Hydrogen Station Data Collection and Analysis

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Project Start Date: October 1, 2011
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Analyze current, state-of-the-art hydrogen infrastructure using several metrics including efficiency, performance, cost, and reliability of station components and systems.
- Perform an independent assessment of technology in real-world operating conditions, focusing on hydrogen infrastructure for on-road vehicles.
- Leverage and develop the data processing and analysis capabilities at the National Fuel Cell Technology Evaluation Center (NFCTEC).
- Publish aggregated results for existing hydrogen stations in the form of composite data products (CDPs).

Fiscal Year (FY) 2019 Objectives

- Obtain/collect data from state-of-the-art hydrogen fueling facilities that receive funding through DOE, California Energy Commission (CEC) awards, and others, to enrich the analyses and the set of publicly available CDPs on hydrogen fueling infrastructure.
- Perform analysis and provide feedback on sensitive data from hydrogen infrastructure for industry and DOE. Aggregate these results for publication.
- Participate in technical review meetings and site visits with industry partners to discuss results from NREL's analysis.
- Publish a set of aggregated results for existing hydrogen stations.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan[1]:

- Lack of Hydrogen Refueling Infrastructure Performance and Availability Data.

FY 2019 Accomplishments

- Published fall 2018 and spring 2019 CDPs based on the available station data.
- Internally processed and analyzed quarterly infrastructure data in the NFCTEC for inclusion in the two sets of published CDPs and the detailed data products shared with those providing data.
- Shared the infrastructure data collection templates with external partners including new station providers.
- Analyzed data from the CEC on their awarded retail stations.
- Kept the NREL Fleet Analysis Toolkit code up to date, fixed bugs, integrated with latest releases of MATLAB, and revised import tools to accept data in multiple formats from stations.
- Presented results at the DOE Hydrogen and Fuel Cells Program 2019 Annual Merit Review and Peer Evaluation Meeting.

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

INTRODUCTION

There are 41 retail stations in California serving more than 6,000 fuel cell electric vehicles (FCEVs). Additionally, in California, there are 22 more stations in the works at various stages from planning to commissioning for a potential of 63 retail stations by 2020. The network of stations has been carefully planned out and funded by California and station providers to cover strategic geographic areas in the state including connector and destination stations. The network coverage helps consumers feel confident about finding fuel for their FCEV across the state as they venture away from their home station. In the northeast United States, efforts are under way to build out a network of 12 stations, with several completed but not in retail service yet, to begin covering that geographic region. As these stations roll out and serve more and more customers, there are many opportunities to learn and improve on previous designs and efforts.

California continues planning to co-fund the first 100 stations to help get the network to a point where it can support itself with growth from private investments. The most recent notice of proposed awards from the CEC came through GFO-15-605, announced in February 2017, proposing $33 million for 16 additional retail stations, three of which are already open to customers. The State of California's funding of hydrogen stations is administered by CEC through the Clean Transportation Program, also known as the Alternative and Renewable Fuel and Vehicle Technology Program, established and continued through 2024 through the state's Assembly Bills 118 and 8.

For better understanding of how these stations are operating and to inform R&D needs, this project aims to gather, analyze, and publish data and results for the hydrogen community. The aggregated results are shared publicly while individual results go back to the provider of the data. The type of data needed is defined using data templates that are provided to the station operators. Working with station operators and funders such as California, we demonstrate the importance of station assessments and propose data requirements through their funding mechanisms.

APPROACH

The emphasis of this project is to document the innovations and equipment performance used in hydrogen fueling and how well they meet customer needs along with areas needing improvement. This includes analysis that captures the technology capability (such as back-to-back filling or impact of precooling the hydrogen fuel) as well as the customer perspective (such as fueling times and rates, safety, and availability). Individual components, such as compressors, are evaluated with the available data to establish status and research needs. NREL also uses the analysis results to support DOE in identifying trends from the data that help guide DOE's R&D activities.

Data analysis is performed on sensitive industry hydrogen fueling data within the confines of the NFCTEC, and recommendations are provided to DOE on opportunities to refocus or supplement R&D activities. Aggregation of the analyzed data allows for creation of composite results for public dissemination and presentation. All this involves working with industry partners to create and publish CDPs that show the current technology status without revealing proprietary data. Feedback to industry partners takes the form of detailed data products (protected results) and provides direct benefit to them from the NREL analysis performed on their data. We will continue exercising the fueling analysis functionality of the NREL Fleet Analysis Toolkit to preserve and archive a snapshot of the analysis results from each quarter. This allows a deeper level of results to be stored in an easy-to-access form within the NFCTEC.

Using unique analysis capabilities and tools developed at NREL, researchers are providing valuable results that lead to technical recommendations to DOE based on real-world experiences with the technology. NREL will continue to provide multiple public outputs in the form of CDPs and presentations and papers at technical conferences.

RESULTS

Using data reported to NREL from 34 retail stations, more than 90 publicly available CDPs were created using NREL's analysis capabilities. Not-for-public detailed data products were created alongside the CDPs for each station, showing its data relative to the aggregated data. Selected public results were presented at the DOE Annual Merit Review and will be presented at the Fuel Cell Seminar. All the aggregated results were published to NREL’s website and cover several analysis categories including deployment, performance, reliability, utilization, safety, energy use, and hydrogen quality.

Fueling Performance

For 2018, the amount of hydrogen dispensed from the retail stations reporting data was 913,194 kg. This is more than twice the amount dispensed in 2017, which was 449,725 kg, and about 9 times the 2016 amount of 104,891 kg. Each quarter since the third quarter of 2015, except for 2018 Q4, has seen an increase in the amount dispensed by quarter, with 2018 Q3 at 244,400 kg. The 2018 Q4 amount is lower only because some stations are no longer reporting data. The continual increase in amount by quarter is due to more FCEVs on the road with more stations opening to support them. The average amount dispensed per station in 2018 Q3 was 7,638 kg while some stations dispensed more than 12,000 kg in a quarter. The average amount of time spent fueling per vehicle in December 2018 was just under 3 min 4 sec and fueling rates for that month averaged 1.03 kg/min. The amount of fuel dispensed per vehicle averaged 3.1 kg at the end of 2018. Most stations are precooling the hydrogen fuel down to a nominal temperature of -40°C, which allows for faster fills while not overheating the vehicle tank.

Utilization

At first, the focus of early stations was to have good geographic coverage so early FCEV customers could drive within and between the clusters of stations without worrying about whether fuel would be available nearby. To that end, most of the stations are on the smaller size (<200 kg per day) and can fill only one vehicle at a time. As more vehicles are introduced—now more than 6,000 vehicles—the stations are seeing demand, and in some cases the demand exceeds the intended daily capacity of the stations. As the demand continues to increase, these stations will not be able to support the vehicles and will have to upgrade their equipment and add dispensers, or more stations would be needed nearby to cover the demand. To see how the stations are being utilized, several CDPs were developed showing amount dispensed by month, by quarter, daily, and by hour of day. The average utilization was also tracked by quarter relative to each station’s nominal daily capacity, the max quarterly capacity utilization, and the max daily capacity utilization. There have been 14 stations over their nominal daily capacity for at least one day. For the max quarterly capacity utilization, there are two stations that have exceeded 100% for a quarter, and the average daily utilization shows three stations over 50% with the highest at 77.3%.

Availability

There have been times this year where stations were down either due to maintenance needs or due to not enough fuel available in the network to support the demand. This can be frustrating to customers who already have a limited network of stations. Analysis shows the missed opportunity based on a station being down compared to what it would normally fuel during that same time frame. For the station downtime, we used California Fuel Cell Partnership SOSS data that records when a station is offline. The normal fueling demand was based on averages of what the station normally sees based on fueling records. Figure 1 is a 2-D histogram binned by hour of day and day of the week showing how much fuel would normally have been dispensed if stations were not offline. We see that in 2018 Q4 for 26 stations, they missed fueling 12,342 kg of fuel because they were offline. The highest missed opportunity bins for that quarter are on Fridays between the hours of 5 p.m. and 8 p.m.

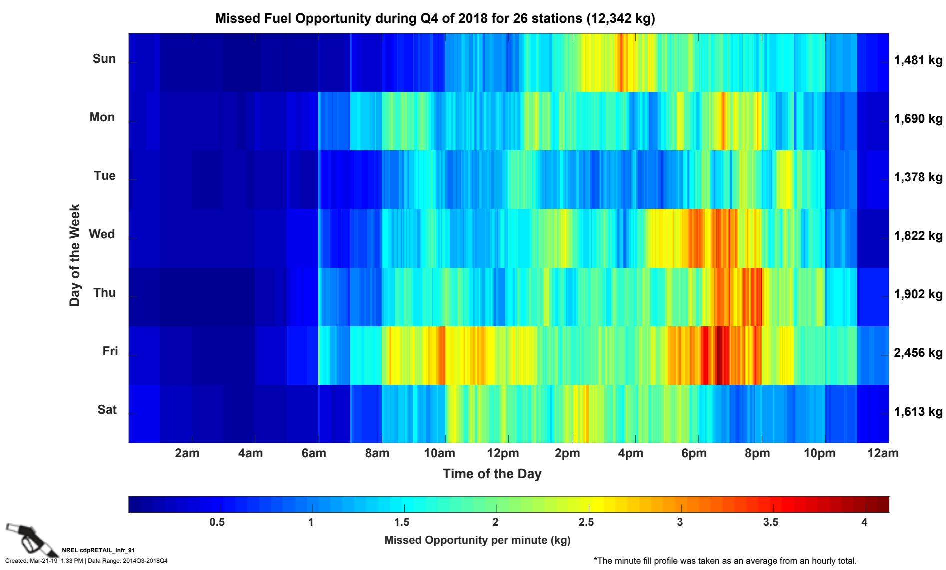

Figure 1. Missed fueling opportunity during 2018 Q4

Maintenance

The top maintenance issue at stations, both for number of events and the labor hours associated with it, is related to dispensers. Compressor issues are the second leading cause for maintenance, followed by chillers. The chiller is responsible for cooling the hydrogen fuel down to -40°C. The temperature swings from ambient to -40°C could be causing issues related to leaks at fittings, freezing conditions from moisture in the air, and other issues with the chiller equipment. Figure 2 shows maintenance by equipment type with 57% of events and 47% of labor hours addressing dispenser items, followed by compressor items at 25% of events and 22% of labor hours, with chiller maintenance events at 12% and 24% of labor hours.

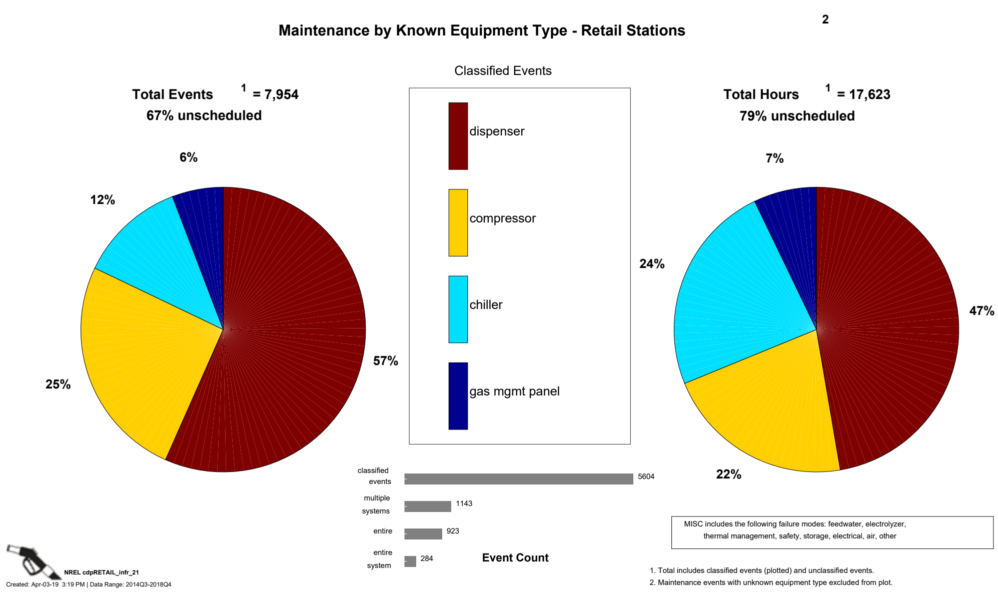

Figure 2. Maintenance by equipment type

Electricity Cost

For stations reporting electricity bills each month, CDPs were developed showing the electrical cost per kilogram of hydrogen dispensed by month. Figure 3 shows the cost per kg by station type. We see the cost coming down over time most likely due to the increase in fuel dispensed. For December 2018, the average electricity cost per kg was $1.58/kg for delivered liquid hydrogen stations, $0.93/kg for delivered compressed hydrogen stations, and $2.76/kg for the stations having delivered compressed hydrogen as well as on-site electrolysis.

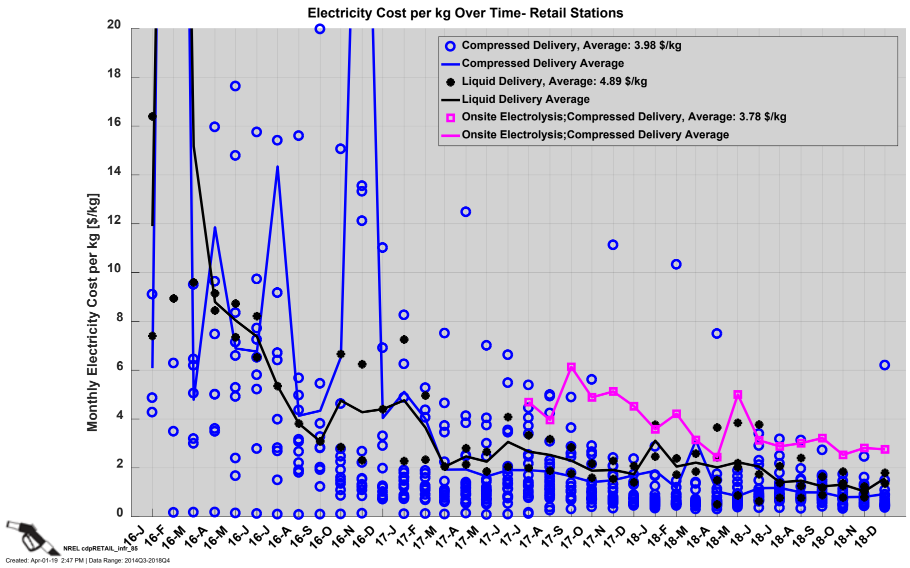

Figure 3. Electricity cost per kg of hydrogen dispensed

Hydrogen Price at the Pump

The price of hydrogen displayed at the dispenser has been relatively high for these early stations. FCEVs are expected to be at least twice as efficient as their gasoline counterparts and so consumers may tolerate a price that is double that of gasoline, aside from valuing other advantages such as no harmful emissions. Because FCEV manufacturers have included fuel as part of the FCEV lease, price of fuel may not be a concern for early customers, but it may be an issue as drivers start paying for their own fuel at the pump. Figure 4 shows the range of prices at the stations over time and weighted by the amount of fuel sold. For the last quarter of 2018, the weighted price at the pump for 70 MPa hydrogen fuel was $16.56/kg of hydrogen based on the stations reporting data.

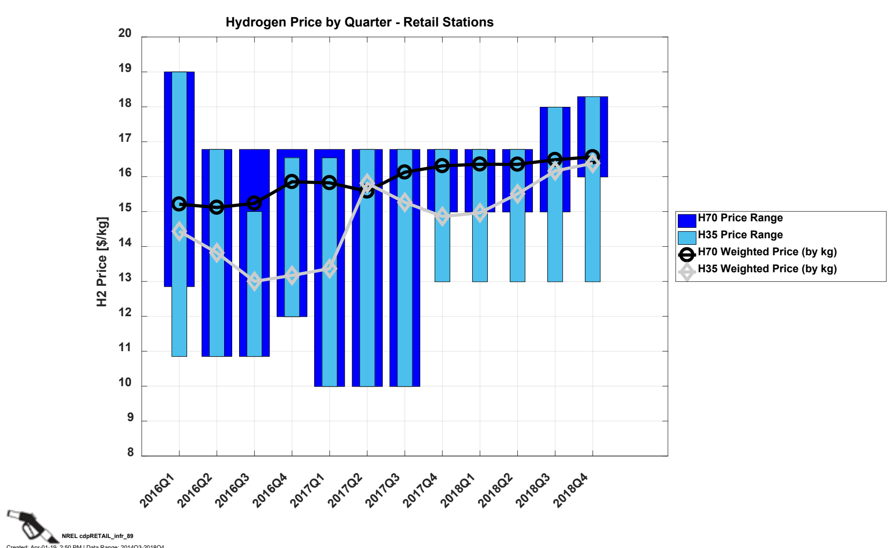

Figure 4. Price of hydrogen dispensed by quarter

Hydrogen Quality

Hydrogen is sampled at the stations periodically for impurity analysis. CDPs based on the data from the lab analysis are created for each individual constituent showing the range of values for each impurity seen at stations. For example, the lab results for carbon monoxide show a range from 0.5 to 10 parts per billion at the stations. This is well below limits of 200 parts per billion, but it is useful for fuel cell developers to see what their equipment will be exposed to at these stations. Impurity CDPs are available for all the constituents listed in the SAE J2719 standard.

The results discussed here were based on a subset of the CDPs developed by this project and are available on NREL's website alongside the complete set of CDPs based on the data reported from retail stations

CONCLUSIONS AND UPCOMING ACTIVITIES

As the network of stations grows, we expect to see new technologies deployed at larger stations with multiple fueling positions as well as the continual operation of the existing stations. Their performance and availability will affect how successfully they support the current and upcoming fleet of fuel cell vehicles. Continual data collection, analysis, and feedback will provide DOE and the hydrogen and fuel cell community with awareness of the benefits and shortcomings of the current technology and identify areas for further R&D. This project will continue to add timely analysis topics and work toward a more automated system for recurring analysis that is desired and useful for the community. For the near term, activities include the next set of CDPs planned to be available in the fourth quarter of 2019.

As more hydrogen markets open for applications such as long-haul and medium-duty trucks, the knowledge from existing stations will serve to inform the development of infrastructure for these applications.

FY 2019 PUBLICATIONS/PRESENTATIONS

1. Genevieve Saur, Sam Sprik, Shaun Onorato, Spencer Gilleon, and Erin Winkler, "TA014: Hydrogen Station Data Collection and Analysis" (presented at the 2019 DOE Annual Merit Review and Peer Evaluation Meeting, Washington, DC, April 30, 2019).
2. Sam Sprik, Jennifer Kurtz, Genevieve Saur, and Spencer Gilleon, "Next Generation Hydrogen Station Composite Data Products: Retail Stations, Data through Quarter 4 of 2018" (Golden, CO: NREL, 2019), https://www.nrel.gov/docs/fy19osti/73658.pdf.
3. Jennifer Kurtz, Sam Sprik, and Thomas H. Bradley, "Review of Transportation Hydrogen Infrastructure Performance and Reliability," *International Journal of Hydrogen Energy* 44, no. 23 (2019): 12010–12023