Overview

Timeline and Budget

- Project\(^1\) start date: July 2009
- FY14 DOE funding: $100k
- FY15\(^2\) planned DOE funding: $85k
- Total DOE funds received to date: $650k

Partners

- U.S. and international fuel cell developers supply data voluntarily and review published results

Barriers

- Lack of data for current fuel cell stack voltage durability

<table>
<thead>
<tr>
<th>Application</th>
<th>2020 Durability Target(^3)</th>
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\(^1\) Project continuation and direction determined annually by DOE

\(^2\) FY09–FY13, and FY15 project objective focused on status of fuel cell durability

FY14 project objective focused on fuel cell price

\(^3\) Fuel Cell Technologies Office Multi-Year RD&D Plan –Section 3.4
Relevance

**Benchmark state-of-the-art fuel cell durability**
- Develop snapshot of state-of-the-art fuel cell durability
- Uniformly apply analysis method to developers’ voluntarily supplied data from lab testing
- Obtain independent assessment and status of state-of-the-art fuel cell technology

**Leverage analysis experience**
- Utilize analysis methods, experience, and data from fuel cell field demonstrations (e.g., DOE’s FCEV Learning Demonstration and early market demonstrations)
- Compare lab and field data

**Collaborate with key fuel cell developers**
- Provide feedback to fuel cell developers
- Study differences between lab and field durability
- Benchmark system price

**FY15 Objectives**
- Receive and analyze new lab durability data
- Update and publish the durability results

**Barrier/Impact**
- Data on fuel cell stack voltage durability is received at the National Fuel Cell Technology Evaluation Center (NFCTEC)
- Consistent and independent source for current and legacy voltage durability
Approach: NFCTEC Analysis and Reporting of Real-World Operation Data

Fuel Cell* Technology Status
Data Supply
Voluntarily supplied from fuel cell developers
Durability – voltage, current, and hours minimum data needed
Test – time frame, objective, protocol, application, and type
Market – system price, availability, and application

*Fuel cell technologies include Polymer Electrolyte Membrane (PEM), Solid Oxide (SO), and Direct Methanol (DM)

Internal analysis completed quarterly in NFCTEC

National Fuel Cell Technology Evaluation Center

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

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

www.nrel.gov/hydrogen/proj_tech_validation.html
Approach: Raw Fuel Cell Data Processing

1. Segment fuel cell voltage and current data
2. Apply polarization fit
3. Record operation hour for segment
4. Record voltages from polarization fit at set currents
5. Plot polarization fit voltage at a specific current
6. Apply robust segmented linear fit (if trend suggests non-linear degradation trend)
7. Record fit y-intercept (nominal voltage drop)
8. Record operation hour when fit crosses 10% nominal voltage drop
9. Investigate fit quality
Approach: CDP and DDP Review

Data Process and Analysis

Example Data Results (if needed) > Draft CDPs > Initial Review (~1 week) > Final Draft CDPs (<1 week) > Final Review (<1 week) > Finalized CDPs (<1 week)

(~4 weeks excluding data processing and analysis)

Example DDPs

FY15 Milestone
Analysis complete and updated results published by 04/2015

Sample Data Set 1
Sample Data Set 2

Op Hr Proj Hr
Automotive
Accomplishments: Data Set Count and Operation Hours

05/2015 CDPs include
145 data sets analyzed
77% retired
47 new data sets since 05/2013
15 CDPs (updated since 05/2013)

1) Data set count at publication of a CDP set - where a data set represents a short stack, full stack, or system test data.
Accomplishments: Voltage Degradation Results by Application

The average projected times (hrs) to 10% voltage drop are **2,500, 3,600, 6,200, 14,600, and 11,100** for backup power, automotive, bus, forklift, and stationary applications, respectively.

Data from lab tested, full active area PEMFC and SOFC short stacks and systems with full stacks. Data generated from constant load, transient load, and accelerated testing and include 17 U.S. and international fuel cell developers.

10% voltage degradation metric is used for assessing voltage degradation; it may not be the same as end-of-life criteria and does not address catastrophic failure modes. DMFC included but not enough data was available for publication. DOE targets are for real-world applications; refer to Fuel Cell Technologies Office Multi-Year RD&D Plan.
Accomplishments: Voltage Degradation by Configuration and Test Condition

Grouping by configuration and test condition is important because of influences on degradation projects. Conclusions are still difficult to identify because of limited data and many variations in these groups. Further study and additional data are needed.

Not all applications have data sets in each configuration or test condition group.

- Steady – little or no change to load profile
- Duty Cycle – load profile mimics real-world operating conditions
- Accelerated – test profile is more aggressive than real-world operating conditions and data not corrected for accelerated conditions
Approach: Current Status to Complement DOE Fuel Cell System Cost Based on Models for High Volume

Projected Transportation Fuel Cell System Cost

at high-volume (500,000 units per year)

Accomplishments: Low Volume Price of Current Fuel Cell Systems

1. Data (in 2013 dollars without incentives) sources include public information, ARRA deployments, and fuel cell developers (voluntarily supplied). Includes over 35 different data points from more than 7 domestic and international fuel cell developers.
2. Prime power data includes multiple system sizes, types, and fuels. Small prime is < 11 kW.
3. Based on DOE MYRDD Fuel Cell section tables 3.4.5 and 3.4.6.
Accomplishments and Progress: Responses to Previous Year Reviewers’ Comments

• This project was not reviewed last year.
Collaborations

• **Multiple fuel cell developers voluntarily supplied data**
  - 18 fuel cell developers contacted have supplied at least one dataset
  - Reasons for developers not providing data include concerns over voluntary proprietary data sharing, availability of data sets with high operation time that are a good fit to include in the analysis, and readily accessible data in the requested format
  - Data contributors are not identified yet because of limited data sets by application category

• **Gathering PEMFC, DMFC, and SOFC datasets**

• **Data sharing is completely voluntary**

• **Participation in DOE durability working group and presentation of status to fuel cell tech team**

• **Ongoing effort with fuel cell developers to:**
  - Include new data sets (particularly in the stationary category)
  - Update datasets already included if applicable
  - Include new fuel cell developers
Remaining Challenges and Barriers

- Voluntarily supplied data
- Inconsistent availability of data and status reporting
- Reporting on additional information relevant to durability
- Analyzing and reporting on the relationship between lowering cost and improving durability
- Analyzing factors that influence durability
Proposed Future Work

- Alternate between a status update on fuel cell durability and system cost/price – price status update planned for FY16
- Continue cultivating existing collaborations and developing new collaborations with fuel cell developers
- Publish a report on the durability analysis method (9/2015)
- Add electrolysis data and published updated results (9/2015)
Summary

Relevance: Independent assessment of state-of-the-art fuel cell technology provides one location for fuel cell durability status from leading fuel cell developers with a uniform analysis and reporting method on a variety of proprietary data.

Approach: Leverage NFCTEC and prioritized industry collaborations.

Accomplishments: Updated sixth annual results for six applications, plus started electrolysis, and included new details based on metadata and durability trends over time and international developers. The data are fully integrated into NRELFAT and an online interface provides information on the project, connection for interested collaborators, and all publications. Improved project information material for details and benefits of participation.

Collaborations and Future Work:
Continue expanding analyzed data sets, included fuel cell developers, and results.

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Technical Back-Up Slides
### Annual CDP Updates – Durability Benchmark

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This table and graph illustrate the annual CDP updates for durability benchmark across different fiscal years (FY) from FY09 to FY15.
Pamphlet with Participation Details and Benefits

Fuel Cell Technology Status Analysis Project: Partnership Opportunities

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) is seeking fuel cell industry partners from the United States and abroad to participate in an objective and credible analysis of commercially available fuel cell products to benchmark the current state of the technology and support industry growth. Interested fuel cell developers should contact NREL's Technology Validation Team at technology.validation@nrel.gov.

Project Features and Benefits

Industry support - NREL supports continued industry growth by providing an independent, credible, and consistent assessment of fuel cell voltage degradation and cost/price.

Uniform analysis - Analyses are applied uniformly to the supplied data sets.

Detailed data products - NREL shares individualized data analysis results on detailed test data products (CDPs) with the partners who supplied the data. The CDPs also identify specific test parameters to the aggregated data.

Composite data products - Aggregated results are published as onepage data products (CDPs) which show the technology status without identifying individual components. Before publication, the CDPs undergo a two-stage review cycle with participating partners.

Technology status - The CDPs are a primary benchmarking tool for DOE and other stakeholders interested in tracking the status of fuel cell technologies. They highlight durability, performance, and scalability factors for development and help set realistic price expectations at commercial production.

Experiences - This project leverages NREL's technology validation experience and proprietary hydrogen and fuel cell systems and components since 2004.

How does it work?

Participating fuel cell developers share price information about their fuel cell products, which is used to generate data related to operations, maintenance, and safety with NREL via the National Fuel Cell Technology Evaluation Center (NFCTEC). The basic access, off-site, or NFCTEC become the data and analysis tools to protect proprietary information.

What type of data?

Market data on pricing, product availability, and quantity of installed units

Lab data, including fuel cell voltage, current, and operation hours for fuel cell systems, fuel stacks, stack stacks, single cells

Test data on options, including durability, test, design, application, fuel cell type, and measurement methodology

Flexible data format (e.g., .xls, .exe, .xml)

Not restricted to DOE-funded testing

More Information

Visit www.nrel.gov/conv/fuel-cell-analysis.html for more information about this project and to see the CDPs published to date. Contact NREL's Technology Validation Team at technology.validation@nrel.gov for more information about partnership opportunities.

Peer Review Feedback from May 2012

"NREL is currently set up to compare data sets from a variety of fuel cell developers for a range of applications. Without this project, such a comparative analysis would not be available."

"This project is essential to benchmarking the progress of fuel cell systems over time and across industries."

The U.S. Department of Energy's National Renewable Energy Laboratory is seeking fuel cell industry partners from the United States and abroad to participate in an objective and credible analysis of commercially available fuel cell product cost/price and durability data to benchmark the current state of the technology and support industry growth."