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Introduction to the U.S. Department of Energy's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Conference Paper
NREL/CP-560-39979
May 2006

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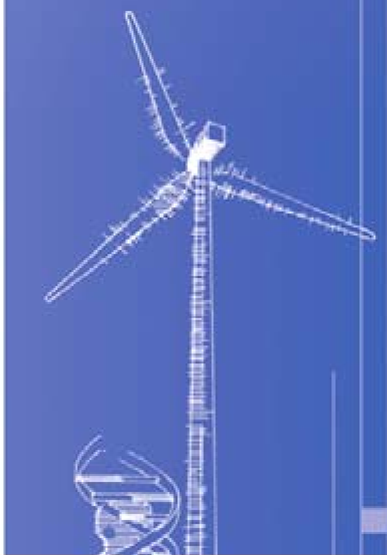
Presented at EVS-21 (Electric Vehicle Symposium)
www.evs21.org
Monte Carlo, Monaco
April 2–6, 2005



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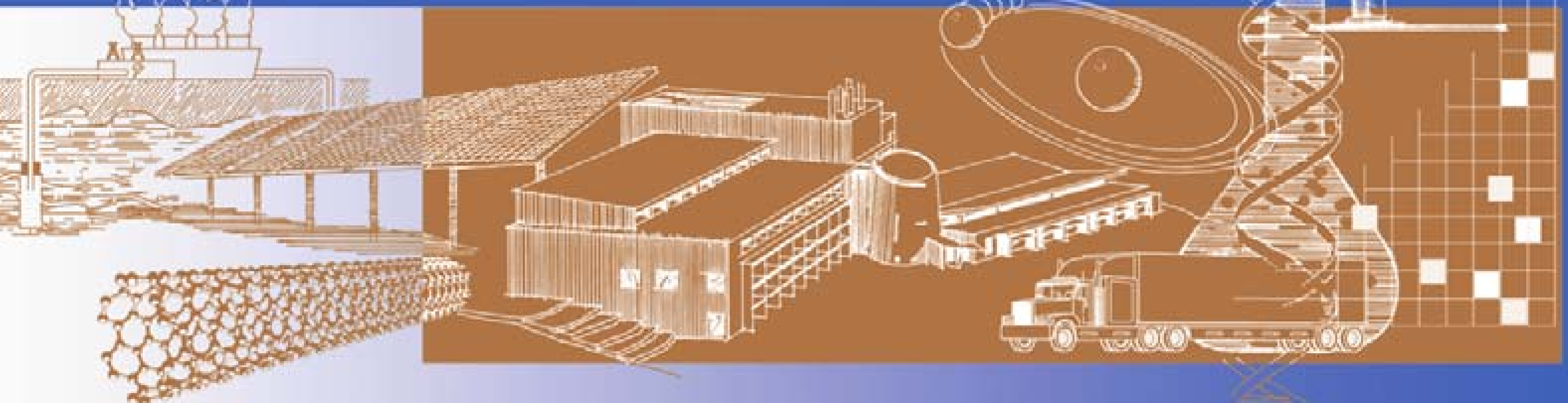

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Introduction to the U.S. Department of Energy's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Keith Wipke, Cory Welch, Sigmund Gronich, John Garbak, Doug Hooker

Abstract

Early in 2003, the U.S. Department of Energy (DOE) initiated the "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" solicitation. The purpose of this project is to examine the impact and performance of fuel cell vehicles and the requisite hydrogen infrastructure in real-world applications. The integrated nature of the project enables DOE to work with industry to test, demonstrate, and validate optimal system solutions. Information learned from the vehicles and infrastructure will be fed back into DOE's R&D program to guide and refocus future research as needed, making this project truly a "learning demonstration."

The first of the Cooperative Agreements between DOE and the industry teams was signed in the fall of 2004, and vehicles are now being introduced at the same time as hydrogen refueling stations are being installed. Estimated government investment in this activity will be around $190 million, coupled with significant cost share from industry for a planned total of around $400 million. This paper describes the teams involved in the project, the general geographic locations of the hydrogen refueling infrastructure to be installed, and the makeup of the initial fleets to be put into operation for data collection. The type of data to be collected from the infrastructure and vehicles is explained, and the nature of the analyses made possible from the data is explored in a generic way.

These collaborative projects with industry will continue for five years, over which multiple generations of technology will be tested as lessons are learned from the initial fleet. Technical performance from this project (at its conclusion and intermediate steps along the way) will ultimately be compared against DOE's 2009 technical targets such as a 250-mile range, 2000-hour fuel cell stack durability per vehicle, and a hydrogen production cost of $3.00 per gallon of gasoline equivalent (gge) untaxed, when produced in quantity.

Keywords: demonstration, fuel cell, hydrogen, infrastructure, passenger car.

1 Introduction

Hydrogen fuel cell vehicles are currently being researched as an approach to introduce a commercially-viable zero-tailpipe emission vehicle into the marketplace. Using hydrogen as the fuel provides a key benefit to the United States in terms of fuel feedstock diversity. The hydrogen could come from a mixture of renewables, natural gas, biomass, coal, and nuclear energy, allowing the United States to decrease its dependence on foreign oil. The vehicles would have all the benefits of being entirely electric-drive, including high efficiency, regenerative braking, and low noise. There are numerous technical challenges remaining before the hydrogen fuel cell vehicle will enter the commercial automotive market, but there is also significant effort underway to make this happen.

The United States Department of Energy (DOE) is working with industry to remove the technical barriers to allow commercialization of these technologies through its Hydrogen, Fuel Cells & Infrastructure Technologies (HFCIT) Program. This multi-faceted program simultaneously focuses on hydrogen production, storage, delivery, conversion (fuel cells), technology validation, education, safety, and codes and standards. While many of the current key technical barriers have already been identified and are being addressed, such as hydrogen storage and fuel cell durability, additional technical challenges may need to be solved that have not yet been identified because the vehicles and infrastructure have not been fully developed. To date, fleets of fuel cell vehicles have been small and focused in several locations in California, limiting the geographic diversity of the data collected and the lessons learned. To simultaneously evaluate and learn from experience gained with both the vehicles and the refueling infrastructure, DOE has taken a unique approach to performing a large-scale “learning demonstration” involving automotive manufacturers and energy (fuel) providers. This learning demonstration, entitled the “Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project,” is the second phase of the HFCIT Program’s Technology Validation effort (see Figure 1).

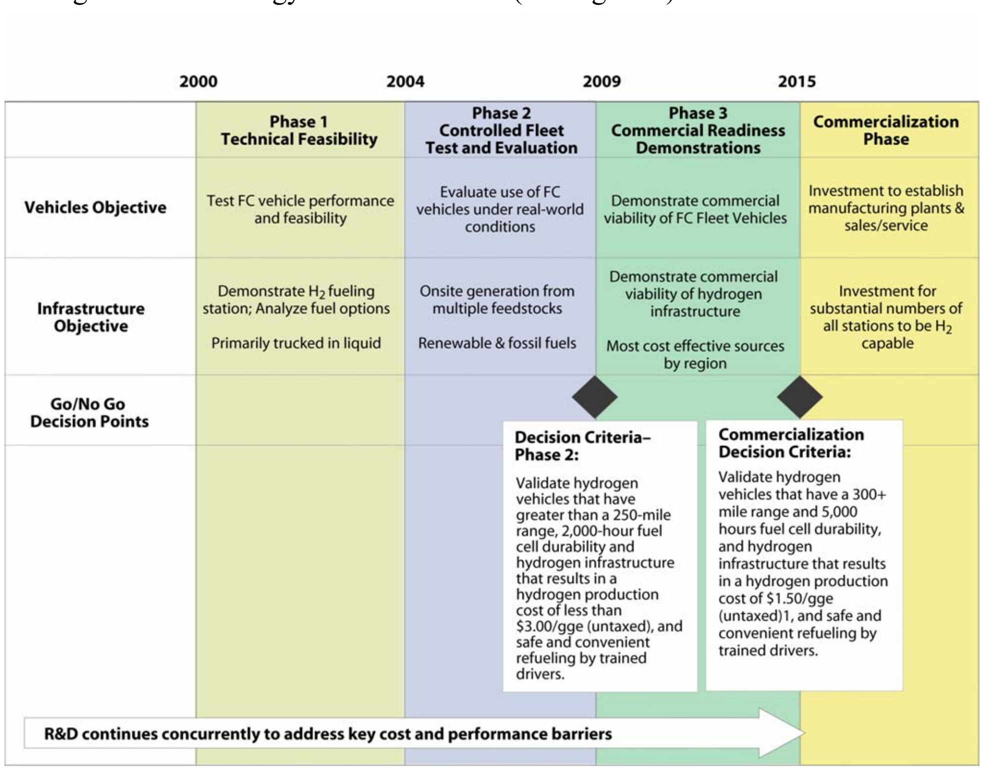

Figure 1. Transportation and infrastructure timeline.

In April 2003, DOE initiated a competitive solicitation for proposals for this project. Proposals were due in October 2003, and selections from this competitive process were announced in April 2004. The first of the Cooperative Agreements between DOE and industry teams was signed in the fall of 2004, and vehicles are now being introduced and hydrogen refueling stations are being installed. Estimated government investment in this activity will be around $190 million with significant cost share from industry for a total of approximately $400 million. This paper describes the teams involved in the project, the general geographic locations of the hydrogen refueling infrastructure to be installed, and the initial fleets to be put into use for data collection. The type of data to be collected from the infrastructure and vehicles is explained, and the nature of the analyses made possible from the data is explored in a generic way. These five-year collaborative projects with industry will span multiple generations of technology as experience is gained from the initial fleet.

2 Project Objectives

One of the HFCIT Program's key strategies is to conduct learning demonstrations of hydrogen infrastructure in parallel with hydrogen fuel cell-powered vehicles to facilitate an industry commercialization decision by the year 2015. Specifically, the project will test, demonstrate, and validate complete system solutions. The quantity, quality, and depth of data being collected are such that they will actually allow (1) DOE's detailed technical program targets to be evaluated and benchmarked, and (2) research to be refocused based on these data. The refocusing of R&D as a result of a demonstration and validation project is part of what makes this project unique.

This project has specific performance targets for the year 2009 that will be used to verify program progress toward the 2015 targets, which will feed the industry commercialization decision. These targets, which are listed in Table 1, have been chosen because they represent the key barriers to successful market entry. Fuel cell durability is key because it represents current automotive customer expectations in terms of product life. If the stack life is shorter than 5,000 hours, representing 100,000 miles of driving, then the cost of ownership of a fuel cell vehicle would be too high. Driving range is also an important consumer expectation. For example, driving range, along with cost, caused the pure electric vehicle in California to fail commercially when forced into the marketplace by regulation. Finally, the hydrogen production cost is key because it could reflect a major cost of ownership for consumers (along with insurance and financing) and cannot be much higher than equivalent gasoline cost for success in the market. The values for these metrics in 2015, as presented in Table 1, reflect estimated performance parity with conventional gasoline technologies.

Table 1: Project Performance Targets for 2009 and 2015

Performance Measure	2009*	2015**
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station	$3.00/gge	$1.50/gge
* To verify progress toward 2015 ** Subsequent projects to validate 2015 target		

3 Project Participants

After the solicitation awards were announced in April 2004, DOE negotiated with the winning teams, resulting in a number of signed Cooperative Agreements. This section describes the four teams now beginning their five-year projects. The solicitation required that the prime recipient of each team had to be either an automotive original equipment manufacturer (OEM) or an energy provider, with both required to be part of each team. Three of the four teams have the automotive OEM as the prime recipient, and one has the energy provider as the prime. Representative examples of fuel cell vehicles developed by the participating companies for previous demonstrations are shown in Figure 2.

Figure 2. Previously demonstrated vehicles from the four industry teams. These vehicles do not necessarily represent the vehicles to be used as part of this demonstration and validation project.

3.1 ChevronTexaco and Hyundai Motor Company

ChevronTexaco teamed with Hyundai, and included UTC Fuel Cells as the fuel cell provider. Their fleet will include roughly 32 fuel cell vehicles that will likely be sport utility vehicles (SUVs). During the five-year project, there will also be two different generations of fuel cell systems from UTCFC that will be tested. The fleet will be serviced by roughly six refueling stations in northern and southern California.

3.2 DaimlerChrysler and BP

The second team consists of DaimlerChrysler and BP, with Ballard as the fuel cell provider. Their fleet will include roughly 36 fuel cell vehicles that will include primarily F-Cell vehicles (small minivans) as well as Sprinter delivery vans. A goal is to try to get more than one generation of fuel cells rotated into service during the project to include improvements learned from ongoing research. The fleet will be serviced by roughly eight refueling stations in northern California, southern California, and the Detroit, Michigan area.

3.3 Ford Motor Company and BP

Ford Motor Company has also teamed with BP as the fuel provider and Ballard as the fuel cell supplier. Their fleet will include roughly 26 fuel cell vehicles that will be serviced by roughly seven refueling stations in northern California, the Detroit area, and central Florida.

3.4 GM and Shell

General Motors' (GM) fuel provider for this project will be Shell, and GM will be providing its own fuel cell stacks to power its vehicle fleet. Their fleet will include roughly 40 fuel cell vehicles that will likely be based on the Opel Zafira minivan. The fleet will be serviced by roughly seven refueling stations in northern and southern California, along with stations in a northeast corridor of the U.S.

4 Fleet Geographic Locations

As shown Figure 3, there are five distinct geographic regions that will be investigated as part of this project, representing most of the climatic conditions experienced in the United States.

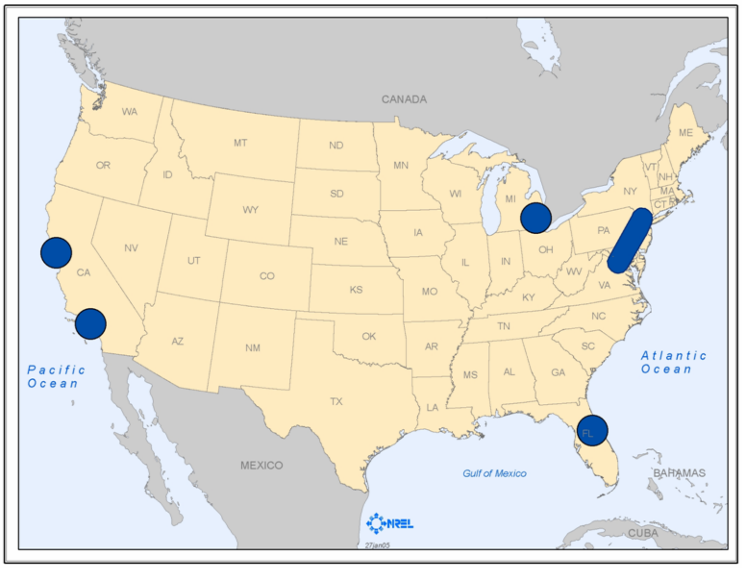

Figure 3: Location of hydrogen fueling stations for DOE's learning demonstration project.

Table 2 outlines the major types of climatic conditions represented by these five regions. These four climates are important for evaluating fuel cell technology because each presents different technical challenges. Cold climates introduce the possibility of extended freeze, which is a known problem for current generation fuel cells that use and produce water during operation. Hot arid and hot humid environments will investigate challenges regarding the vehicles' heat rejection systems, which for a fuel cell vehicle are at a lower temperature than a typical internal conventional vehicle's cooling system. All of the regions include moderate conditions at some point in the year, allowing some comparison of the vehicles at different sites under similar thermal conditions.

Table 2: Four Climatic Conditions Represented by Learning Demonstration Site Geographies

Station/Vehicle Location	Climate			
	Cold	Moderate	Hot Arid	Hot Humid
Northern CA		X	X	
Southern CA		X	X	
Detroit, MI	X	X		
Washington D.C./NYC	X	X		X
Orlando, FL		X		X

5 Data Reporting and Analysis

A significant amount of data will be collected and analyzed over the course of the learning demonstration. Due to the large monetary investment that all the automotive OEMs have made in fuel cell research (billions of dollars by each company), the detailed data provided by each team will not be shared among the companies or with the public. A Hydrogen Secure Data Center (HSDC) was established at NREL to house, protect and analyze the data. The only data products to leave the HSDC are those classified as "composite data products." A list of around 25 such composite data products has been developed and agreed to by all of the industry and government partners (see Table 3).

Table 3. Composite Data Products for the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Critical Program Metrics
1. Fuel Cell Durability, Actual vs. DOE Targets, All OEM's
2. Vehicle Ranges, Actual vs. DOE Targets, All OEM's
3. Hydrogen Production Cost, Actuals/Projections vs. DOE Targets
Composite Performance Tracking
Vehicles
4. Reliability (FC System & Powertrain, MTBF)
5. Start Times vs. DOE Target
6. Fuel Economy: Dyno, On-Road
7. Normalized Vehicle Fuel Economy
8. Fuel Cell System Efficiency
9. Safety Incidents - Vehicle Operation
10. Weight % Hydrogen Stored
11. Energy Density of Hydrogen Storage
12. Vehicle Hydrogen Tank Cycle Life
Hydrogen Infrastructure
13. Hydrogen Production Efficiency vs. Process
14. Combined Heat and Power (CHP) Efficiencies
15. Hydrogen Production Cost vs. Process
16. Hydrogen Purity vs. Production Process
17. Hydrogen Impurities - Range for Production Process A
18. Histogram: Refueling Rate
19. Average Maintenance Hours - Scheduled and Unscheduled
High Level Program Progress
Vehicles
20. Range of Actual Ambient Temperatures During Vehicle Operation - All Vehicle Teams
21. Histogram: # Vehicles vs. Operating Hours to Date
22. Histogram: # Vehicles vs. Miles Traveled to Date
23. Cumulative Vehicle Miles Traveled - All Teams
24. Progression of Low to High Pressure On-board H2 Storage
Hydrogen Infrastructure
25. Cumulative Hydrogen Production - All Teams

The composite data products allow the government to report progress toward targets and publish any mid-course program changes needed without compromising any company's data or competitive advantage.

The data are used to identify trends and consistent problem areas for the technologies that current research does not seem to be adequately addressing. Figures 4 and 5 show two examples of the high-level composite data products (using fictitious data for now) that will be published at as they become available.

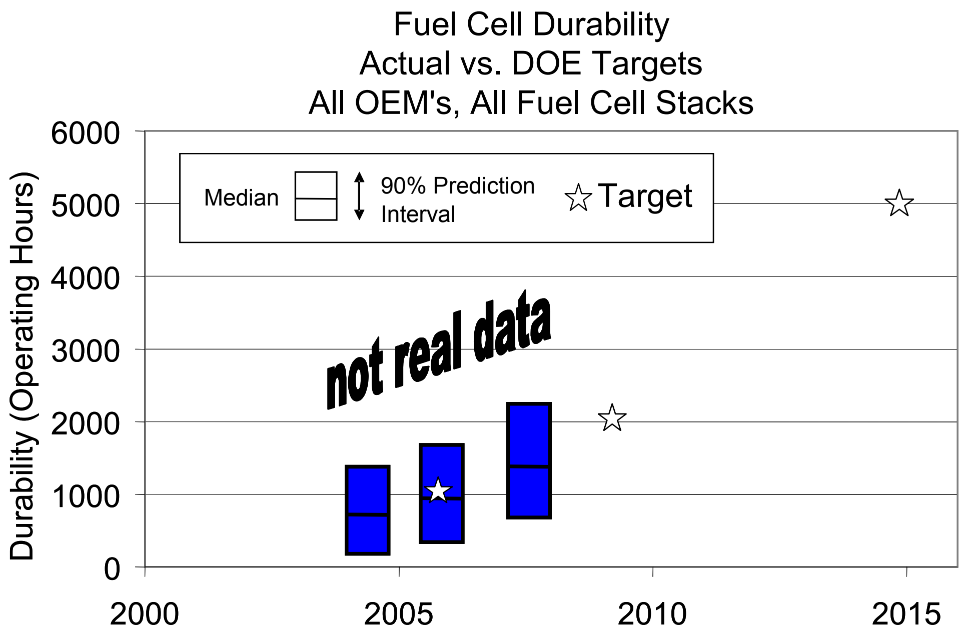

Figure 4: An example of the many composite data products that will result from this project. Note that the targets in this graph are real, but the data are fictitious and for illustrative purposes only.

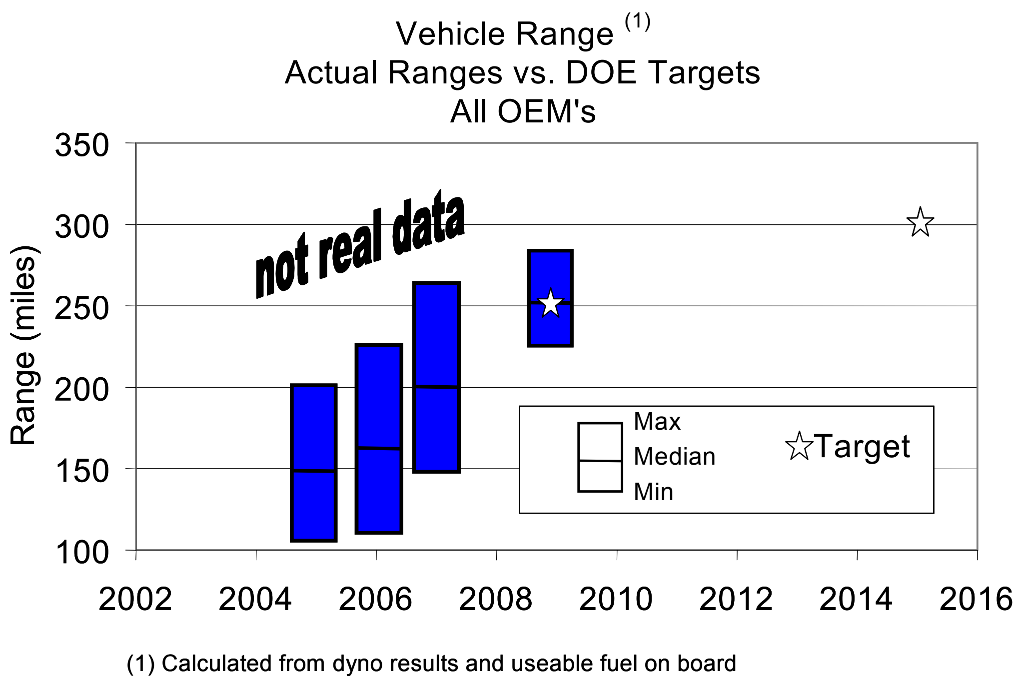

Figure 5: A second example of the type of composite data products resulting from this project.

6 Status

Currently, most of the negotiations on both contractual and technical issues have been completed. Initial data has begun to be been delivered to the HSDC, and the first complete set of analyses should be completed in the summer of 2005. The infrastructure data sets will increase as the number of refueling stations increases, and the number of vehicle data sets will increase as more vehicles are put into service. Composite data products will not be published until a sufficient number of data sets from different companies have been received, in order to establish the ranges necessary to protect all proprietary data. The project will continue until 2009, at which time the project may be extended to validate the 2015 targets that will be used in the industry commercialization decision.

7 Conclusion

Early in 2003, DOE solicited proposals for the "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project." The purpose of this integrated field validation project is to examine the impact and performance of fuel cell vehicles and the requisite hydrogen infrastructure simultaneously. The integrated project structure enables DOE to test, demonstrate, and validate optimal system solutions. Information learned from both the vehicles and infrastructure is then fed back into DOE's R&D program to guide and refocus future research, making this truly a "learning demonstration." This paper described the teams involved in the project, the general geographic locations of the hydrogen refueling infrastructure to be installed, and the makeup of the initial fleets to be put into use for data collection. The type of data to be collected from the infrastructure and vehicles was explained, and the nature of the analyses made possible from the data was explored in a generic way.

These collaborative projects with industry will continue for five years, over which several generations of technology will be tested as lessons are learned from the initial fleets. Technical performance from this project will ultimately be compared against DOE's 2009 technical targets such as a 250-mile range, 2000 hour fuel cell stack durability per vehicle, and a hydrogen production cost of $3 per kg untaxed, when produced in quantity. Composite data products will be presented to the public in the future to show the progress of the project, while the more detailed data will be used to help guide and refocus DOE's R&D activities as necessary.

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Mr. Wipke has worked at NREL in the area of advanced vehicles for 12 years. The majority of that time has been spent researching hybrid electric vehicles through data collection and analysis and computer modeling using NREL's advanced vehicle simulator ADVISOR. In 2003, ADVISOR was licensed to AVL for commercialization and Mr. Wipke moved to the hydrogen group at NREL to work on the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. **REPORT DATE** *(DD-MM-YYYY)*	2. **REPORT TYPE**	3. **DATES COVERED** *(From - To)*
May 2006	Conference Paper	April 2-6, 2005

4. TITLE AND SUBTITLE
Introduction to the U.S. Department of Energy's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
K. Wipke, C. Welch, S. Gronich, J. Garbak, and D. Hooker

5d. PROJECT NUMBER
NREL/CP-560-39979

5e. TASK NUMBER
HF65.8100

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/CP-39979

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
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15. SUBJECT TERMS
technology validation; hydrogen fleet; hydrogen infrastructure; controlled hydrogen fleet and infrastructure demonstration and validation project

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER (*Include area code*)

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18