VII.B.2 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 the data processing and analysis capabilities at the National Fuel Cell Technology Evaluation Center (NFCTEC), originally developed under the Fuel Cell Vehicle Learning Demonstration, as well as from forklift, backup power, and bus projects.
- Publish aggregated results for existing hydrogen stations in the form of composite data products (CDPs).

Fiscal Year (FY) 2017 Objectives

- Obtain and collect data from state-of-the-art hydrogen fueling facilities that receive funding through DOE Funding Opportunity Announcement DE-FOA-0000626 awards, 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 and 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 (AFDC) station locator for accurate and up to date hydrogen station information through close partnership with CEC, California Fuel Cell Partnership (CaFCP), 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 which 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.

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

Contribution to Achievement of DOE Technology Validation Milestones

This project will contribute to achievement of the following DOE milestone from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Milestone 4.4: Complete evaluation of 700-bar fast fill fueling stations and compare to SAE J2601 specifications and DOE fueling targets. (3Q, 2016)

FY 2017 Accomplishments

- Created and published Winter 2016 and Spring 2017 CDPs based on available station data.
- Provided input to the AFDC to keep the hydrogen station information up to date through close partnership with CaFCP, CEC, station providers, and the northeastern United States stations.
- Participated in the CaFCP working group meetings and H2USA hydrogen fueling station working group.
- 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.

- Kept the infrastructure data collection templates up to date and reviewed with external partners including new station providers.
- Gathered and provided updates on stations under the DOE Funding Opportunity Announcement DE-FOA-0000626-funded projects.
- Analyzed data from the CEC on their awarded retail stations.
- Updated NREL Fleet Analysis Toolkit code to accept and analyze data in multiple formats from stations.
- Presented results at the 2017 Annual Merit Review.

INTRODUCTION

In the past, approximately 60 hydrogen fueling stations supported a few hundred FCEVs in the United States. Of these stations, 25 supported the 183 DOE Learning Demonstration vehicles. As we moved out of a learning demonstration environment into a commercialization environment, manufacturers carefully ramped up FCEV production to match the infrastructure effort. This effort moved from demonstration type stations, of which most have been decommissioned, to a network of consumer-friendly retail stations, focusing on a few clusters of stations to cover strategic areas where vehicles are introduced.

California has been a leader in supporting hydrogen infrastructure with a goal of 100 stations within a carefully planned network. Early efforts in California focus on clusters of stations near population centers in the Los Angeles and San Francisco Bay areas along with connector stations and destination stations. Through past funding efforts, 28 retail stations are in place in California supporting over 1,000 FCEVs with 14 more in near-term development. The most recent notice of proposed awards from the CEC through GFO-15-605, announced in February of 2017, proposes $33 million for 16 additional retail stations. California State funding of hydrogen stations comes through the CEC's Alternative and Renewable Fuel and Vehicle Technology Program. The retail stations that are open in California are currently providing data to this project. Besides California, there are efforts in the northeastern states to build 12 retail stations, with several already under construction, which will establish hydrogen infrastructure for the upcoming FCEVs and will also contribute data to this project.

Keys to success for improving hydrogen fueling availability are selecting the fueling location, ensuring customer-friendly public access, and providing adequate and reliable output to support the vehicles. Hydrogen output from existing and upcoming facilities varies from 50 kg/d to 350 kg/d, with most new fueling facilities being more than 100 kg/d. Although it is currently most economical to make hydrogen from natural gas, there are efforts and requirements to make hydrogen from renewable sources. Using available hydrogen energy from landfills and wastewater treatment plants is one way to make use of a renewable feedstock and to lower greenhouse gas emissions. Another renewable pathway is to make hydrogen through electrolysis with the electrical energy coming from a renewable source such as wind or solar. As more vehicles come online, these fueling facilities will need to have higher uptimes/availability and be more cost effective to operate and maintain. The continued data collection and analysis will show the progress being made in these areas and determine future technology development needs.

APPROACH

The emphasis of this project is documenting the innovations in hydrogen fueling and how well they meet customer needs. This includes analysis that captures the technology capability (such as back-to-back filling capability, impact of pre-cooling temperature, and radio frequency identification of vehicles to allow unique fueling profiles) 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 current 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 in 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 creation of composite results for public dissemination and presentation. Some existing CDPs from the previous learning demonstration will be updated with new data, as appropriate. 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 form in 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 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

As stations are built or retired, the publicly viewable AFDC station database is updated by this project, through California updates, and by station providers. Currently, there are 37 public stations (28 are considered retail) in the United States with 19 more planned in the near future. The newer stations are being built to be accessible to the public in a retail environment and most are located in California with several also under construction in the Northeast United States this year. Using the data reported to NREL by 26 of these retail stations and nine non-retail stations over 80 CDPs were developed for the retail group of stations and over 80 CDPs were created for all the stations combined. Additionally, Detailed Data Products were created for each station showing their data relative to the aggregated data. The public results were presented at the DOE Annual Merit Review. Results were also published to NREL's website and cover several analysis categories including deployment, performance, reliability, utilization, safety, energy use, and hydrogen quality.

The goals of the early stations included covering geographic areas to prevent range anxiety by FCEV customers. This goal is partially achieved, but the current analysis (Figure 1) shows that max daily utilization is beginning to approach station capacity at a few stations. This implies a need for larger and/or more stations to meet the upcoming vehicle demand beyond just having a single station in the area. An increase in the amount of hydrogen dispensed each quarter (Figure 2) results from both more stations being built and more FCEVs on the road. For 2016, over 107,000 kg of hydrogen were dispensed from retail stations. A look at maintenance by equipment type (Figure 3) shows that hydrogen dispenser equipment is now the primary item needing maintenance both in terms of number of events and labor hours. Entire system, compressor, chiller, and safety system (e.g., false alarms and sensors), are the next highest items in terms of number of maintenance events. Many of the maintenance items, especially for the chiller and the dispenser are due to temperature variations resulting from chilling the hydrogen down to -40°C at the stations. Several new CDPs show cause and effects for maintenance items for the different components. For the dispenser, most of the effects are alarms followed by hydrogen leaks but causes are mostly undetermined. Causes do include operator error, failed parts, communications errors, and environmental factors. As more detail comes in for maintenance items these cause and effect plots should help identify common issues with the stations. Through processing of data from the HyStEP device to measure performance at the stations, we see that most fills are not meeting the temperature requirements within the 30 s after start of fill that is required from the SAE J2601 standard (Figure 4). Second by second data has been requested from the stations that would help compare the target pressures and average pressure ramp rates that the standard specifies. This detailed data will hopefully be available next year as it would prove very useful. Other CDPs show results including levels of contaminants in

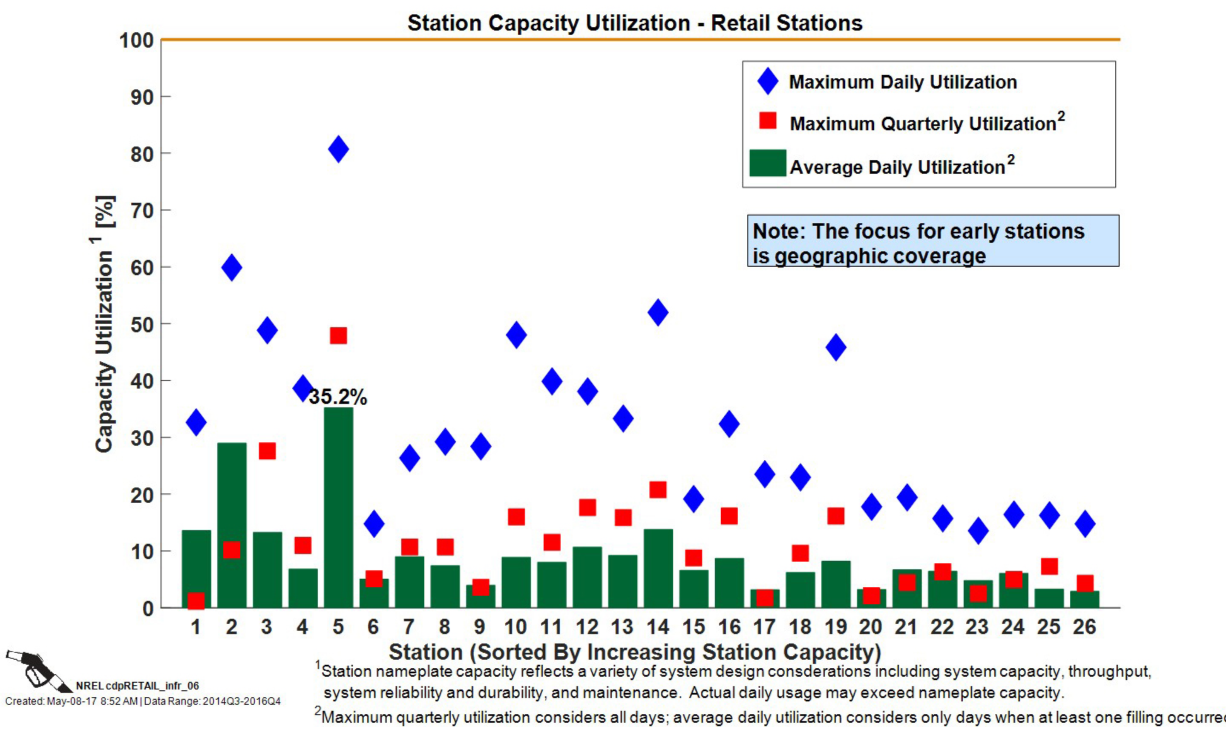

FIGURE 1. Station capacity utilization

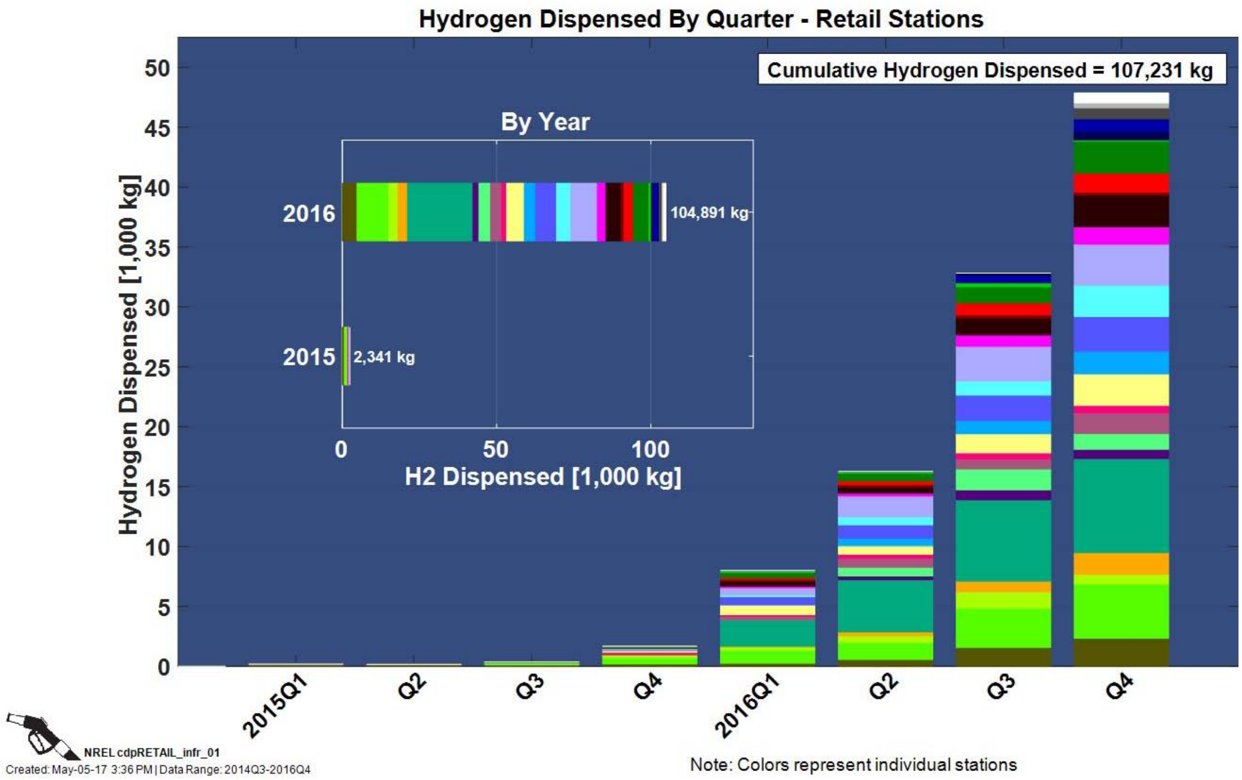

FIGURE 2. Amount of hydrogen dispensed

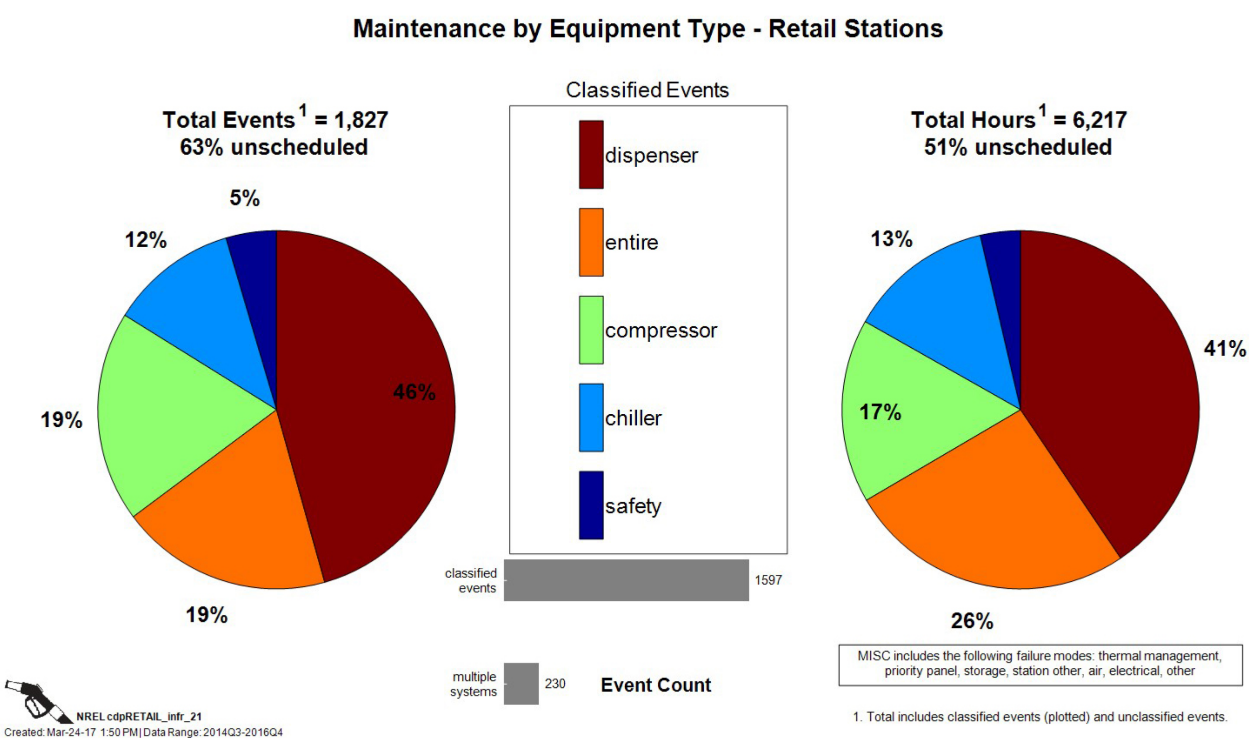

FIGURE 3. Maintenance by equipment type

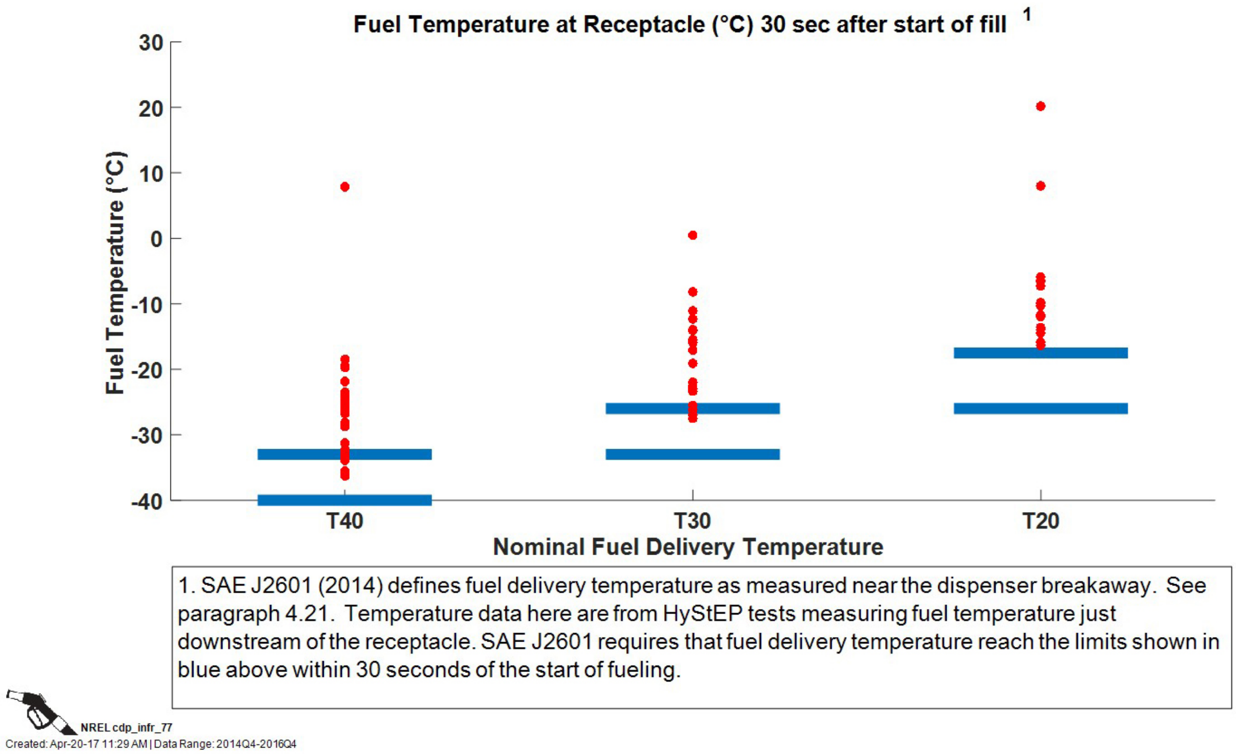

FIGURE 4. Fuel temperature at receptacle after 30 s

the hydrogen, energy used per kilogram dispensed and energy cost per kilogram dispensed. Fueling rates average 0.83 kg/min, fueling amounts average 2.86 kg and fueling time averages 3.6 min. Compressors use 3.65 kWh per kg and electrolyzers use 62 kWh per kg on average. There are 23 h of maintenance at a station on average per month and there are 289 fills per hydrogen leak reported. These results and all the other CDPs are published on NREL's website.

CONCLUSIONS AND UPCOMING ACTIVITIES

As new stations come online or are updated, 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 technology readiness and identify areas for improvement that could be research topics. Many new stations are coming online and will be included in the data set as they report data. Their data will be aggregated and published in CDPs without revealing individual station identity and will help identify general trends for the latest stations. As more data become available from newer stations and as more FCEVs enter the market, there will be an increase in data analysis possibilities to validate the technology for hydrogen infrastructure including focusing on trends over time for usage, reliability, and performance of the stations.

FY 2017 PUBLICATIONS/PRESENTATIONS

1. Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, and Mike Peters, "TV017: Hydrogen Station Data Collection and Analysis" (presented at the 2017 DOE Annual Merit Review and Peer Evaluation Meeting, Washington, DC, June 2017).

2. Next Generation Hydrogen Station Composite Data Products: All Stations (Retail and Non-Retail Combined), Data through Quarter 4 of 2016, Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, and Michael Peters (May 2017) http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.

3. Next Generation Hydrogen Station Composite Data Products: Retail Stations , Data through Quarter 4 of 2016, Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, and Michael Peters (May 2017) http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.

4. Next Generation Hydrogen Station Composite Data Products: All Stations (Retail and Non-Retail Combined)PDF, Data through Quarter 3 of 2016, Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, Michael Peters, and Matthew Jeffers (January 2017) http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.

5. Next Generation Hydrogen Station Composite Data Products: Retail StationsPDF, Data through Quarter 3 of 2016, Sam Sprik, Jennifer Kurtz, Chris Ainscough, Genevieve Saur, Michael Peters, and Matthew Jeffers (January 2017) http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html.