# VII.8 Next Generation Hydrogen Infrastructure Evaluation

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Project Start Date: October 1, 2011
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.
- Leverage data processing and analysis capabilities developed under the Fuel Cell Vehicle Learning Demonstration as well as from forklift, backup power and bus projects.

## Fiscal Year (FY) 2013 Objectives

- Collect data from state-of-the-art hydrogen (H2) fueling facilities, such as those funded by the California Air Resources Board (CARB), to enrich the analyses and composite data products (CDPs) on H2 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 (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 in an interactive manner.
- 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 (CaFCP), 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 2013 Accomplishments

- Created new fall 2012 CDPs based on previously supplied data.
- Updated NREL's internal database of stations and their locations and submitted updates to AFDC.
- Participated in the CaFCP working group meetings.
- Internally processed and analyzed quarterly infrastructure data in the HSDC for later inclusion in CDPs once aggregation is possible.
- Provided assistance in filling out and modifying templates for those providing infrastructure data.
- Gathered and provided updates on stations under the DOE Funding Opportunity Announcement 626 projects that are not providing data yet.
- Updated NREL Fleet Analysis Toolkit code to accept data in multiple formats from stations outside the DOE Funding Opportunity Announcement 626 stations.
- Analyzed data from station provider outside DOE Funding Opportunity Announcement 626 projects.

- Gathered additional data outside the standard template to provide SAE J2601 with data on idle times during fueling events.
- Presented this project at Fuel Cell Seminar 2012 and at the 2013 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 additional hydrogen infrastructure through multiple state agencies, including CARB and the California Energy Commission. Two separate actions by CARB funded seven stations of which several are online with the remainder soon to be open in 2012. California Energy Commission is also working on funding stations, moving the state toward the CaFCP goal of 68 stations by 2015 when FCEVs will be introduced in larger numbers. These stations are expected to be included in subsequent evaluations.

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 hydrogen energy from landfills and wastewater treatment plants 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 vehicles. 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 research and development activities.

Data analysis will be performed on sensitive industry hydrogen fueling data in NREL's HSDC 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 HSDC.

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 U.S. 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 53 stations in the U.S. and 10 are considered open to the public at this point with most of those in California. Recently, for this project, a few more stations have started providing data to NREL so there is now data from four stations which means that aggregation is possible and CDPs can be created for public dissemination in the fall.

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 per hour. The capacity utilization CDPs have been presented in the past with updates expected this fall and can be found

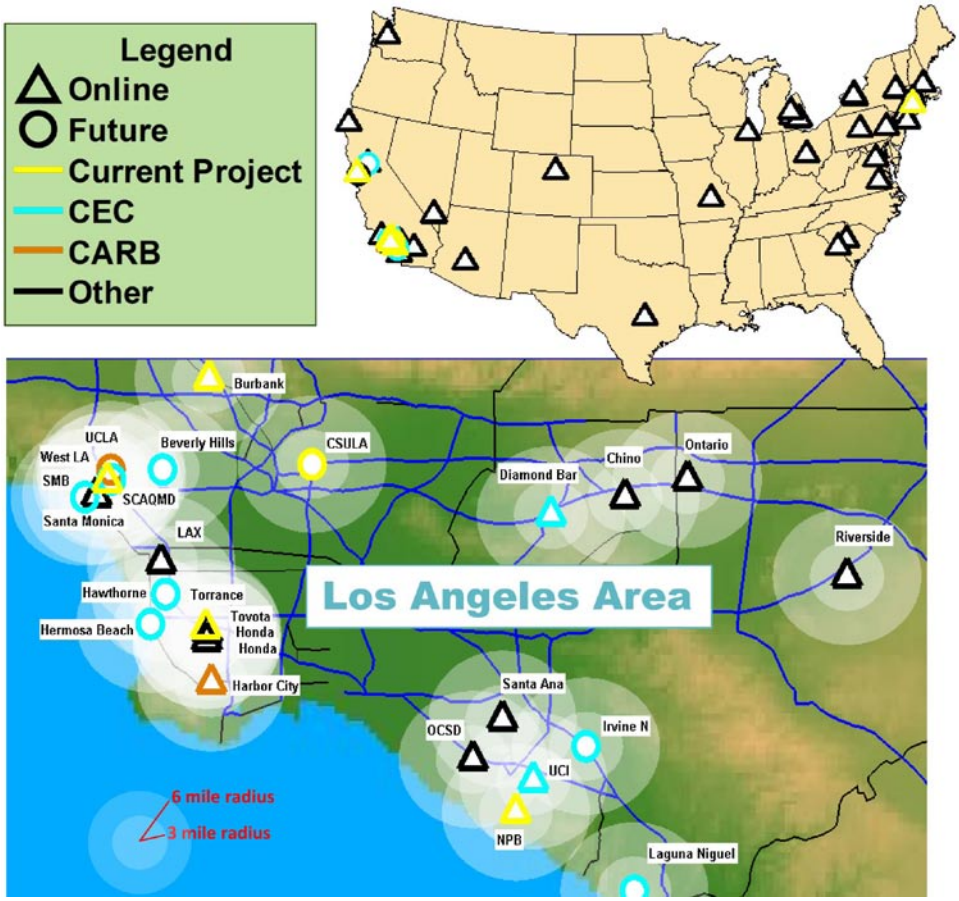


**FIGURE 1.** Hydrogen Station Locations

on the website. A new analysis (based on older data) was created this year to show the station usage per hour. The number of fills in an hour (only for hours for which there was dispensing) are presented in Figure 2. There were 1 to 7 fills per hour with an average of 1.5 per hour and a median of 1 per hour. This shows low usage compared with the material handling projects where there are many forklifts filling per hour. A second analysis was created to show how much hydrogen has been dispensed per hour and can be seen in Figure 3. On average there are 4.1 kilograms of hydrogen dispensed per hour with a median of 3.5 kilograms and a maximum of 14.9 kilograms. Figure 4 shows the graphical comparison with material handling equipment and reveals about the same amount being dispensed per hour for cars and forklifts even though there are many more fills per hour for the forklifts. This is a result of the cars having larger tanks than the forklifts allowing them to have more hydrogen per fill. As more data comes in there will be more analysis focusing on the usage of the stations.

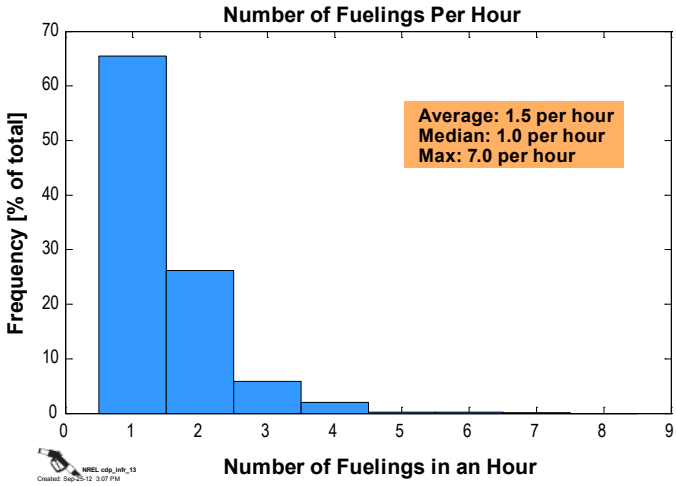


**FIGURE 2.** Number of Fueling Events per Hour

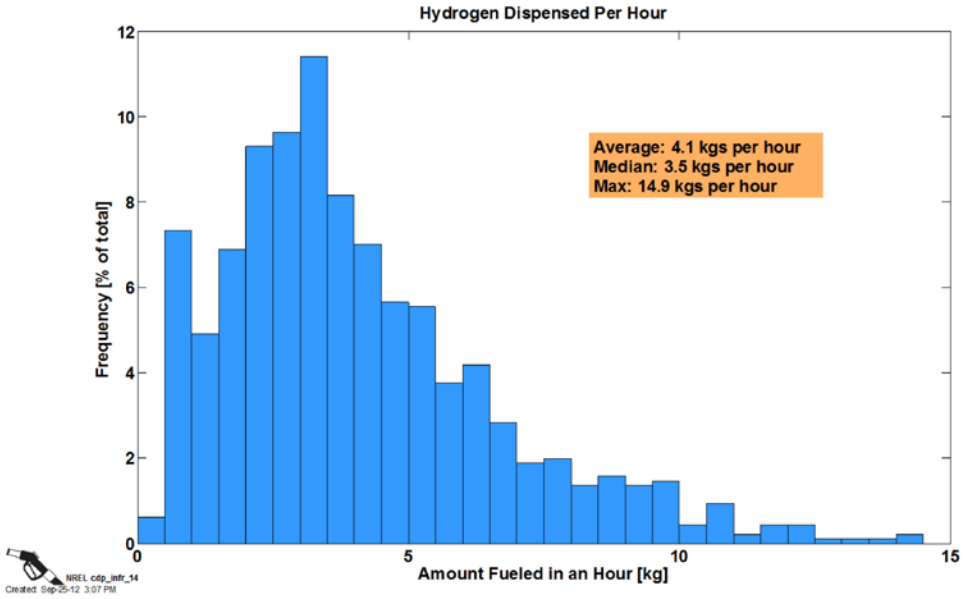


**FIGURE 3.** Amount of Hydrogen Dispensed per Hour

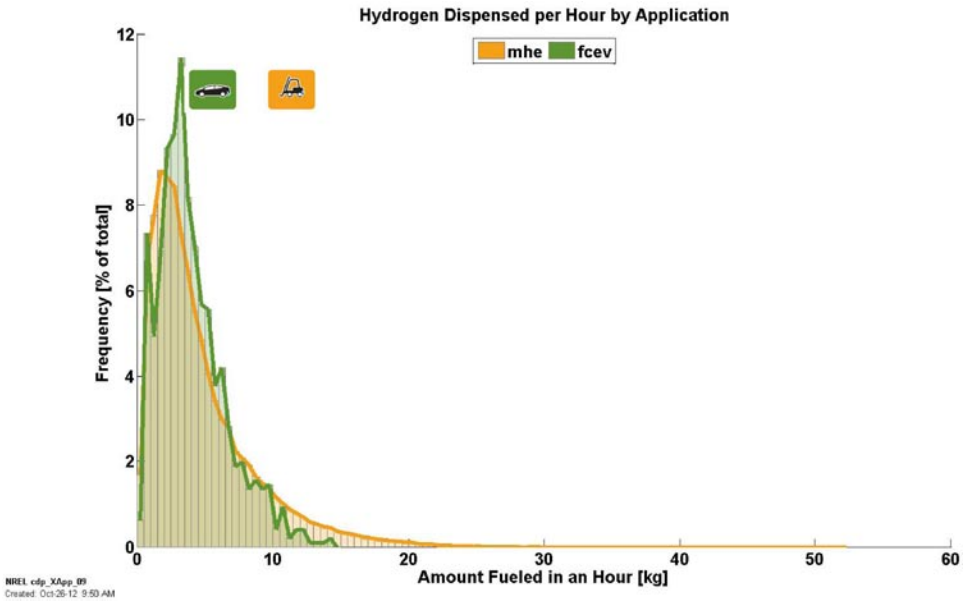


**FIGURE 4.** Amount of Hydrogen per Hour across Applications

## 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 will provide DOE and the hydrogen and fuel cell community with awareness of the technology readiness and identify research areas for improvement. Few stations have been providing data during this project startup but that is starting to change and NREL is receiving more and more data 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, there will be an increase in data analysis possibilities to validate the technology for hydrogen infrastructure.

## FY 2013 PUBLICATIONS/PRESENTATIONS

**1.** "Next Generation Hydrogen Infrastructure Evaluation," poster presented at the 2013 DOE Annual Merit Review and Peer Evaluation Meeting, May 16, 2013, Washington, D.C.

**2.** "Analyzing the Next Generation of Hydrogen Stations," presentation at 2012 Fuel Cell Seminar, November 6, 2012, Uncasville, CT.

**3.** CDPs and other publications available on the Hydrogen Infrastructure section of NREL's Technology Validation website, http://www.nrel.gov/hydrogen/proj_tech_validation.html.