analysis component reliability, maintenance trends, network health
 - Working on more time-series analysis for different generations of stations
 - Pursue all data collection opportunities including in the Northeast corridor

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 42 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

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NREL/PR-5400-82909

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Technical Backup and Additional Information

Technology Transfer Activities

- This is a third-party evaluation of demonstration and early market projects. There is no intention to transfer the technology.

Publications and Presentations

Publications and presentations from last year listed only

- Saur, Genevieve, Gilleon, Spencer, and Sprik, Sam. Next Generation Hydrogen Station Composite Data Products: Retail Stations; Winter 2020: Data through Quarter 4 of 2020 (2021). Web.
- Saur, Genevieve, Gilleon, Spencer, and Sprik, Sam. Next Generation Hydrogen Station Composite Data Products: Retail Stations; Summer 2021: Data through Quarter 2 of 2021 (forthcoming)