VII.0 Technology Validation Sub-Program Overview

INTRODUCTION

The Technology Validation sub-program demonstrates, tests, and validates hydrogen and fuel cell technologies and uses the results to provide feedback to Fuel Cell Technologies Office (FCTO) research and development (R&D) activities.

Continuing efforts include real-world evaluation and data collection associated with light-duty fuel cell electric vehicles (FCEVs), fuel cell electric buses (FCEBs), hydrogen stations, advanced hydrogen refueling components, and early market applications of fuel cells, such as stationary power and material handling equipment (MHE). The sub-program is also implementing projects that support the advancement of hydrogen infrastructure by developing and validating a prototype device to measure hydrogen dispenser performance, and by developing tools to enhance access to hydrogen station status information. Activities of the sub-program have expanded into examining hydrogen-based energy storage, where electrolyzers may be used as a controllable electrical load that can provide real-time grid services.

GOAL

The goal of the Technology Validation sub-program is to validate the state-of-the-art of fuel cell systems in transportation and stationary applications, as well as hydrogen production, delivery, and storage systems, and assess technology status and progress to determine when technologies should be moved to the market transformation phase.

OBJECTIVES

The objectives of the Technology Validation sub-program are as follows.

- Validate hydrogen FCEVs with greater than 300-mile range and 5,000-hour fuel cell durability by 2019
- Validate a hydrogen fueling station capable of producing and dispensing 200 kg H_2/d (at 5 kg/3 min; 700 bar) to cars and/or buses by 2019
- Validate large-scale systems for grid energy storage that integrate renewable hydrogen generation and storage with fuel cell power generation, operating for more than 10,000 hours, with a round-trip efficiency of 40% by 2020

FISCAL YEAR (FY) 2015 TECHNOLOGY STATUS AND ACCOMPLISHMENTS

FCEV Evaluation

Six major automakers (General Motors, Honda, Hyundai, Mercedes-Benz, Nissan, and Toyota) are demonstrating advanced light-duty FCEVs, where data are being collected from up to 48 vehicles. During the data collection period of October 2012 through December 2014, the 48 FCEVs traveled a total of over 2.4 million miles, demonstrating an average on-road fuel economy of 51 mi/kg and an average fleet voltage durability of 3,930 h. A maximum of 5,605 fuel cell operation hours (which surpasses the 2020 DOE target of 5,000 hours) was also demonstrated[1]. These results, along with previous ones[2], reveal that steady progress has been demonstrated over the past 10 years, with improvements especially in fuel cell durability, range, and fuel economy. (National Renewable Energy Laboratory [NREL])

FCEB Evaluation

During FY 2015, data from 15 FCEBs at two transit agencies, AC Transit (Oakland, California) and SunLine (Thousand Palms, California), were collected and analyzed. The objective of this effort is to determine the status of fuel cell systems for buses and to aid fleets with the implementation of next generation FCEBs. Fuel cell buses continue to show improved fuel economy (ranging from 1.7 to 2.1 times higher) compared to baseline (diesel and compressed natural gas) buses in similar service. The average fuel economy for the FCEBs was 7.26 mi/DGE (diesel gallon equivalent), approaching the Federal Transit Administration's performance target for FCEB fuel economy

[1] However, this vehicle may not meet efficiency and cost targets.
[2] The Learning Demonstration evaluation, 2006-2012, results available at: http://www.nrel.gov/hydrogen/pdfs/54860.pdf

of 8 mi/DGE. The top fuel cell power plant (FCPP) accumulated over 19,000 h of operation, surpassing the DOE/Department of Transportation target of 18,000 h for 2016, while 67% of FCPPs accumulated over 8,000 h. Values for fuel cell system miles between road call—a measure of reliability—surpassed the 2016 target and were found to be approaching the ultimate target. FCEB average availability was found to be 70%. The majority of the road calls were due to bus-related general maintenance, batteries, and hybrid propulsion systems, while fuel cell-related issues made up approximately 10–15% of the road calls. (NREL)

Hydrogen Station Evaluation

The objective of this project is to collect data from state-of-the-art hydrogen fueling facilities, such as those operated by California State University, Los Angeles (CSULA), Proton OnSite, and Gas Technology Institute (GTI), providing valuable feedback on data related to hydrogen infrastructure. Over the period from the first quarter of 2009 to the fourth quarter of 2014, data collected on 10 hydrogen stations revealed that a cumulative 62,784 kg of hydrogen was dispensed (43% improvement over previous year's cumulative), with average dispensing rates of 0.6 kg/min. Average fill time was found to be 5.6 min, with 49% of fills taking less than five minutes and 20% taking less than three minutes. (NREL)

CSULA's electrolyzer-based hydrogen station was commissioned in May 2014. Power meters, flow meters, and buffer tanks were installed, and performance evaluation data are being provided. The station was the *first in the United States* to receive a seal of approval for sale of hydrogen on a per-kilogram basis as of January 2015. Testing was conducted in collaboration with the California Department of Weights and Measures, California Fuel Cell Partnership, and California Air Resources Board. Up to 242 kg H_2/month were sold between October 2014 and March 2015. (CSULA)

Proton OnSite's high pressure (57 bar) electrolyzer at the SunHydro #1 station in Wallingford, Connecticut, was built and tested, and data monitoring is ongoing. The SunHydro #2 station has been designed, and fabrication of components is underway. (Proton OnSite)

GTI's West Sacramento, California, station—using liquid hydrogen and 900 bar ionic compression technology—was commissioned in December 2014, and instrumentation is installed, allowing for data collection. Permits for the San Juan Capistrano, California, site have been granted, and construction is expected to begin mid-2015. For the remaining three sites (Cupertino, California; Mountainview, California; Foster City, California), equipment is being fabricated and construction dates will depend on permitting. (GTI)

Hydrogen Compressor Evaluation

As compressors account for one-third of maintenance hours at hydrogen stations, the main objective of this project is to perform accelerated compressor testing to reproduce component failures, which are correlated to real-world usage with statistical methods. Compressor performance and reliability data (from four compressors) were compared to data collected in the field (through composite data products), and deep dive failure analyses were performed. The compressors demonstrated consistent power consumption with varying pressure and temperature. Seal weakness was found to be the main failure mechanism, with five seal failures occurring (four in compressor heads and one on a check valve seal). Catastrophic seal failure was detected preemptively through a leak detection circuit to continuously monitor leaks (alarms were set at levels above what may indicate the beginning of a failure). NREL found that repairs of common failures are expensive (up to $1,200) and time consuming (up to six weeks parts lead time). In addition, Fourier transform infrared spectroscopy analysis of various contaminants (detected at second stage discharge tube immediately after the head) revealed that the most abundant contaminant is siloxane (mainly from vacuum grease typically applied to elastomer seals), which harms fuel cells by causing membrane embrittlement and crossover issues. A suitable replacement chemical was suggested, with minimal effects on fuel cells. (NREL)

Cryogenic Pressurized Hydrogen Storage and Delivery Evaluation

The use of a 100 kg H_2/h, 875 bar high pressure liquid hydrogen pump is being investigated and validated, as liquid hydrogen pumps have the potential to increase hydrogen storage density (and vehicle driving range) by up to 30%, while enabling five-minute refueling and minimizing delivery costs. A thin-lined vessel with 81% volume ratio (versus 70% for conventional vessels) at 700 bar pressure was manufactured, and its cryogenic strength was demonstrated. The liquid hydrogen pump was instrumented for a power analyzer, boil-off mass flow meter, and outlet temperature sensor. Operational approvals from DOE and Lawrence Livermore National Laboratory (LLNL) were obtained, and civil construction of a cryogenic hydrogen pressure vessel test facility was completed. The installation of other components, such as containment vessels and heat exchanger, will follow in FY 2016. (LLNL)

Stationary Fuel Cell Evaluation

This project evaluates the deployment and performance of stationary fuel cell systems operating under real-world conditions while reporting on the baseline, progress, and technical challenges. In FY 2015, installation data from California's Self Generation Incentive Program were collected for 397 fuel cell-based units[3] (totaling 161 MW). Deployment of fuel cells (combined heat and power [CHP] and electric only) has exceeded the deployment of internal combustion engines, and most of these fuel cell units use natural gas. However, renewable fuels[4] fare better in terms of installed *capacity* by fuel type, versus *number* of deployments by fuel type. The mean availability of the fuel cell systems was 92%, with about 60% of systems having availability over 90%. The mean electrical efficiency of the fuel cells (>100 kW) exceeded the 2015 DOE target of 43% (on a lower heating value basis). Installed costs ranged from $5,620/kW to $11,275/kW for electric-only fuel cell systems, and from $3,706/kW to $11,303/kW for CHP fuel cell systems, depending on system size and availability of incentives. (NREL)

Early Markets Analysis

Early market analysis of fuel cell technologies includes validating fuel-cell-based MHE performance based on real-world operation data from high-use facilities. By the third quarter of FY 2014, 720 MHE fuel cell units were operating as part of the Technology Validation sub-program, refueling on average in 2.5 min, and operating an average of 3.7 h between fills. Over 350,000 fills took place, with more than 280,000 kg of H_2 dispensed. About one-third of fills were back-to-back (within five minutes), and 60% were within 20 minutes of each other. (NREL)

Hydrogen Station Equipment Performance (HyStEP) Device

The objective of this new effort is developing and validating a prototype device to measure hydrogen dispenser performance, to help accelerate commercial hydrogen station acceptance. The device was co-designed by the HyStEP project team of the H2FIRST project[5]. Powertech Labs fabricated the device. The design and safety aspects of the device were reviewed and approved by the project team, DOE, and the Hydrogen Safety Panel, allowing for a “go” decision on device fabrication. The device will initially be tested at NREL, followed by two pre-deployment tests at California stations. (NREL and Sandia National Laboratories)

Station Operational System Status

Station Operational System Status (SOSS) is a platform designed to use a database to collect, store, and distribute data about the operational status of hydrogen stations. Stations automatically transmit operational data to the database server, and station status is made available to end users. The goal of the current phase (SOSS 3.0 upgrade) of the project is to improve customer satisfaction and station demand by upgrading the software to improve user interface and data quality and improve data transmission interval (which currently ranges from once a day to once every 15 minutes) to 15 minutes. The application has been implemented at five hydrogen stations in California and is planned to be implemented at a station in Boulder, Colorado, plus seven stations in California later in 2015.

Hydrogen Energy Storage/Grid Integration

DOE has established a grid modernization program, which is a cross-cutting effort involving various offices within DOE, with an objective to help set the nation on a cost-effective path to an integrated, secure, and reliable grid that is flexible enough to provide an array of emerging services while remaining affordable to consumers. Hydrogen-based energy storage could provide value to many applications and markets. Electrolyzers may be utilized as a controllable electrical load that can provide real-time grid services. FCTO is exploring these value-added services through related projects. An electrolyzer stack test bed was designed, built, commissioned, and is in operation. The first-of-its-kind real-time digital simulator (RTDS®)-to-RTDS® communications network between labs was established for hardware-in-the-loop simulations, with electrolyzer hardware at NREL and grid simulation at Idaho National Laboratory (INL). High-value locations to implement demand response and ancillary services using hydrogen stations are also to be identified in this project. (NREL and INL)

[3] Fuel cell electric + fuel cell combined heat and power.

[4] Renewable fuels exclude those defined as conventional in Section 2805 of the California Public Utilities Code and are categorized here as gas derived from biomass, digester gas, or landfill gas.

[5] H2FIRST: Hydrogen Fueling Infrastructure Research and Station Technology; see http://www.energy.gov/eere/fuelcells/h2first

BUDGET

The funding portfolio for Technology Validation enables the sub-program to continue to collect and analyze data from fuel cells operating in transportation and stationary applications, as well as hydrogen production and delivery technologies. In FY 2015, $11 million in funding was appropriated for the Technology Validation sub-program, and $7 million was requested for FY 2016 (subject to congressional appropriations).

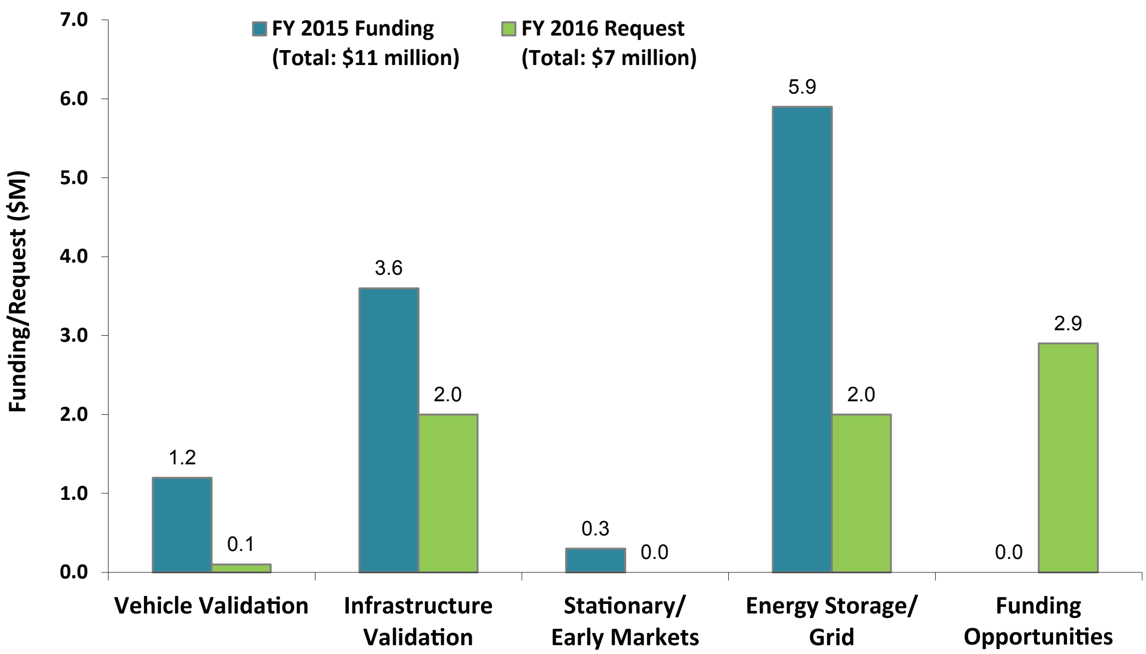

FIGURE 1. Technology Validation R&D Funding. Subject to appropriations, project go/no-go decisions, and competitive selections. Exact amounts will be determined based on research and development progress in each area and the relative merit and applicability of projects competitively selected through planned funding opportunity announcements.

FY 2016 PLANS

In FY 2016, the Technology Validation sub-program will continue its detailed evaluations of FCEVs, FCEBs, hydrogen fueling stations, advanced hydrogen refueling components, stationary power deployments, and early market applications. In coordination with DOE's Office of Energy Efficiency and Renewable Energy and Office of Electricity, a key focus in FY 2016 will be hydrogen-based energy storage and grid integration activities. The design, deployment, and validation of advanced, low cost, mobile hydrogen refuelers will also be pursued, based on selections from a Funding Opportunity Announcement that closed in June 2015. Potential future funding opportunities may emphasize hydrogen refueling station and components validation, subject to appropriations. Prototype fuel cell hybrid electric medium-duty trucks (extending battery electric vehicle range) are expected to be developed and deployed under real-world conditions, and data will be collected to evaluate their performance. Targets are being developed for medium- and heavy-duty fuel cell trucks, and a related request for information is expected to be issued.

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