VIII.F Systems Analysis

VIII.F.1 Controlled Hydrogen Fleet and Infrastructure Analysis

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Start Date: October 2003
Projected End Date: Project continuation and direction determined annually by DOE

Objectives

- By 2009, validate hydrogen (H_2) vehicles with greater than 250-mile range, 2,000-hour fuel cell durability, and $3/gallon of gasoline equivalent (gge) hydrogen production cost.
- Assist DOE in demonstrating use of fuel cell vehicles (FCVs) and hydrogen infrastructure under real-world conditions (validating total system solutions for hydrogen transportation), using multiple sites, varying climates, and a variety of sources for hydrogen.
- Identify current status of technology and its evolution over the 5-year project duration.
- Analyze data from vehicles and infrastructure to obtain maximum value for DOE and industry from this learning demonstration.
- Provide feedback and recommendations to refocus hydrogen and fuel cell research and development (R&D).
- Support industry commercialization decision by 2015.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Hydrogen, Fuel Cells & Infrastructure Technologies (HFCIT) Program Multi-Year Research, Development and Demonstration Plan:

- A. Vehicles – lack of controlled and on-road H_2 vehicle data
- B. Storage – not yet providing necessary 300+ mile range
- C. Hydrogen Refueling Infrastructure – cost and availability
- D. Maintenance and Training Facilities – lack of facilities and trained personnel
- E. Codes and Standards – lack of adoption/validation
- H. Hydrogen from Renewable Resources – need for cost, durability, and efficiency data for vehicular application
- I. H_2 and Electricity Co-Production – cost and durability

Contribution to Achievement of DOE Technology Validation Milestones

This project will gather data and provide analysis in the next five years that will contribute to achievement of the following DOE Technology Validation milestones from the Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 2: Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles (Q3FY05 [quarter 3, fiscal year 2005]). We will be analyzing all of the data that are collected on the roughly 120 vehicles involved in this project. Data have just begun being delivered this year, and we will report against this target when there is a statistically significant set of vehicle data.
- Milestone 4: Go/No-Go decision for purchase of additional vehicles based on projected vehicle performance and durability, and hydrogen cost criteria (Q4FY06).
- Milestone 5: Validate fuel cell demonstration vehicle range of ~200 miles and durability of ~1,000 hours (Q4FY06).
- Milestone 6: Validate vehicle refueling time of 5 minutes or less (Q4FY06).
- Milestone 9: Validate FCVs with 250-mile range, 2,000-hour fuel cell durability, and a hydrogen cost of $3.00/gge (based on volume production) (Q3FY09). This is the final major milestone of the learning demonstration project, and will be assessed in FY 2009.
- Milestone 14: Validate $2.50/gge hydrogen cost (Q4FY08).

Approach

- Provide facility and staff for securing and analyzing industry-sensitive data. This includes establishing and maintaining the NREL Hydrogen Secure Data Center (HSDC).
- Perform analysis and simulation using detailed data in the HSDC to
  - Evaluate current status and progress toward DOE vehicle and infrastructure targets
  - Feed current technical challenges and opportunities back to the DOE HFCIT R&D program
  - Provide analytical feedback to originating companies on their own data.
- Publish/present progress of project to public and stakeholders (composite data products).

Accomplishments

- Created six Excel spreadsheet data templates with agreement from industry team partners on hydrogen vehicle and infrastructure data.
- Developed and obtained agreement on 26 sample composite data products from the project that can be made public.
- Established the HSDC at NREL to protect and manage the raw data and our analysis results from this project.
- Created 7-page security document, with buy-in from industry, for handling the data that they deemed commercially valuable in the HSDC.
- Created automated MATLAB analyses for analyzing stack current/voltage degradation, on-road fuel economy, and on-road range.
- Performed preliminary correlation of vehicle simulation models with on-road data.
- Completed first two internal quarterly validation assessment reports including analysis of early vehicle and infrastructure data as industry teams ramp up vehicle rollouts and refueling station construction.
- Performed industry site visits to review vehicle dynamometer test facilities and test procedures.
- Provided detailed NREL data analysis results from one industry team back to the auto company that originated the data.

Future Directions

- Complete final auto company site visit and review of vehicle test facilities and procedures.
- Obtain initial vehicle and infrastructure data sets from all teams in project for the HSDC.
- Perform analysis on data received and perform complete model validation.
- Annually compare technical progress to program objectives and DOE targets.
- Prepare composite data products and write quarterly Validation Assessment Reports.
- Actively feed findings from project back to HFCIT program R&D activities (continue to ensure that it remains a learning demonstration).
- Develop materials for the public that report on technology and project progress.

Introduction

The primary goal of this project is to validate the total system solution for hydrogen as a transportation fuel for light-duty vehicles. This means validating the use of FCVs and hydrogen infrastructure under real-world conditions using multiple sites, varying climates, and a variety of sources for hydrogen (see Figure 1 for a map of the United States with the five project sites identified). Specifically, by 2009 we will be validating hydrogen vehicles with greater than 250-mile range, 2,000-hour fuel cell durability, and $3/gge hydrogen production cost. We will identify the current status of the technology and track its evolution over the 5-year project duration. NREL's role in this project is to provide maximum value for DOE and industry from this learning demonstration. We seek to gain knowledge about the progress toward the technical targets, and provide insight into how the HFCIT program research could be refocused to move more quickly toward cost-effective, reliable hydrogen FCVs and supporting refueling infrastructure.

Approach

Our approach to accomplishing the project's objectives is structured around a highly collaborative relationship with each of the four industry teams, including Chevron and Hyundai/Kia, DaimlerChrysler and BP, Ford and BP, and GM and Shell (Figures 2 and 3 show examples of representative vehicles and infrastructure). We are receiving raw data from both the hydrogen vehicles and refueling infrastructure that allows us to perform unique and valuable analyses across all four teams. To protect the commercial value of these data to each company, we needed to establish the HSDC to house the data and perform our analysis. To ensure value is

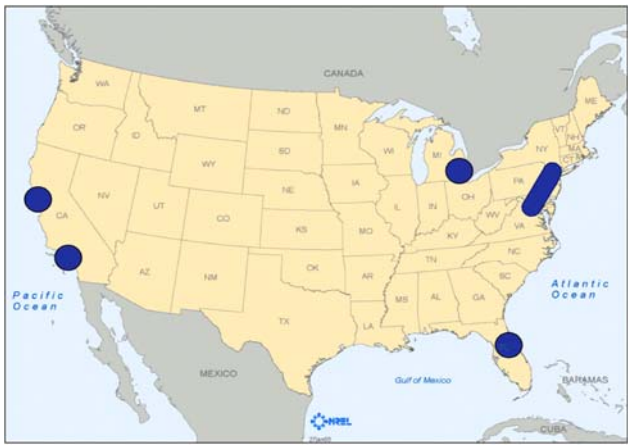

Figure 1. Five Geographical Regions Address Key U.S. Climates

Figure 2. Representative FCVs from Each of the Four Industry Teams

Figure 3. Sample Hydrogen Refueling Infrastructure: Rollout of Stations Began This Year

fed back to the hydrogen community, we will be publishing 26 composite data products that report on the progress of the technology and the project as well as presenting progress and significant results at technical conferences.

Results

There were several major accomplishments for this project in FY 2005, including developing and obtaining agreement from industry on the six Excel spreadsheet data templates and the composite data products, establishing the NREL HSDC, and beginning the process of automating data analysis and looking at early project data.

A major emphasis this year was placed on clearly defining the data inputs and outputs of the project. On the input side, in order to obtain a uniform and complete set of data for analysis from each industry team, NREL created six Excel spreadsheet data templates (four for vehicles, two for infrastructure) and worked with industry to obtain agreement to use these templates. Table 1 summarizes both high-level and detailed data that the industry teams will provide. NREL has begun analyzing some of these data.

As part of the agreement to obtain this highly sensitive data from industry, including details such as fuel cell voltage, current, and vehicle fuel economy, NREL needed to assure industry representatives that the data would be handled securely. To establish a systematic and secure way of handling the data, NREL established the HSDC to house all the raw data and allow the information to be analyzed.

Table 1. Type of Vehicle and Infrastructure Data Being Collected

Key Vehicle Data	Key Infrastructure Data
Stack Durability	Conversion Method
Fuel Economy (Dyno & On-Road) and Vehicle Range	Production Emissions
Fuel Cell System Efficiency	Maintenance, Safety Events
Maintenance, Safety Events	Hydrogen Purity/Impurities
Top Speed, Accel., Grade	Refueling Events, Rates
Max Pwr & Time at 40C	H2 Production Cost
Freeze Start Ability (Time, Energy)	Conversion, Compression, Storage and Dispensing Efficiency
Continuous Voltage and Current (or Power) from Fuel Cell Stack, Motor/Generator, Battery & Key Auxiliaries: (Dyno & On-Road)	

we perform the analyses that are then used to create the composite data products and provide DOE with technical recommendations for R&D within the program.

On the output side, NREL created a list of 26 representative composite data products. These are graphs (using hypothetical data) showing the types of results that could become public after the industry data are aggregated to high-level trend results. Figure 4 shows a flow diagram of this process, and includes one of the sample composite data products on the right-hand side.

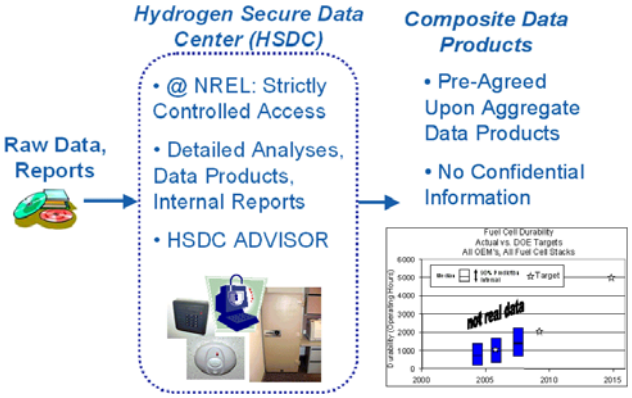

Figure 4. Overview of Data Collection and Analysis Process

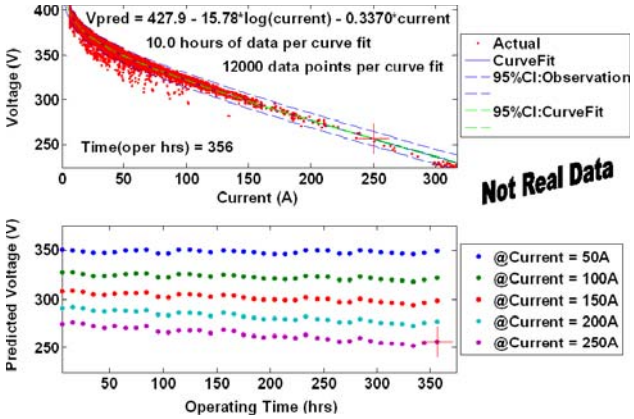

Figure 5. Automated analysis created for analyzing stack current/voltage degradation

Finally, as the HSDC began receiving data, we programmed analysis routines for automatic processing of the data. To date, this has included voltage and current analysis from the fuel cell stack (Figure 5), on-road fuel economy and range analysis, and analysis of early infrastructure data. Within the next year there should be adequate data to publish some of the first composite data products.

Summary

- We obtained industry agreement on input data reporting templates and output composite data products.
- We established the HSDC at NREL to protect raw data and detailed analysis results.
- The HSDC began received early data on which analysis has been performed. The volume and breadth of these data is not yet sufficient to allow any composite data products to be published.

Special Recognitions & Awards/Patents Issued

1. Project staff members Keith Wipke and Cory Welch received a joint NREL Director's Award in recognition of their efforts to establish the HSDC as well as obtain agreement from the industry teams on the data templates and the planned composite data products.

FY 2005 Publications/Presentations

1. Gronich, S., Garbak, J., Wipke, K., Welch, C. "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," 2004 Fuel Cell Seminar, San Antonio, TX, November 2004. (presentation only)
2. Welch, C. "Composite Data Products for the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," Golden, CO: National Renewable Energy Laboratory, November 2004.
3. Welch, C., Wipke, K. *DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project: Quarterly Validation Assessment (Q4 2004).* Golden, CO: National Renewable Energy Laboratory, February 2005. (HSDC paper only)
4. Wipke, K. "Hydrogen Secure Data Center: Procedures to Protect Technical Data Submitted Under the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project." Golden, CO: National Renewable Energy Laboratory, February 2005.
5. Welch, C., Wipke, K., Gronich, S., Garbak, S. "Hydrogen Fleet & Infrastructure Demonstration and Validation Project: Data Analysis Overview." NHA Annual Hydrogen Meeting and Exposition, Washington, DC, March 2005. (paper and presentation)
6. Wipke, K., Welch, C., Gronich, S., Garbak, J., Hooker, D. "Introduction to the U.S. Department of Energy's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project." The 21st Worldwide Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition, Monaco, April 2005. (paper and presentation)
7. Welch, C. "Data Templates for Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project." Golden, CO: National Renewable Energy Laboratory, April 2005. (6 Excel spreadsheets)
8. Welch, C. Wipke, K. *DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project: Quarterly Validation Assessment (Q1 2005).* Golden, CO: National Renewable Energy Laboratory, May 2005. (HSDC paper only)
9. Welch, C. Wipke, K. *Fuel Cell Vehicle Range.* Golden, CO: National Renewable Energy Laboratory, June 2005. Written in support of DOE Joule milestone. (HSDC paper only)