VII.D.1 Stationary Fuel Cell Evaluation

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Project Start Date: October 1, 2011
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Independently assess, validate, and report operation targets and performance of stationary fuel cell (FC) systems in real-world operating conditions.

Fiscal Year (FY) 2016 Objectives

- Develop more voluntary data partners, especially for operations data.
- Conduct stationary fuel cell efficiency analysis at varying operating conditions.
- Publish 39 technical stationary fuel cell composite data products (CDPs) biannually.
- Update a public website for dissemination of CDPs.

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.

(B) Lack of Data on Stationary Fuel Cells in Real-World Operation

Contribution to Achievement of DOE Technology Validation Milestones

This project contributes to the 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 1.2: Complete validation of commercial fuel cell CHP systems that demonstrate 45% efficiency and 50,000 hour durability. (4Q, 2017)

FY 2016 Accomplishments

- Operations Data (power, fuel flow, temperature, etc.); Units >100 kW
  - The mean fuel cell electrical efficiency is 45% lower heating value (LHV), exceeding the DOE target of 43% LHV.
  - Mean capacity factor of base load units was 89.2% of the rated capacity.
  - Capacity factor of load-following units was between 40% and 100% of rated capacity.
    - Capacity factor is dependent on the size of the fuel cell relative to the building load profile.
  - Mean availability of both the base load and load-following units exceeds the DOE Technology Validation target for 2015 and 2020 for commercial power availability of 97% and 98%, respectively.
- California's Self-Generation Incentive Program (SGIP)
  - Mean cost per unit capacity was \$(2010) 10,709/kW without incentives and \$(2010) 7,616/kW with incentives.
  - SGIP costs may include additional costs not included in a 2020 DOE target of \$1,500/kW or 2015 DOE target of \$3,000/kW installed cost for commercial fuel cells running on natural gas.

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INTRODUCTION

This project aims to provide status on stationary fuel cell systems to inform DOE, the public, fuel cell manufacturers, and other stakeholders. This is the only technology validation project working directly on Technical Barrier (B): Lack of Data on Stationary Fuel Cells in Real-World Operation.

APPROACH

The project's data collection plan builds on other technology validation activities. Data (operation, maintenance, and safety) are collected on site by the project partners for the fuel cell system(s) and infrastructure. NREL receives the data quarterly and stores, processes, and analyzes the data in NREL's National Fuel Cell

Technology Evaluation Center (NFCTEC). The NFCTEC is an off-network room with access provided to a small set of approved users. An internal analysis of all available data is completed quarterly, and a set of technical CDPs is published every six months. Publications are uploaded to NREL's technology validation website and presented at industry-relevant conferences. The CDPs present aggregated data across multiple systems, sites, and teams in order to protect proprietary data and summarize the performance of hundreds of fuel cell systems and thousands of data records. A review cycle is completed before the CDPs are published. This review cycle includes providing detailed data products of individual system- and site-performance results to the specific data provider. Detailed data products also identify the individual contribution to the CDPs.

RESULTS

In April 2015, a set of 39 CDPs was published, which included updates to 33 CDPs and 6 new CDPs. The set includes efficiency, operation hours, capacity factors, and availability. The operations CDPs have now been segmented into fuel cells that are less than 100 kW and greater than 100 kW. New load profile CDPs for fuel cell units greater than 100 kW show the frequency of operation time at different load fractions and the ratio of electrical output per rated capacity of the fuel cell unit, separately, for both base load and load-following units. The load profiles show that base load units operate mostly in the 90–100% load fraction range as expected, load-following units have operation time at a wider range, and some units spend time above 100% rated capacity.

The electrical efficiency for fuel cells greater than 100 kW has also been validated, and shown to exceed the 2015 DOE Technology Validation target of 43% based on the lower heating value of hydrogen (39% higher heating value, HHV, of hydrogen). The mean fuel cell electrical efficiency is 45% LHV (Figure 1).

A new analysis was completed to study the stationary fuel cell system availability, where availability is the percentage of unscheduled downtime over total time period. Downtime in this analysis may include scheduled maintenance decreasing calculated availability. The mean availability for fuel cells >100 kW exceeds the DOE Technology Validation target for 2015 and 2020 for commercial power availability at 97% and 98%, respectively. The mean availability for units operating as base load is 98.3% (Figure 2). The mean availability for units operating as load-following is 99.4%.

The size of the fuel cell relative to the building profile affects the capacity factor greatly, where capacity factor is defined as the ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period. Base load units operated at 89.2% of the rated capacity and load-following units operated between 40% and 100% of rated capacity with a mean of 72.9% (Figure 3).

California's SGIP has helped deploy 460 fuel cell systems, for a total of 178 MW, since 2001. The fuel cell deployment increased approximately 16% in 2015. These fuel cell deployments have shown that fuel cells may be applied with a wide variety of fuels, including renewable

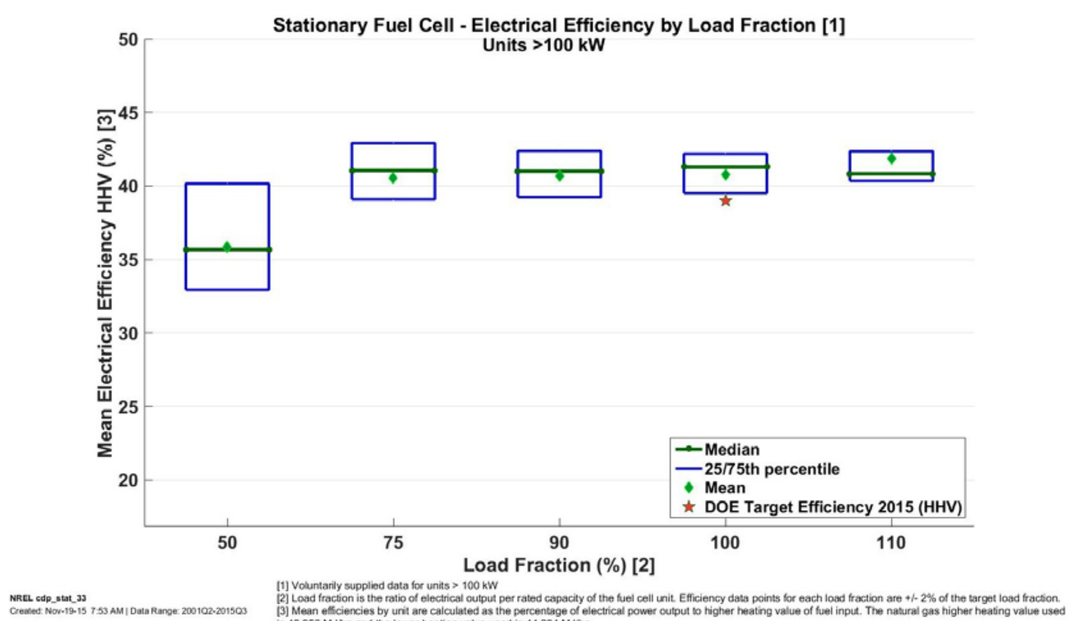

FIGURE 1. Electrical efficiency by load fraction for stationary fuel cells >100 kW

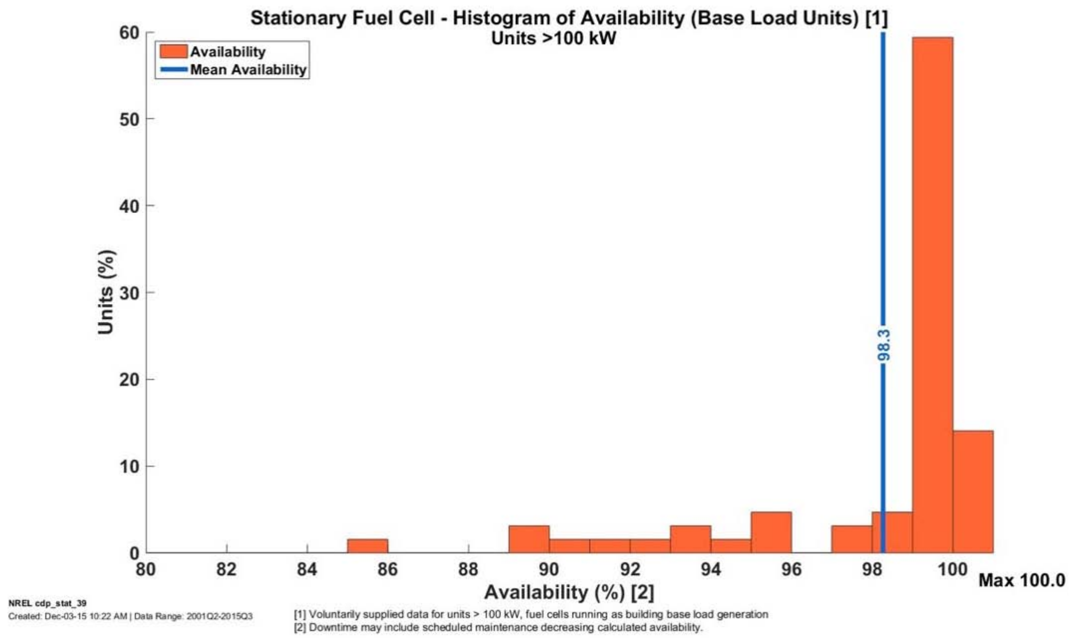

FIGURE 2. Availability of base load units >100 kW

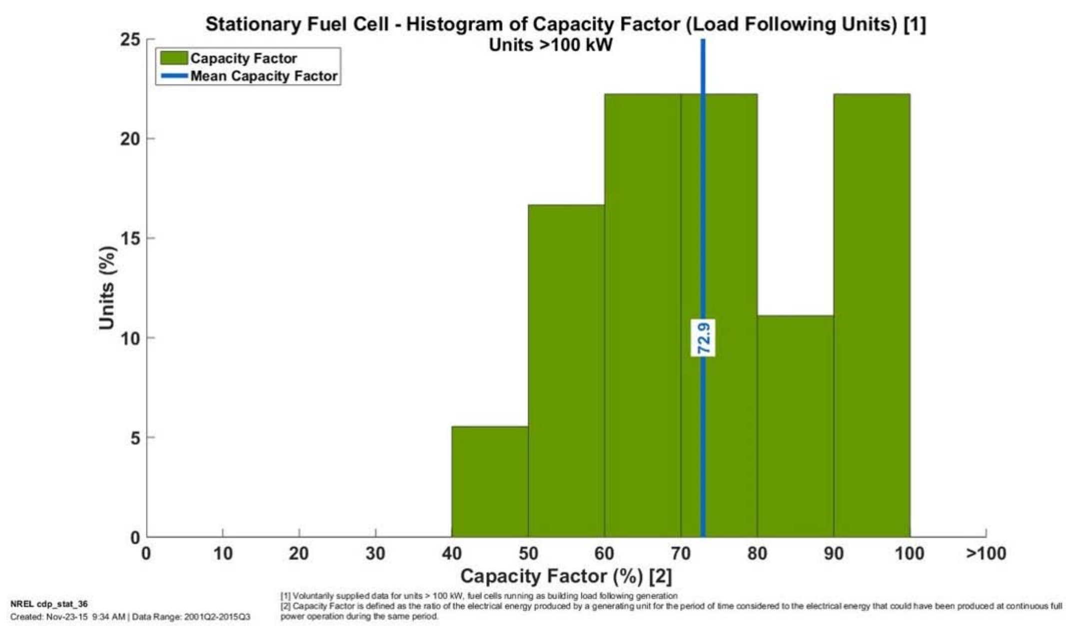

FIGURE 3. Capacity factor for load-following units

biogas from landfill, biomass, and digester sources. Natural gas is the dominant fuel type, accounting for 82% of projects and 73% of the capacity. Since 2011, electric-only fuel cell projects have been increasing at a rate (number and capacity) greater than other competing technologies, which include gas turbines, internal combustion turbines, microturbines, and pressure reduction turbines. Deployment numbers have increased even in a climate of declining incentives. Also, in 2014, fuel cell combined heat and power systems neared the cost per kilowatt of gas turbines, and beat the cost when incentives were applied.

The average unit costs in the SGIP are significantly higher than the DOE target of $1,500/kW; however, SGIP costs may include additional costs that are not included in the DOE target. Generally, larger projects (those with larger capacities) have lower unit costs and also receive more incentives. Mean cost per unit capacity was $(2010)

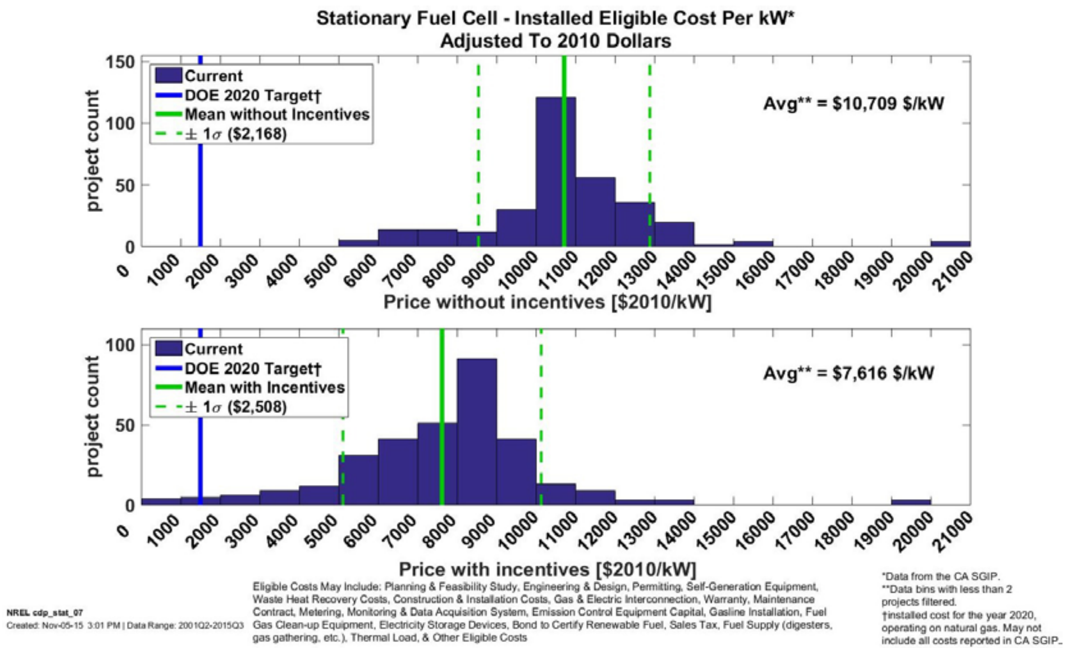

FIGURE 4. California SGIP installed costs with and without incentives

10,709/kW without incentives and $(2010) 7,616/kW with incentives (Figure 4). SGIP costs may include additional costs not included in a 2020 DOE target of $1,500/kW or 2015 DOE target of $3,000/kW installed cost for commercial fuel cells running on natural gas. SGIP eligible costs may include planning and feasibility study, engineering and design, permitting, self-generation equipment, waste heat recovery costs, construction and installation costs, gas and electric interconnection, warranty, maintenance contract, metering, monitoring and data acquisition system, emission control equipment capital, gasline installation, fuel gas clean-up equipment, electricity storage devices, bond to certify renewable fuel, sales tax, fuel supply (digesters, gas gathering, etc.), thermal load, and other eligible costs.

CONCLUSIONS AND FUTURE DIRECTIONS

- Stationary fuel cell deployments in California have increased steadily with the support of the SGIP, and the deployment numbers have increased even in a climate of declining incentives.
- Stationary fuel cell systems >100 kW have surpassed the DOE targets for electrical efficiency and availability.
- Voluntarily supplied operation data has been difficult to obtain and has limited the quantity and breadth of operation/performance CDPs.
- The project will complete a final report summarizing current benchmark and progress documented.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Saur, G., Kurtz, J., Ainscough, C., Sprik, S., Post, M. “Stationary Fuel Cell System Composite Data Products: Data through Quarter 3 of 2015,” Golden, CO: National Renewable Energy Laboratory, published December 2015. (report)

2. Saur, G., Kurtz, J., Ainscough, C., Sprik, S. “Stationary Fuel Cell Evaluation: 2015 Annual Merit Review,” DOE Annual Merit Review meeting, June 2015. (presentation)

3. “Stationary Fuel Cell Systems Analysis Project: Partnership Opportunities” Fact sheet describing opportunities for fuel cell developers and end users to participate in an analysis of stationary fuel cell systems to benchmark the current state of the technology. (June 2015)