

## VII.8 Next Generation Hydrogen Infrastructure Evaluation

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Project End Date: Project continuation and direction determined annually by DOE

### Overall Objectives

- Study current, state-of-the-art hydrogen fueling stations. Analyze efficiency, performance, cost, and reliability of station components and systems from existing stations.
- Perform an independent assessment of technology in real-world operating conditions, focusing on hydrogen infrastructure for on-road vehicles.

### Fiscal Year (FY) 2014 Objectives

- Collect data from state-of-the-art hydrogen fueling facilities funded by DOE Funding Opportunity Announcement (FOA) 626 and others, such as those funded by the State of California, to enrich the analyses and composite data products (CDPs) on hydrogen fueling originally established by the Learning Demonstration project.
- Work with codes and standards activities and fueling facility owners/operators to benchmark performance of the fueling events relative to current SAE International 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.
- Maintain an accurate database (location and status) of all online hydrogen stations in the United States, and provide periodic updates to other online resources, specifically NREL's Alternative Fuels Data Center

(AFDC) station locator, the Fuel Cell and Hydrogen Energy Association, the California Fuel Cell Partnership, and FuelCells.org.

### 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 milestones 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 2014 Accomplishments

- Internally processed and analyzed quarterly infrastructure data in the National Fuel Cell Technology Evaluation Center (NFCTEC) for inclusion in CDPs every six months.
- Created new fall 2013 and spring 2014 CDPs based on available data.
- Updated NREL's internal database of stations and their locations and submitted updates to the AFDC.
- Provided assistance in filling out and modifying templates for those providing infrastructure data.
- Gathered and provided updates on stations under the DOE FOA 626-funded projects.
- Updated NREL Fleet Analysis Toolkit code to accept data in multiple formats from stations outside the DOE FOA 626 stations.
- Analyzed data from station provider outside DOE FOA 626-funded projects.
- Participated in the California Fuel Cell Partnership working group meetings and H2USA hydrogen fueling station working group.
- Presented this project at Fuel Cell Seminar 2013 and at the 2014 Annual Merit Review.



## INTRODUCTION

In the past decade, approximately 60 hydrogen fueling stations supported a few hundred fuel cell electric vehicles (FCEVs) in the United States. Of these stations, 25 supported the 183 DOE Learning Demonstration vehicles. As original equipment manufacturers are ramping up FCEV bus, forklift, and car production, there is an effort to build additional stations, increase individual station fueling output, and cluster stations to cover the area where vehicles are located.

California has been a leader in supporting hydrogen infrastructure with a goal of a 100-station network. There are now nine public stations in California with 17 more in near-term development. To further support the rollout of FCEVs coming in 2015-2017 and beyond, the California Energy Commission proposed awards for PON-13-607 in May of 2014. This would fund 28 new stations and a mobile refueler with more than \$46 million of state money through the California Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program. These stations are expected to be included in subsequent evaluations and would bring the California public station count to 54.

Keys to success for improving hydrogen fueling availability are selecting the fueling location, ensuring public access, and providing adequate output to support the vehicles. Developing multi-use facilities that can serve cars, buses, and/or forklifts may help the economics and capacity utilization. Hydrogen output from existing and upcoming facilities varies from 12 to 140 kg/day, with most new fueling facilities being in the 100 kg/day range. There is an effort to focus on clusters of stations near population centers in the Los Angeles area. Using available biogas resources from landfills and wastewater treatment plants for hydrogen production is one way to make use of a renewable feedstock and to lower greenhouse gas emissions. As more vehicles come online, all fueling facilities will need to be accessible to anyone with a hydrogen vehicle. Long construction lead times need to be accounted for when planning for the upcoming stations. As these optimized fueling facilities are developed, there is a need to continue data collection and analysis to track the progress and determine future technology development needs.

## APPROACH

The emphasis of this project is documenting the innovations in hydrogen fueling and how it will meet vehicle 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 R&D activities.

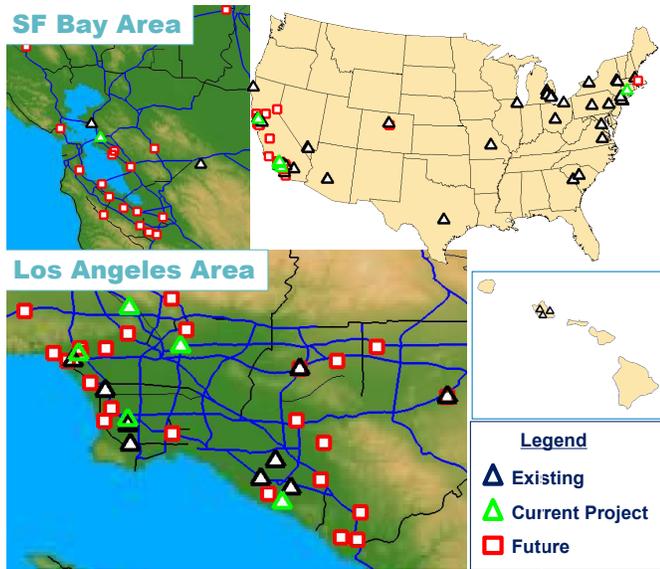
Data analysis will be performed on sensitive industry hydrogen fueling data in NREL's National Fuel Cell Technology Evaluation Center and recommendations will be provided to DOE on opportunities to refocus or supplement R&D activities. Aggregation of the analyzed data allows for creation of composite results for public dissemination and presentation. 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

The hydrogen station locations in the United States can be seen in Figure 1. As stations are built or retired, updates are made to the internal database and shared with others, including the AFDC. There are currently 52 stations in the United States and 12 are considered open to the public, with most of those in California. This year, enough stations started reporting data to NREL to make data aggregation possible in the form of CDPs, which were publicly available through presentations at Fuel Cell Seminar and the DOE Annual Merit Review. Results were also published on NREL's website.

Although the primary goal of the early stations is for coverage, we still want to show how the stations are being used in regards to capacity utilization and usage patterns. The capacity utilization CDPs have been presented and can be found on the NREL website. The amount of dispensed hydrogen per day of the week (Figure 2) shows more filling is happening Monday through Friday than on Saturday and Sunday. The highest station shows an average of 33 kg/day



"Current Projects" are projects providing data as part of the DOE Technology Validation sub-program.

FIGURE 1. Hydrogen Station Locations

on Thursdays. The number of fills per day (Figure 3) at each station range from 3 to 11 on average with maximum daily fills at each station ranging from 7 to 30 fills per day. The amount of hydrogen dispensed per fill (Figure 4) is 2.46 kg on average ranging mostly between 1.5 and 3.5 kg. Some of the lower amounts in the histogram are due to incomplete fills where the station stops the fill for various reasons. A preliminary look at maintenance by equipment type (Figure 5) shows that hydrogen compressors are the primary items needing maintenance both in terms of number of events and hours. Dispenser maintenance, safety items (e.g., false alarms and sensors) and thermal management are the next highest items in terms of number of maintenance events. As more data comes in there will be more analysis focusing on usage, reliability, and performance of the stations.

### CONCLUSIONS AND FUTURE DIRECTIONS

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

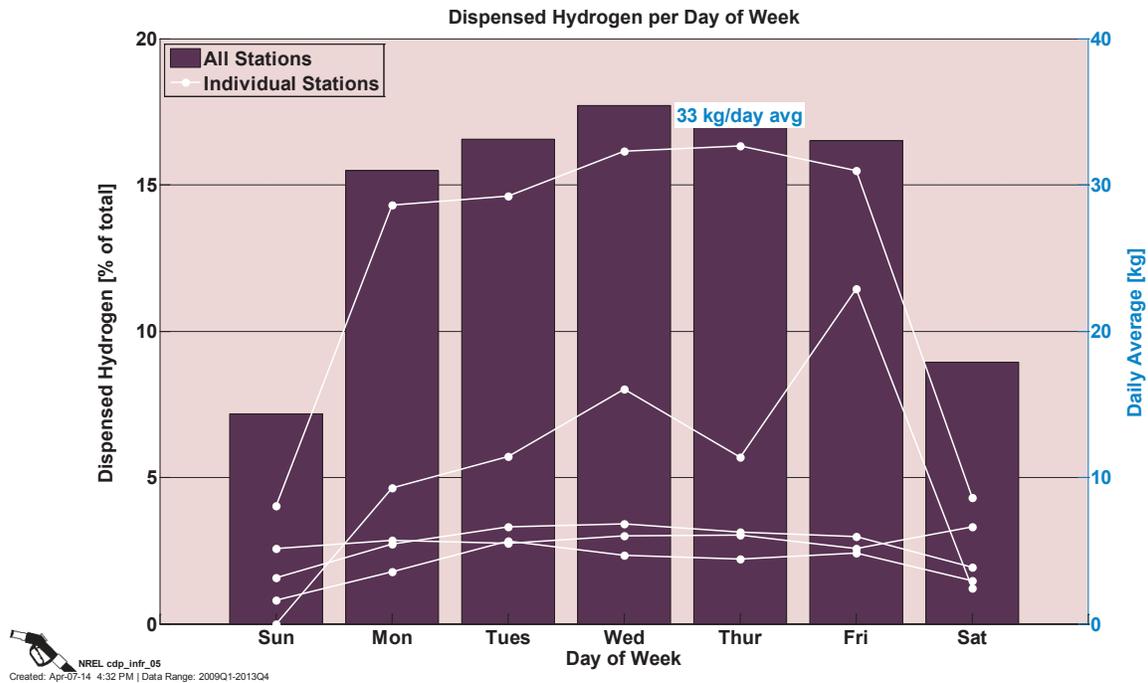


FIGURE 2. Dispensed Hydrogen per Day of Week

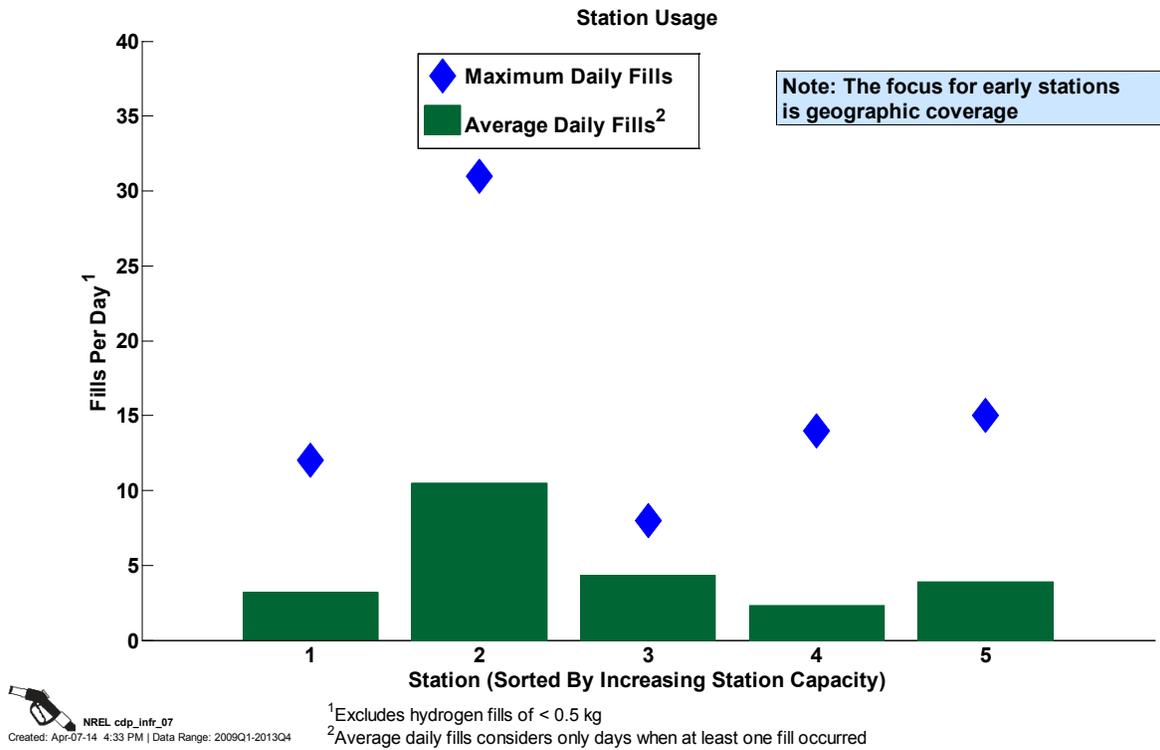


FIGURE 3. Station Usage – Number of Fills per Day

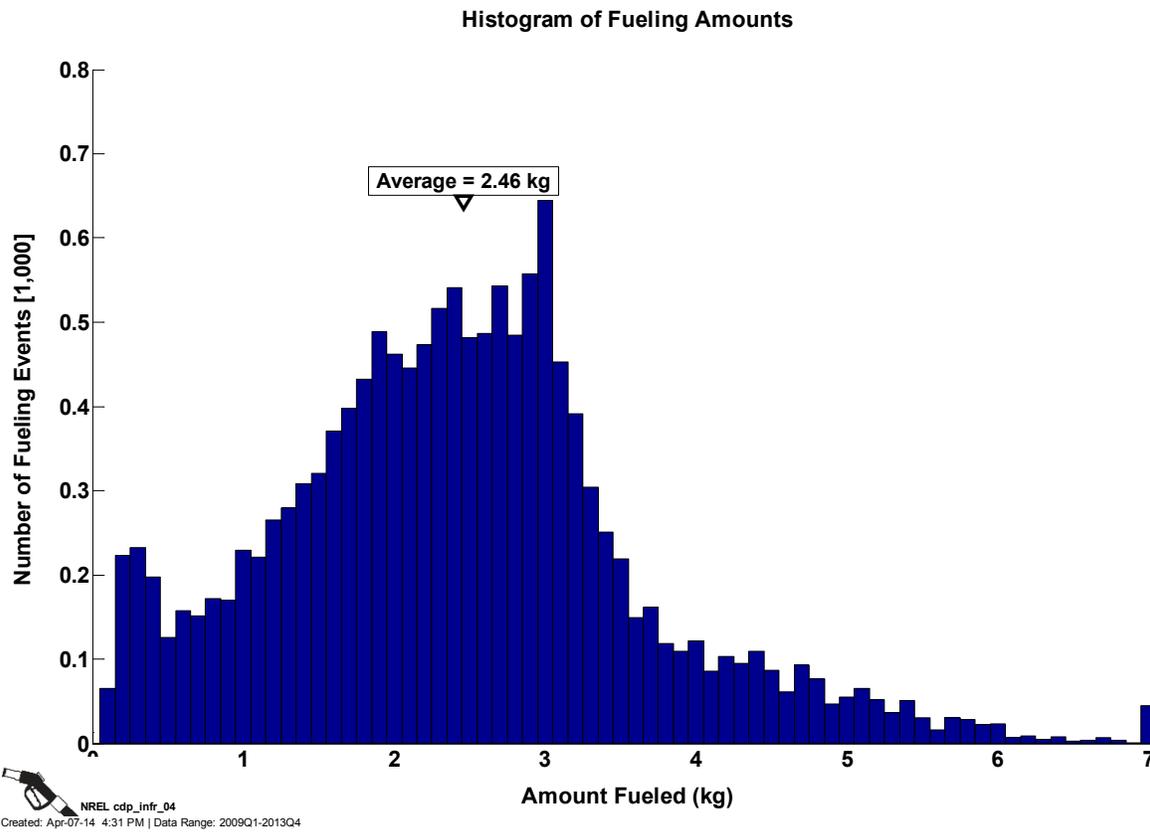
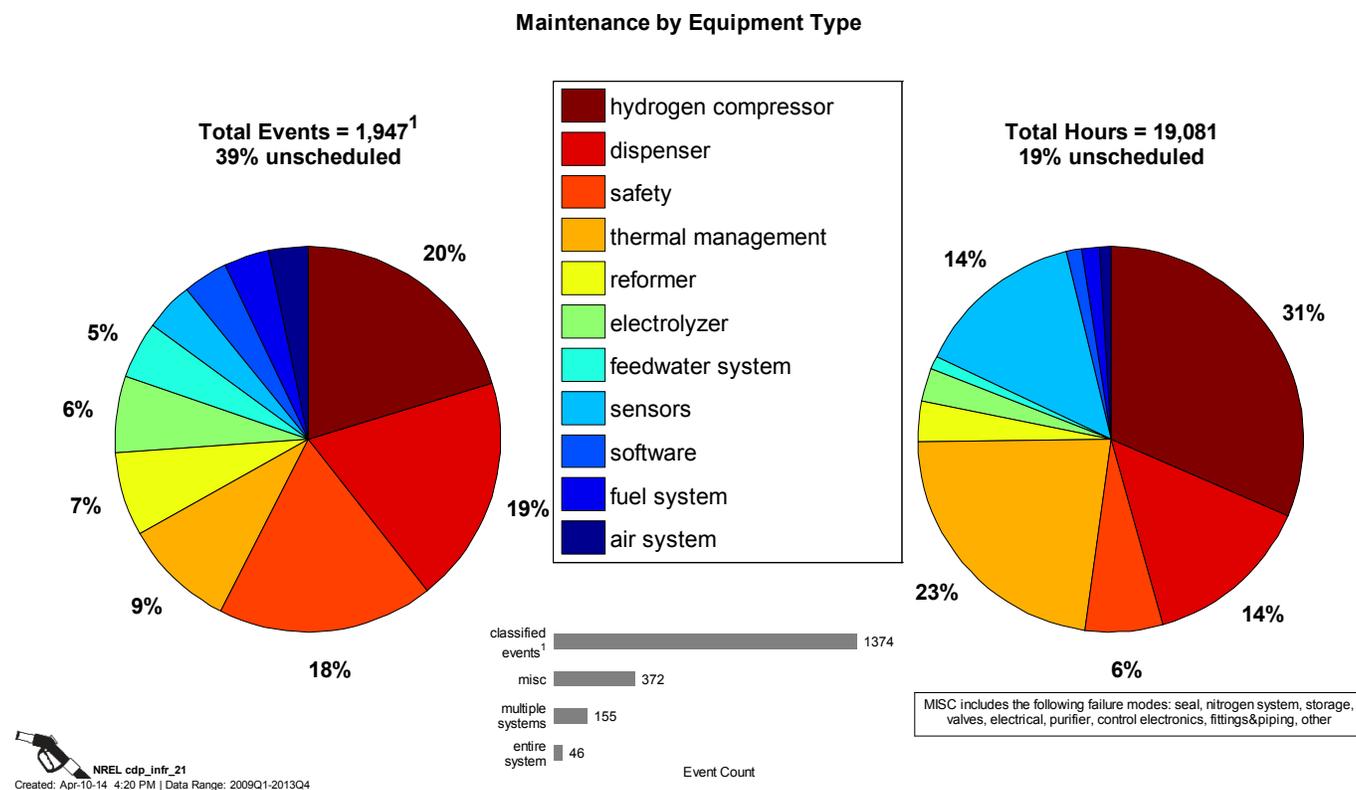


FIGURE 4. Histogram of Fueling Amounts



**FIGURE 5.** Maintenance by Equipment Type

will provide DOE and the hydrogen and fuel cell community with awareness of the technology readiness and identify research areas for improvement. Few stations had been providing data during this project startup but more of the stations have reported data in 2014, making it possible to start aggregating the data in CDPs without revealing individual station identity and to identify general trends in the industry. As more data become available from more stations and as more FCEVs enter the market, there will be an increase in data analysis possibilities to validate the technology for hydrogen infrastructure.

**FY 2014 PUBLICATIONS/PRESENTATIONS**

1. S. Sprick, J. Kurtz, M. Peters. “TV017: Hydrogen Station Data Collection and Analysis,” 2014 DOE Annual Merit Review and Peer Evaluation Meeting, June 2014, Washington, D.C. (Poster Presentation)
2. S. Sprick, J. Kurtz, K. Wipke, G. Saur, C. Ainscough. “Technology Validation of Fuel Cell Vehicles and Their Hydrogen Infrastructure,” 2013 Fuel Cell Seminar, October 2013, Columbus, OH. (Oral Presentation)
3. CDPs and past publications are available on the Hydrogen Infrastructure section of NREL’s Technology Validation website: [http://www.nrel.gov/hydrogen/proj\\_tech\\_validation.html](http://www.nrel.gov/hydrogen/proj_tech_validation.html).