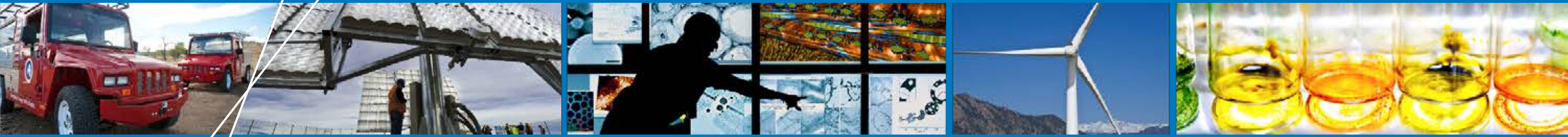
Stationary Fuel Cell Evaluation



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National Renewable Energy Laboratory

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Project ID # TV016

Overview

Timeline and Budget

- **Project start date: October 2011**
- **FY15 DOE funding (if applicable): $100k**
- **FY16 planned DOE funding (if applicable): $35k (carryover)**
- **Total DOE funds received to date: $465k**

Barriers

- B. Lack of Data on Stationary Fuel Cells in Real-World Applications
- E. Codes & Standards

Partners

- California Stationary Fuel Cell Collaborative (review results)
- National Fuel Cell Research Center (UCI) (subcontractor)
- Five OEM data providers

Relevance - Objectives

Independently assess, validate, and report operation targets and stationary fuel cell system performance under real operating conditions.

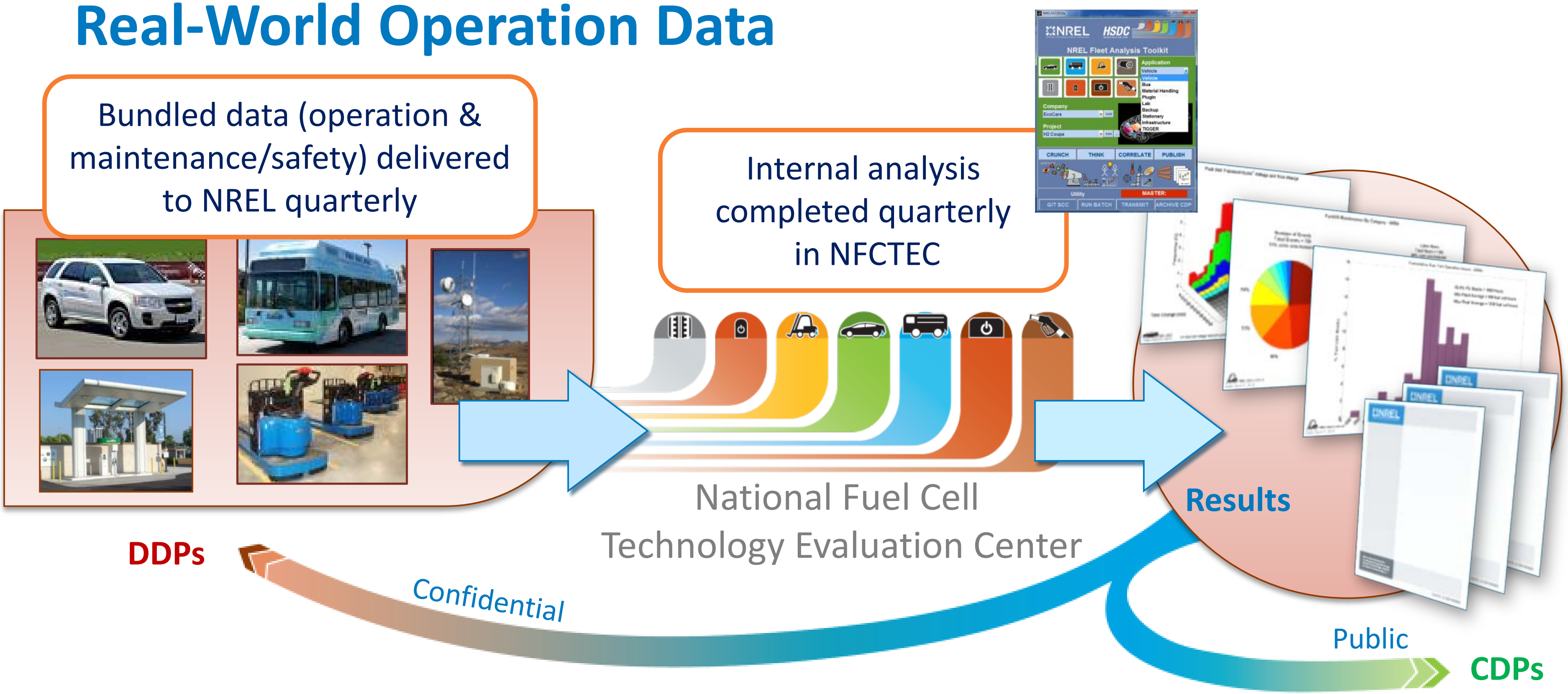
B. Lack of Data on Stationary Fuel Cells in Real-World Applications

Addressing the gap in knowledge as stationary fuel cell installations have increased dramatically

E. Codes & Standards

Providing data and context to C&S activities.

Approach: NFCTEC Analysis and Reporting of Real-World Operation Data



Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results every six months without revealing proprietary data

www.nrel.gov/hydrogen/proj_tech_validation.html

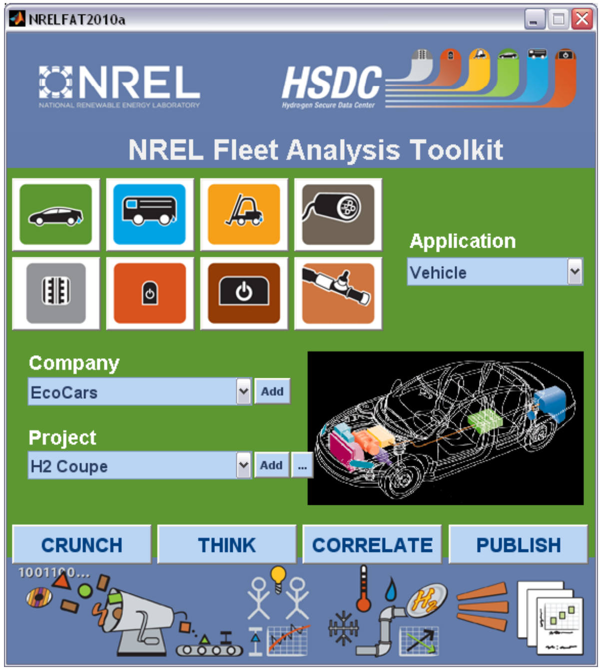
Approach – Data Sources and Scope

➢ **Project is reliant on voluntary data sharing – partner development is ongoing.**

- **Operations data (power, fuel flow, temperature, etc)**
  - All data voluntarily supplied
- **Deployment and cost data**
  - Publically available data from California SGIP (Self Generation Incentive Program) (2001-present)
  - Includes systems providing prime, continuous, or regular power to a site (not backup power)
  - Includes multiple fuel cell types - proton exchange membrane (high and low temperature), solid oxide, phosphoric acid, and molten carbonate
  - Includes fuel types for fuel cells (natural gas, biomass, digester gas, landfill gas)
  - Small, kilowatt-scale to large, megawatt-scale
  - Cost data for projects including incentives
- **39 total CDPs**
  - Quarterly data analysis (based on available data), **biannual publications**

Approach - Data Processing, Analysis, and Reporting Tools

- **NREL Fleet Analysis Toolkit (NRELFAT)**
  - Developed first under fuel cell vehicle Learning Demonstration
  - Restructured architecture and interface to effectively handle new applications and projects and for flexible analysis
  - Leverage analyses already created



- **Report results**
  - Detailed and composite results
  - Target key stakeholders such as fuel cell and hydrogen developers, and end users

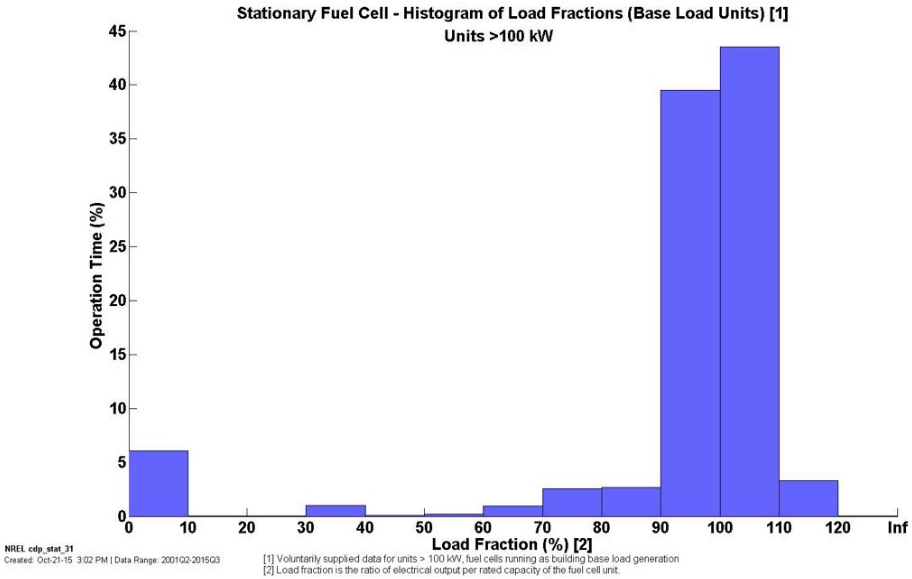
➢ Public results available at

http://www.nrel.gov/hydrogen/proj_fc_systems_analysis.html

- ➢ (Dec 2015) Composite Data Products: Data through 2015Q3
- ➢ (Summer 2016 Planned) Composite Data Products: Data through 2016Q1

Accomplishments: Load Profile

Load Profile – Base Load Units



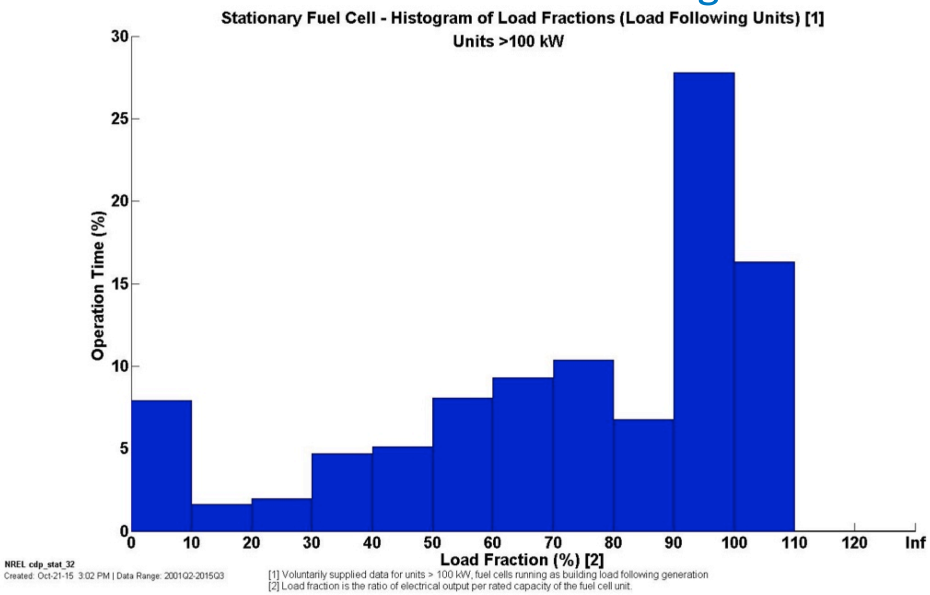
How stationary fuel cells are used changes the operation profiles.

- **At base load most operation is 90-100% load fraction of rated capacity**
- **Some fuel cells may even be operated for significant time above rated capacity**

Fuel cell sizing

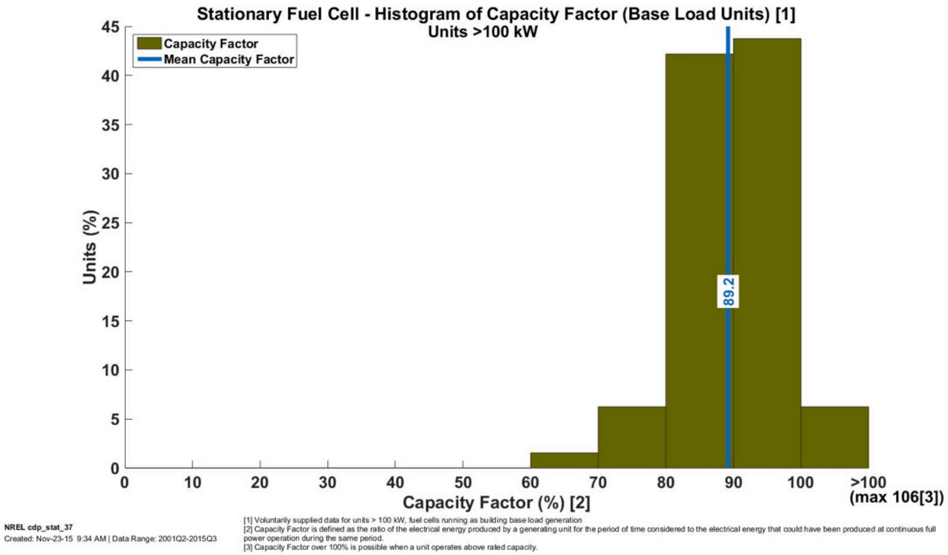
- For base load the fuel cells are sized for minimum load.
- For load following the fuel cells may be sized for near peak load.

Load Profile – Load Following Units



Accomplishments: Capacity Factor

Capacity Factor– Base Load Units



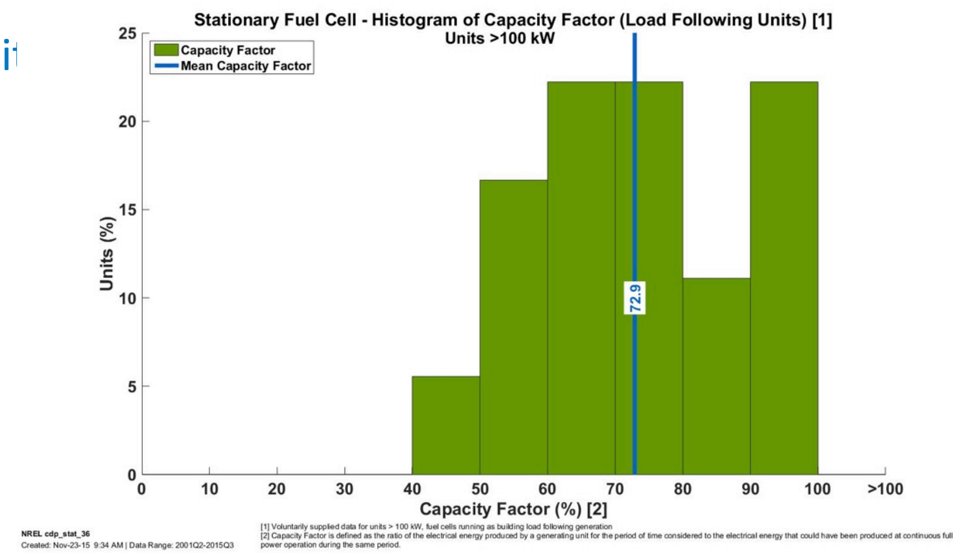
The size of the fuel cell relative to the building profile affects the capacity factor greatly*.

- **Base load units operated at 89.2% of the rated capacity.**
- **Load following units operated between 40% and 100% of rated capacity with a mean of 72.9%.**

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.

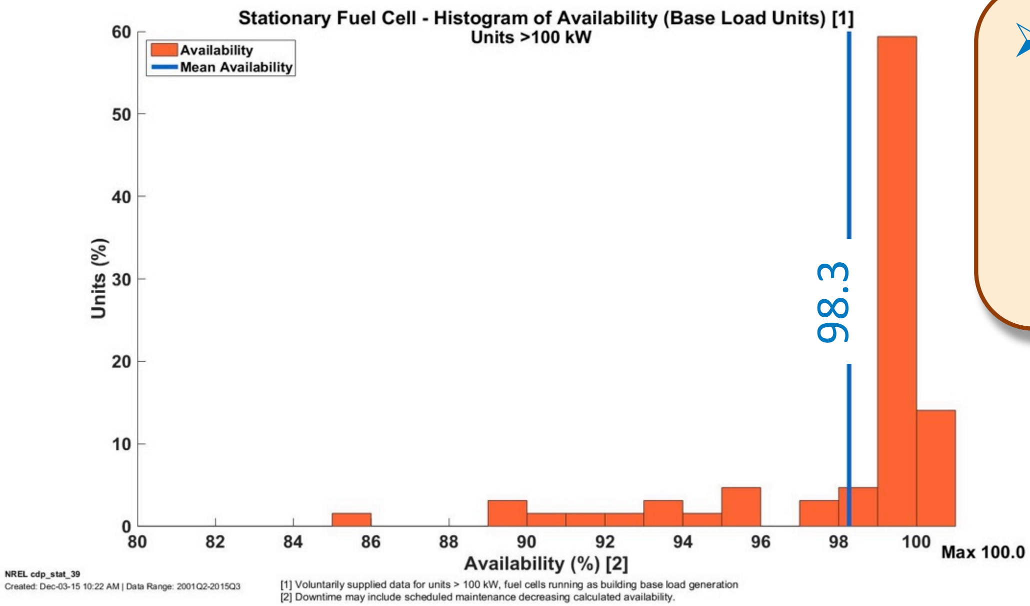
* Only the fuel cell generation profile is analyzed here, building load profiles not available.

Capacity Factor– Load Following Units



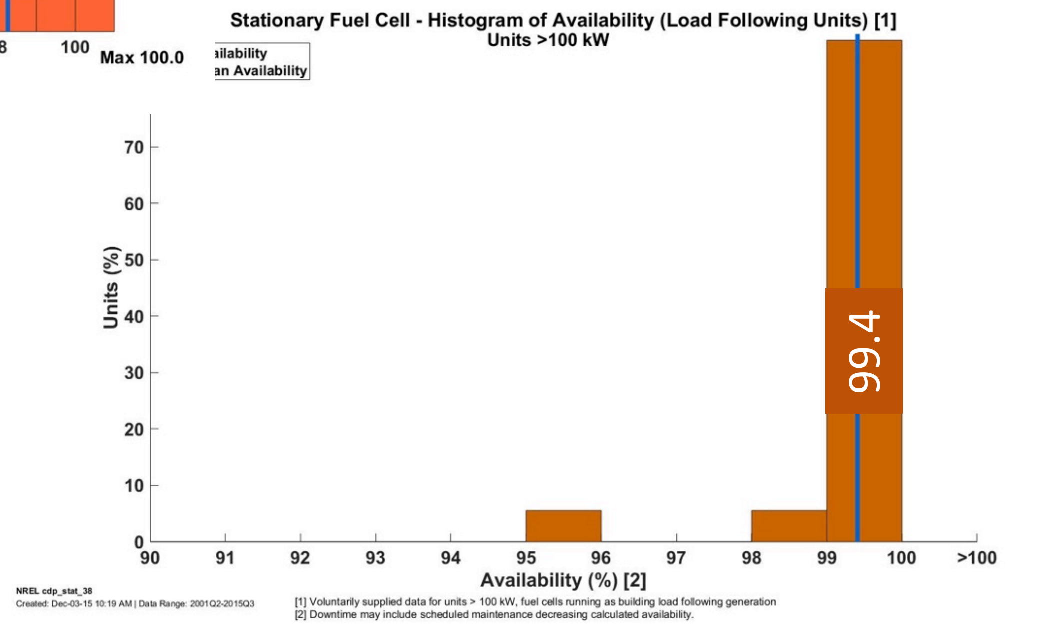
Accomplishments: Availability

Availability Base Load Units > 100 kW



- **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.**

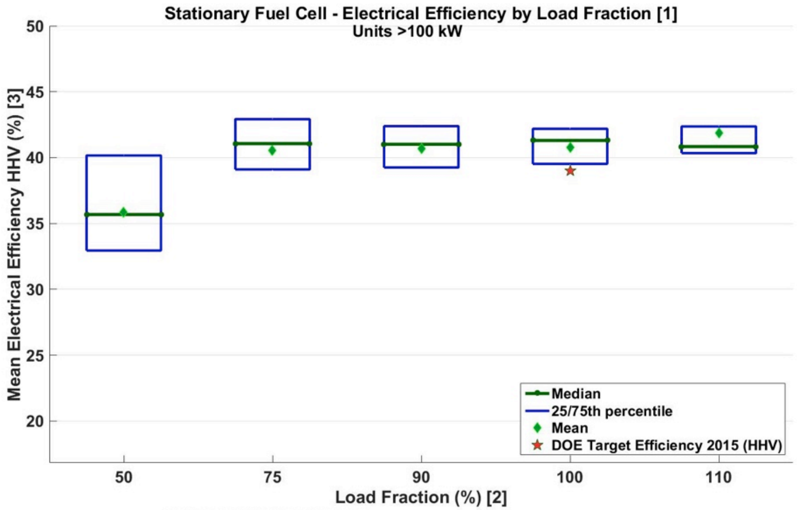
Availability Load Following Units > 100 kW



Availability is the percentage of unscheduled downtime over total time period. Downtime in this analysis may include scheduled maintenance decreasing calculated availability.

Accomplishments: Efficiency

Electrical Efficiency – Units > 100 kW



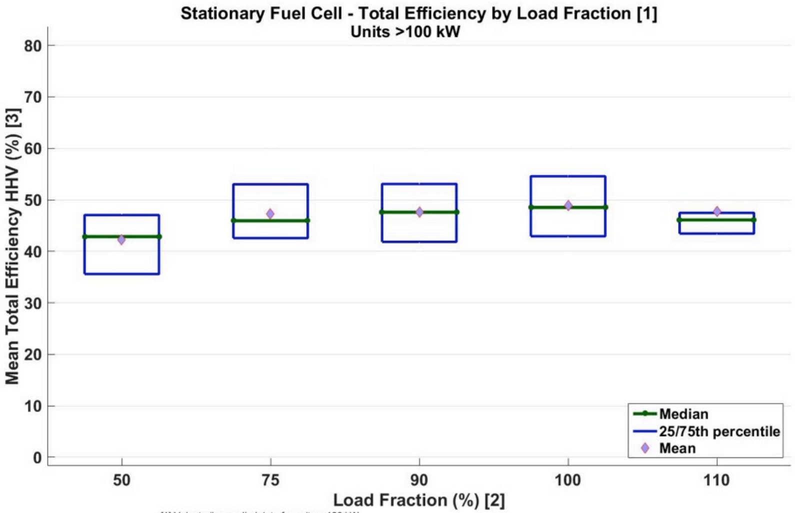
NREL cdp_stat_33
Created: Nov-19-15 7:53 AM | Data Range: 2001Q2-2015Q3

[1] Voluntarily supplied data for units > 100 kW
[2] Load fraction is the ratio of electrical output per rated capacity of the fuel cell unit. Efficiency data points for each load fraction are +/- 2% of the target load fraction.
[3] Mean efficiencies by unit are calculated as the percentage of electrical power output to higher heating value of fuel input. The natural gas higher heating value used is 48.956 MJ/kg and the lower heating value used is 44.294 MJ/kg.

- **Electrical efficiency for fuel cells > 100 kW is 45% LHV and that exceeds the 2015 DOE technology validation target of 43% LHV (39% HHV) at load fractions over 50% (Results confirmed in April 2015 and December 2015 CDPs)**

Total Efficiency includes electrical and heat energy provided by the fuel cell

Total Efficiency – Units > 100 kW



NREL cdp_stat_34
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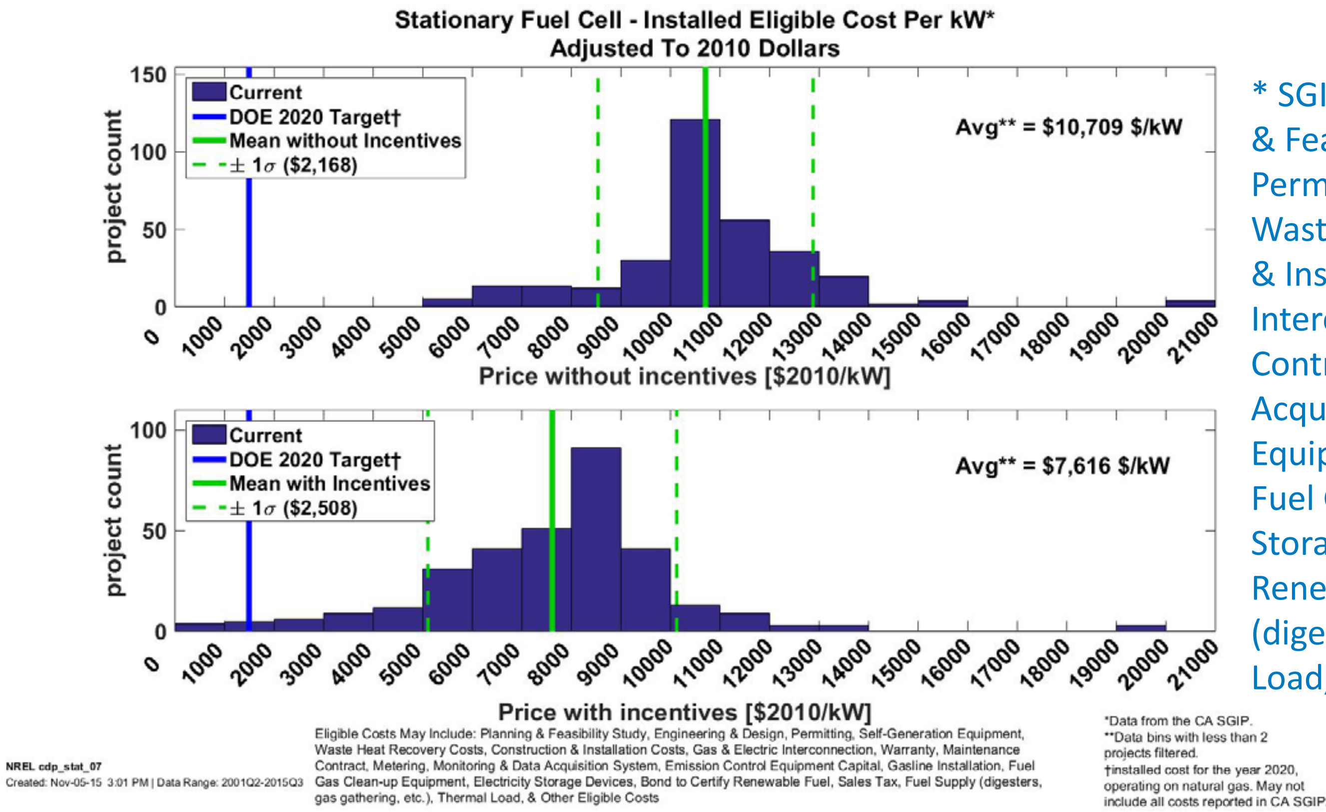
[1] Voluntarily supplied data for units > 100 kW
[2] Load fraction is the ratio of electrical output per rated capacity of the fuel cell unit. Efficiency data points for each load fraction are +/- 2% of the target load fraction.
[3] Mean total efficiencies by unit are calculated as the percentage of electrical plus heat outputs to higher heating value of fuel input. The natural gas higher heating value used is 48.956 MJ/kg and the lower heating value used is 44.294 MJ/kg.

Accomplishments: CA SGIP Installed Costs with and without incentives

- **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**



* SGIP Eligible Costs May Include: Planning & Feasibility Study, Engineering & Design, Permitting, Self-Generation Equipment, Waste Heat Recovery Costs, Construction & Installation Costs, Gas & Electric Interconnection, Warranty, Maintenance Contract, Metering, Monitoring & 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, & Other Eligible Costs.

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- This project was not reviewed last year.

Collaborations

- **Partners for data delivered at the end of 2014**
  - National Fuel Cell Research Center
  - California Stationary Fuel Cell Collaborative
  - Five fuel cell OEMs
- **Communicating with several organizations to establish agreements for sharing data with NREL**
  - Connecticut Department of Transportation (through TIGGER - separately funded project)
  - California Public Utilities Commission
  - Verizon
  - State and regional fuel cell organizations
  - Fuel cell developers

Remaining Challenges and Barriers

- **Voluntary operation data has been difficult to obtain and has limited the quantity and breadth of operation/performance CDPs**

Proposed Future Work

- **Q3 2016 milestone: Update all CDPs with current data and publish technical report**
- **Remainder of FY2016:**
  - Continue to analyze current California SGIP deployment data
  - Collect additional operations data
  - Expand analysis
    - Explore options for other operation/performance CDPs
  - Continue to develop other data partners (state and federal programs)
  - Work with fuel cell OEMs for possibility of additional data sets

Technology Transfer Activities

- Use data to inform other projects about how stationary fuel cells are used and could be used.
- Created personalized, non-public analysis for FC OEM to aide their understanding of the data

Summary

- NREL is leveraging a large pool of technology validation analyses and knowledge
- Operations Data units > 100 kW (power, fuel flow, temperature, etc)
  - The mean fuel cell **electrical efficiency** is 45% 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 relative size of the fuel cell 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.
- CA 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