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 Renewable Energy Laboratory's (NREL's) 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) 2018 Objectives

- Obtain/collect data from state-of-the-art hydrogen fueling facilities that receive funding through DOE, the California Energy Commission (CEC) awards, and others, to enrich the analyses and the set of publicly available CDPs on hydrogen fueling infrastructure.
- Work with codes and standards activities and fueling facility owners/operators to benchmark performance of the fueling events relative to current SAE procedures.
- 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.
- Provide input to the Alternative Fuels Data Center station locator for accurate and up-to-date hydrogen station information through close partnership with CEC, California Fuel Cell Partnership, and station providers, including efforts in the northeastern United States.
- Publish a set of aggregated results for all stations including stations that are not considered retail and another set for just the retail stations that are open to all original equipment manufacturer fuel cell electric vehicle (FCEV) customers.

Technical Barriers

This project addresses the following technical barrier 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 2018 Accomplishments

- Published fall 2017 and spring 2018 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.

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

- Analyzed data from CEC on their awarded retail stations.
- Kept 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.
- Provided input to the Alternative Fuels Data Center to keep the hydrogen station information up to date through close partnership with California Fuel Cell Partnership, CEC, station providers, and the northeastern U.S. stations.
- Presented results at the 2017 Fuel Cell Seminar and the 2018 Annual Merit Review.

INTRODUCTION

There are 35 retail stations in California serving more than 5,000 FCEVs. Additionally, in California, there are 29 more stations in the works at various stages from planning to commissioning for a potential of 64 retail stations by 2020. The funding of the network of stations has been carefully planned out by California and station providers to cover strategic geographic areas in the state including connector and destination stations for the consumer to feel confident about finding fuel for their FCEV as they travel about. In the northeast United States, efforts are under way to build out a network of 12 stations, with several near completion, to begin covering that geographic region. Counting retail and non-retail stations together, there are 40 stations open in the United States. 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 is not stopping at 64 stations. It's 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. California's funding of hydrogen stations comes through the CEC's Alternative and Renewable Fuel and Vehicle Technology Program.

For a better understanding of the status of these stations and to inform research and development needs, this project aims to gather, analyze, and publish data and results for the hydrogen community. The aggregated results are shared publicly, and individual results go back to the providers 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

This project documents the innovations and equipment performance used in hydrogen fueling, explores how well customer needs are met, and identifies areas that need 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, will be evaluated with the available data to establish status and research needs. Station locations will be evaluated within the context of both available vehicles and future vehicles and their fueling patterns. NREL will also use the analysis results to support DOE in identifying trends from the data that will help guide DOE's research and development activities.

Data analysis will be performed on sensitive industry hydrogen fueling data within the confines of the NFCTEC and recommendations will be provided to DOE on opportunities to refocus or supplement research and development activities. Aggregation of the analyzed data allows for the 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 takes the form of detailed data products (protected results) and provides direct benefit from the NREL analysis performed on industry 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 technical recommendations to DOE based on real-world experiences with the technology. NREL will continue to provide multiple outputs in the form of CDPs and presentations and papers at technical conferences.

RESULTS

Using data reported to NREL from 29 retail and 9 non-retail stations, more than 90 CDPs were created for the retail group of stations and more than 90 CDPs were created by combining the retail and non-retail stations. Additionally, detailed data products were created for each station showing its data relative to the aggregated data. Selected public results were presented at the DOE Annual Merit Review and 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 2017, the amount of hydrogen dispensed from the retail stations that were reporting data was 438,352 kg, more than four times the amount dispensed in 2016, which was 104,981 kg. Each quarter since the third quarter of 2015 has seen an increase in the amount dispensed by quarter, with the fourth quarter of 2017 at 143,900 kg. This is because more FCEVs are on the road with more stations opening to support them. The average amount dispensed per station in 2017 Q4 was 4,963 kg, with some stations approaching 10,000 kg in a quarter. The average amount of time spent fueling per vehicle in December 2017 was 3.2 minutes and fueling rates for that month averaged 1.02 kg/min. The amount of fuel dispensed per vehicle averaged 3.2 kg at the end of 2017. Most stations are precooling the 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 fuel availability. 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 numbering more than 5,000, 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, we have developed several CDPs showing amount dispensed by month, quarter, day, and hour of day. We also track the average utilization by quarter relative to their nominal daily capacity, the max quarterly capacity utilization, and the max daily capacity utilization. We have seen four stations near or over their nominal daily capacity for at least one day with several approaching 80%. For the maximum quarterly capacity utilization, there are two stations that have exceeded 80% for a quarter and the average daily utilization shows two stations over 50% with the highest at 63.4%.

Availability

There have been times this year where stations were down either because of maintenance needs or insufficient fuel availability in the network to support the demand. This can be frustrating to customers who already have a limited network of stations. Analysis was done this year to show missed opportunities 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 State of the State Survey 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 two-dimensional 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 for the fourth quarter of 2017 for 22 stations, they missed fueling 4,683 kg of fuel because they were offline. The highest missed opportunity bins for that quarter are on Wednesdays from noon to 2 p.m. and then from 5–6 p.m.

Maintenance

In the past, we have seen most of the maintenance events and labor time performed on compressors at the stations. We are gradually seeing a shift from compressor issues, as operators learn to avoid failures through preventative maintenance and upgrades while responding more quickly to compressor issues and shifting to dispenser issues. There were many maintenance items related to the chiller that 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 46% of events and 31% of labor hours addressing dispenser items, followed by compressor items at 21% of events and 13% of labor hours, with chiller maintenance events at 11% and 14% of labor hours.

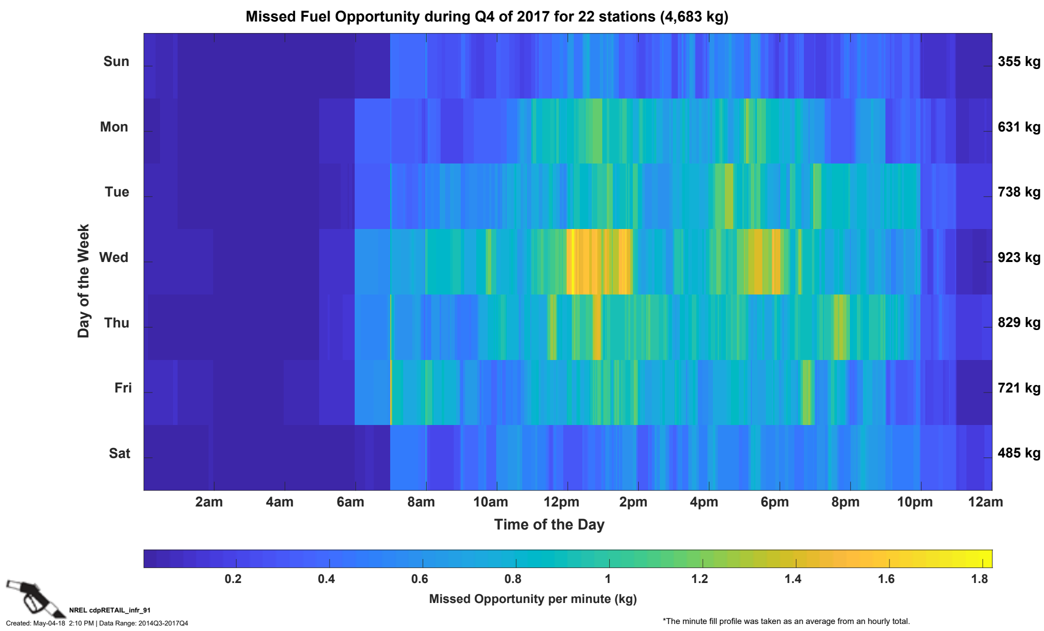

Figure 1. Missed fueling opportunity

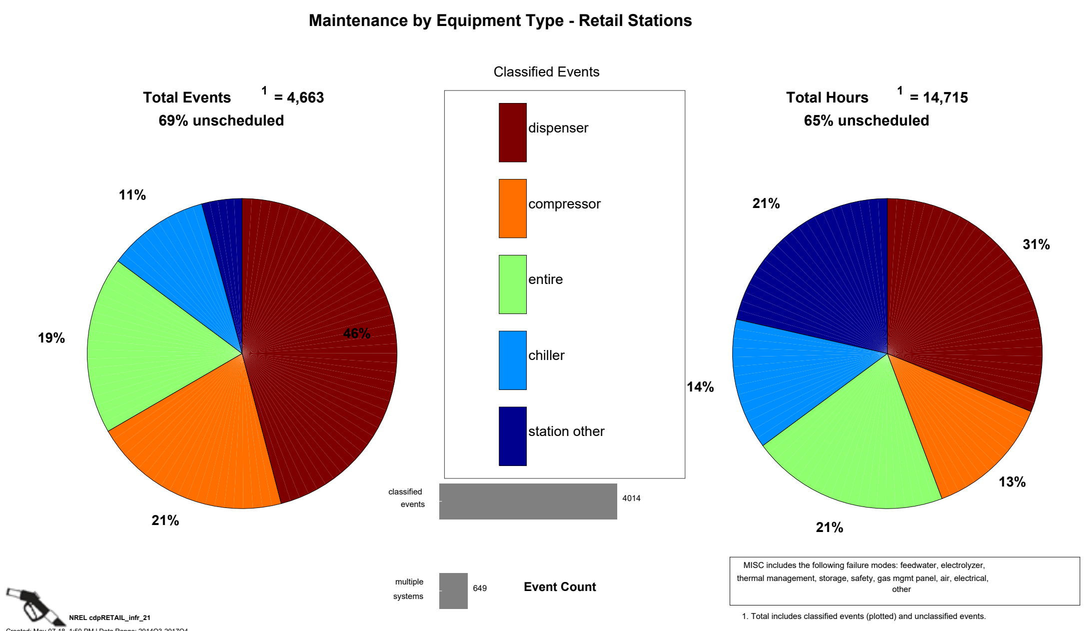

Figure 2. Maintenance by equipment type

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 2017, the average electricity cost per kg for delivered liquid hydrogen stations was $1.74 per kg, for delivered compressed it was $1.70 per kg, and for the stations with delivered compressed as well as on-site electrolysis, it was $4.53 per kg.

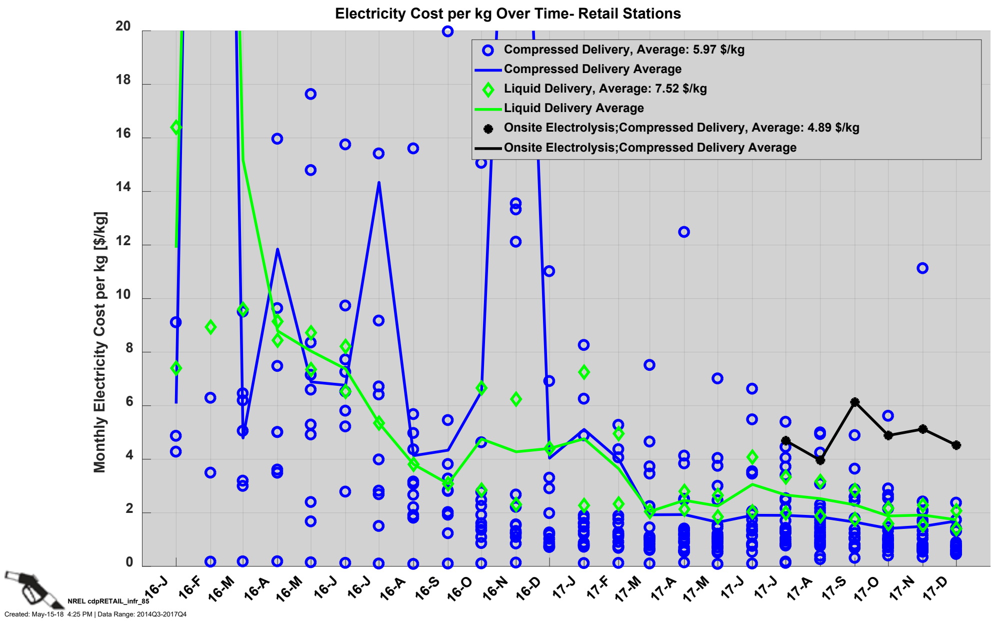

Figure 3. Electricity cost per kilogram hydrogen dispensed

Hydrogen Price at the Pump

The price of hydrogen displayed at the dispenser has been relatively high for these early stations. This may not be a concern for early customers that have fuel included with the lease of their FCEVs but 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 2017, the weighted price at the pump for 70 MPa hydrogen fuel was $16.31 per kg of hydrogen.

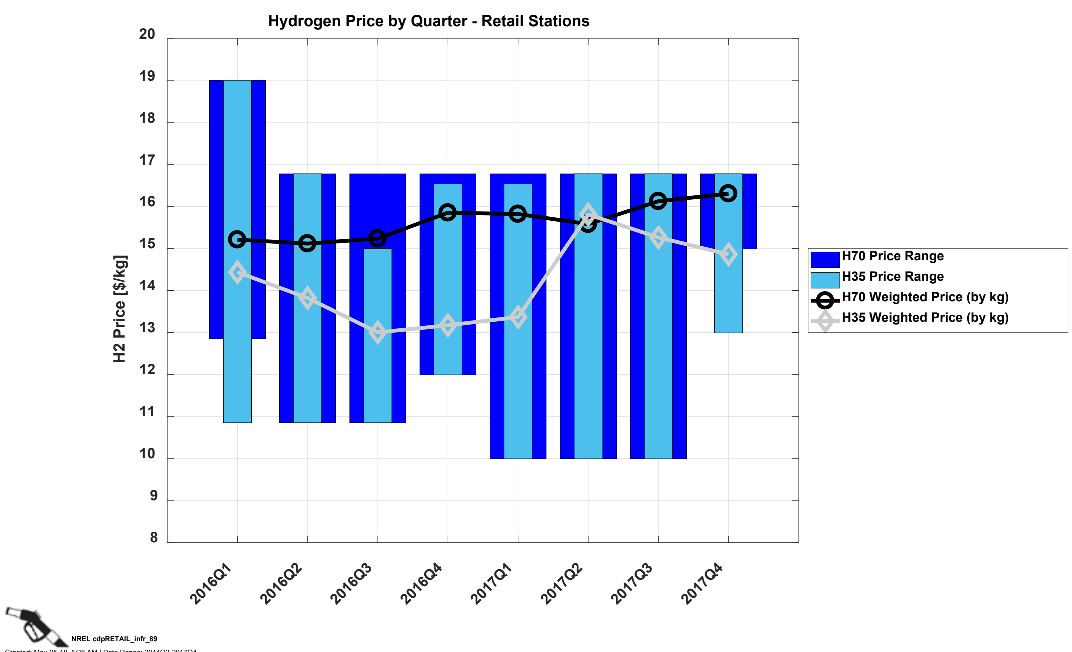

Figure 4. Price of hydrogen dispensed

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 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 for retail stations and the set for the combination of non-retail and 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 research and development. 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 2018.

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 2018 PUBLICATIONS/PRESENTATIONS

1. Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, Shaun Onorato, and Matt Ruple, "TV017: Hydrogen Station Data Collection and Analysis" (presented at the 2018 DOE Annual Merit Review and Peer Evaluation Meeting, Washington, DC, June 14, 2018).
2. Sam Sprik, Jennifer Kurtz, Genevieve Saur, Shaun Onorato, Matt Ruple, and Chris Ainscough, "Next Generation Hydrogen Station Composite Data Products: All Stations (Retail and Non-Retail Combined), Data through Quarter 4 of 2017" (May 2018), http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.
3. Sam Sprik, Jennifer Kurtz, Genevieve Saur, Shaun Onorato, Matt Ruple, and Chris Ainscough, "Next Generation Hydrogen Station Composite Data Products: Retail Stations, Data through Quarter 4 of 2017" (May 2018), http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.
4. Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, and Michael Peters, "Next Generation Hydrogen Station Composite Data Products: All Stations (Retail and Non-Retail Combined), Data through Quarter 2 of 2017" (November 2017), http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.
5. Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, and Michael Peters, "Next Generation Hydrogen Station Composite Data Products: Retail Stations, Data through Quarter 2 of 2017" (November 2017), http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.
6. Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, Mike Peters, and Keith Wipke, "Performance of Existing Hydrogen Stations" (presented at the 2017 Fuel Cell Seminar and Energy Exposition, Long Beach, CA, November 8, 2017).