2005 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review

Controlled Hydrogen Fleet & Infrastructure Analysis

Keith Wipke
NREL
May 25, 2005

Project ID# TV7

This presentation does not contain any proprietary or confidential information

Project Objectives and Targets

- Objectives
  - Validate "System" Solutions for H_2 Transportation
  - Identify Current Status of Technology and its Evolution
  - Re-Focus H2 Research and Development
  - Support Industry Commercialization Decision by 2015

Hydrogen and gasoline station, WA DC

Key Targets

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 targets
** Subsequent projects to validate 2015 targets

Project Overview

Timeline

- Project start: FY03
- Project end: FY09
- ~15% complete (see timeline slide)

Budget

- NREL FY04 funding: $630K
- NREL FY05 funding: $750K
- Context: Overall DOE project is $190M project over 5 years
  - Equal investment by industry

Tech. Val. Barriers

A. **Vehicles** – lack of controlled & on-road H2 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

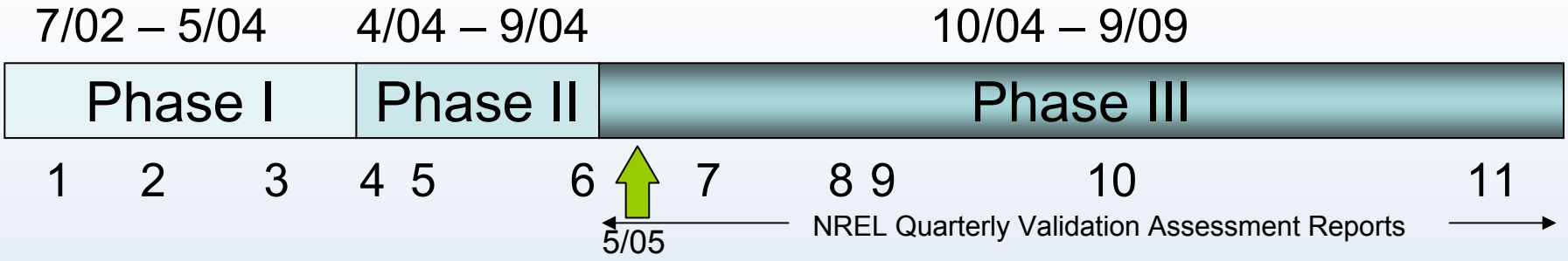
H. **Hydrogen Production from Renewables** – need for cost, durability, efficiency data for vehicular application

I. **H2 and Electricity Co-Production** – cost and durability

Partners

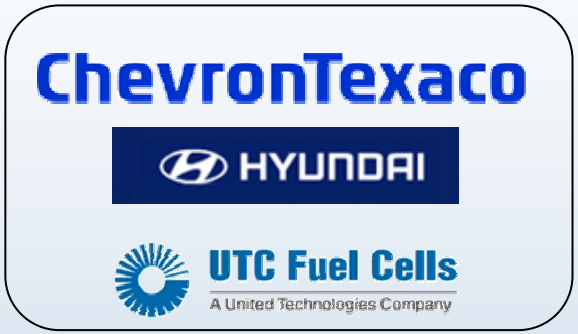
- See partner slide

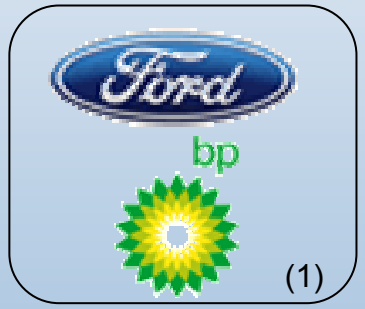
Project Timeline



- **Phase I – Project Preparation**
  - 1 Support Development of RFP, Statement of Objectives (Appendix C)
  - 2 Bidder's meeting in Detroit – launch of RFP
  - 3 Create data analysis plan and presentation for discussion with industry
- **Phase II – Project Launch**
  - 4 Announcement of successful bidders (timing TBD)
  - 5 Kick-off meetings and cooperative agreement awards
  - 6 Preliminary data collection, analysis, and first quarterly assessment report
- **Phase III – Data Analysis and Feedback to R&D activities (partial list)**
  - 7 Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles
  - 8 Validate demonstration FCV range of ~200 miles, 1000 hour durability
  - 9 Go/No-Go: Decision for purchase of additional vehicles based on perf., durability, cost
  - 10 Validation on a vehicle 2.0 kWh/kg, 1.2 kWh/L compressed gas tank
  - 11 Validate FCVs with 250-mile range, 2,000 hour durability, and $3.00/gge (based on volume production)

Industry Partners





(1) Fuel cells supplied by Ballard

Teams Will Field Four Main* Types of Vehicles

*DaimlerChrysler will also have FCV Sprinter vans

Sample Hydrogen Refueling Infrastructure: Rollout of Stations Began this Year

DTE/BP Power Park, Southfield, MI

LAX refueling station

Hydrogen and gasoline station, WA DC

Photo:Shell Hydrogen

Chino, CA

Photo: H2CarsBiz

Project Approach

- Provide facility and staff for securing and analyzing industry sensitive data
  - NREL Hydrogen Secure Data Center (HSDC)
- Perform analysis and simulation using detailed data in HSDC to:
  - Evaluate current status and progress toward DOE vehicle and infrastructure targets
  - Feedback current technical challenges and opportunities into DOE H2 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)

Approach: Data Collection Overview

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	H_2 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)	

Approach: Overview of Data Collection & Analysis Process

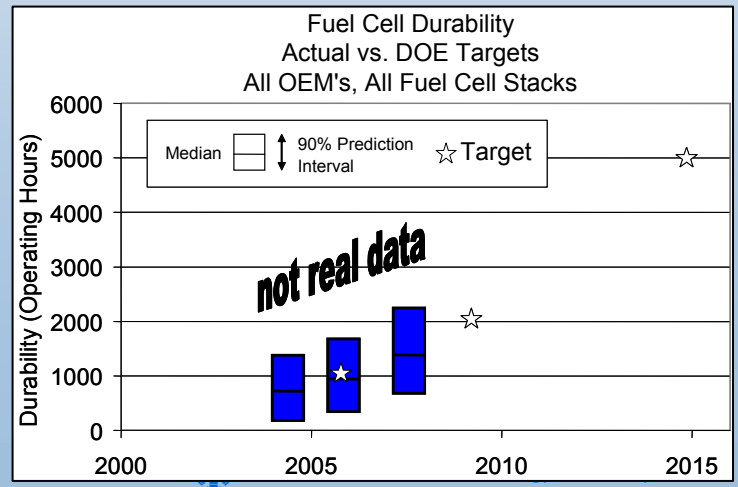
Raw Data, Reports

Hydrogen Secure Data Center (HSDC)

- @ NREL: Strictly Controlled Access
- Detailed Analyses, Data Products, Internal Reports
- HSDC ADVISOR

Composite Data Products

- Pre-Agreed Upon Aggregate Data Products
- No Confidential Information



Accomplishments: Creation/Agreement of 6 Excel Data Templates for Vehicles and Infrastructure

Vehicle Example

On-Road Fuel Economy Table (1)

Data since the inception of the program, all vehicles

Footnotes:

(1) May be collected manually (via driv
Data Acquisition System).

Report Date	*insert date of report*
Automaker	*insert name of automaker*
Vehicle Model:	*Wolverine XJ7*
Location of Operation:	*San Diego, CA*
FC Powerplant Model:	*Gen I*
Vehicle #	*Example*

Date	Fill-up Number	Odometer at Fill (miles)	kg H2 filled	miles/kg H2	Comments (1)
1/1/2005	1	150	2.5	60.0	
1/15/2005	2	350	3	66.7	
1/29/2005	3	475	2	62.5	
2/12/2005	4	650	3	58.3	
2/26/2005	5	850	3.2	62.5	
3/12/2005	6	1050	3	66.7	
3/26/2005	7	1250	2	100.0	Not filled complete
4/9/2005	8	1350	3.2	[illegible]3	
4/23/2005	9	1550	[illegible]	[illegible]2.5	
5/7/2005	10	1750	[illegible]	62.5	
5/21/2005	11	1950	3.2	62.5	
6/4/2005	12	2250			kg H2 missing
6/18/2005	13	2450	3.2	62.5	
7/2/2005	14	2650	3.2	62.5	
7/16/2005	15	2850	3.2	62.5	
7/30/2005	16	3050	3.2	62.5	
8/13/2005	17	3250	2.2	90.9	Not filled complete
8/27/2005	18	3350	3.2	31.3	
9/10/2005	19	3550	3.2	62.5	
					Replaced FC Stac

not real data

Revision History / Performance Summary / Fleet Summary / Stack Durability Summary / Mainte

Infrastructure Example

On-Site Hydrogen Production Efficiency Summary

Data since the inception of the program

Total On-Site Efficiency Table is calculated from the Monthly Site Logs (e.g., Reformer Log, Compression Log, etc.) Only the items shaded in yellow require input on this table.

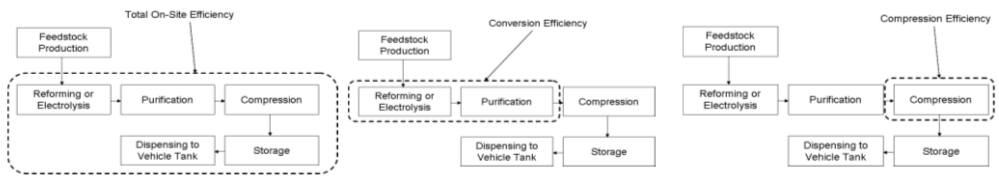
Report Date	*insert date of report*
Energy Provider	*insert name of energy provider*
Conversion Type (Reformation or Electrolysis)	*Reformation*
Unique Station Identifier	*insert identifier*

	Metric	Units	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-0
1	Primary Energy Efficiency (1)(3), Total On-Site	(%, LHV (2))	57.24%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/
2	Primary Energy Efficiency (1), Conversion	(%, LHV (2))	68.56%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/
3	Primary Energy Efficiency (1), Compression	(%, LHV (2))	83.79%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/
4	Primary Energy Efficiency (1), Dispensing and Storage	(%, LHV (2))	99.64%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/
5	Comments	N/A												

not real data

Footnotes:

(1) Primary Energy Efficiency is defined as Hydrogen Output (LHV) / Energy Input (LHV) of the process step. For each efficiency calculation, include all energy associated with the processes illustrated in the figure below.



H2 Production Cost Log / Maintenance Log / Safety Log / H2 Purity Log / Refueling Rate Log / On-Site Efficiency Log / Reformer Log / Electrolyzer Log / Compression Log /

Tabs cover multiple data sets

Performance Summary / Fleet Summary / Stack Durability Summary /
Maintenance Summary / Safety Summary / On-Road Fuel Economy /

Accomplishments: Developed and Obtained Agreement on 25 Sample Composite Data Products

A. 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. H2 Production Cost, Actuals/Projections vs. DOE Targets

B. 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
11. Mass of Hydrogen per Liter
12. Vehicle Hydrogen Tank Cycle Life

Hydrogen Infrastructure

13. H2 Production Efficiency vs. Process
14. Combined Heat and Power (CHP) Efficiencies
15. H2 Production Cost vs. Process
16. H2 Purity vs. Production Process
17. Hydrogen Impurities - Range for Production Process A
18. Histogram: Refueling Rate
19. Average Maintenance Hours - Scheduled and Unscheduled

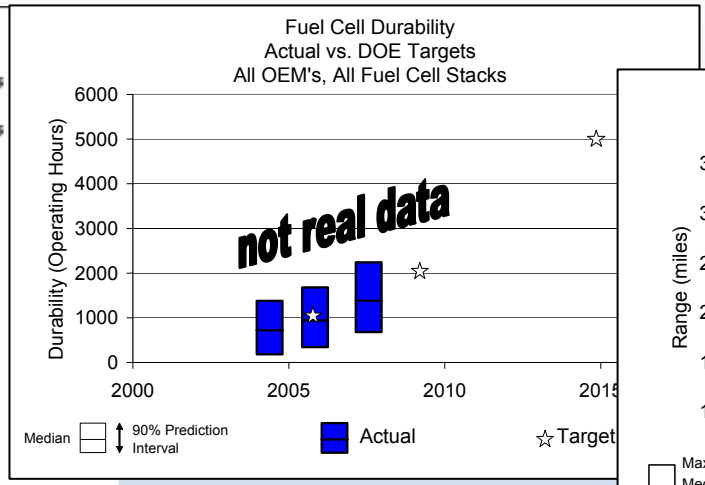
C. High Level Program Progress:

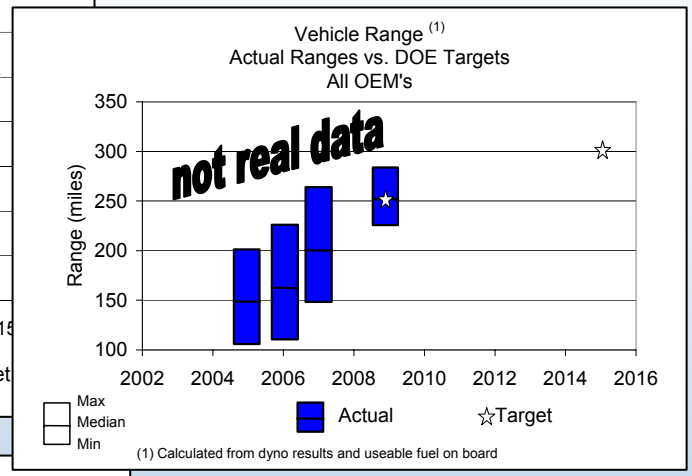
Vehicles

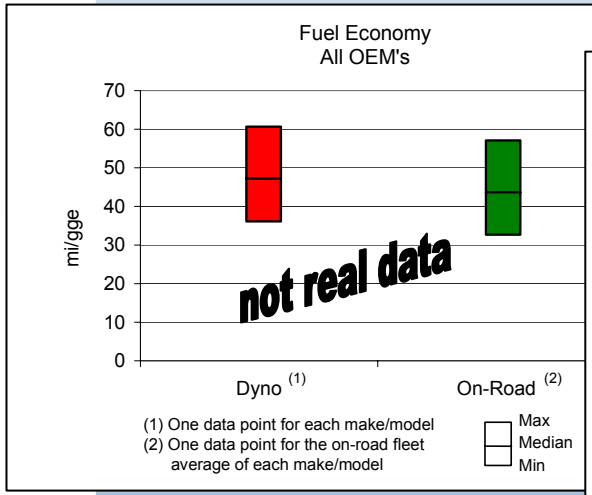
20. Range of Actual Ambient Temperatures During Vehicle Operation – All Vehicle Teams
21. Histogram: # Vehicles vs. Operating Hours to Date
22. Histogram: # Vehicles vs. Miles Traveled to Date
23. Cumulative Vehicle Miles Traveled - All Teams
24. Progression of Low to High Pressure On-board H2 Storage

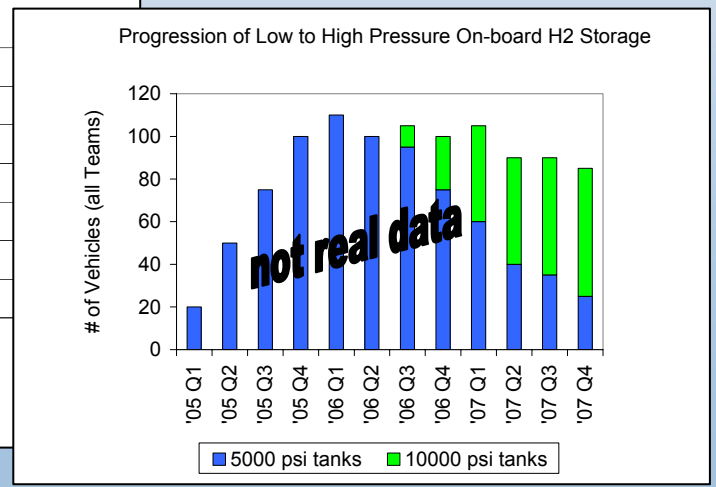
Hydrogen Infrastructure

25. Cumulative Hydrogen Production – All Teams







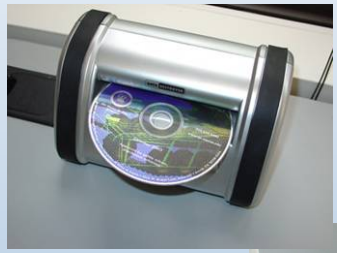


Accomplishments: Established Hydrogen Secure Data Center at NREL

- Protects all raw data and our analysis results
- Only things that leave room:
  - composite data results
  - trend feedback into R&D
  - Analysis back to originating company

Server, workstation, tape backup and UPS

Two computer workstations



CD/DVD shredder

Motion sensors

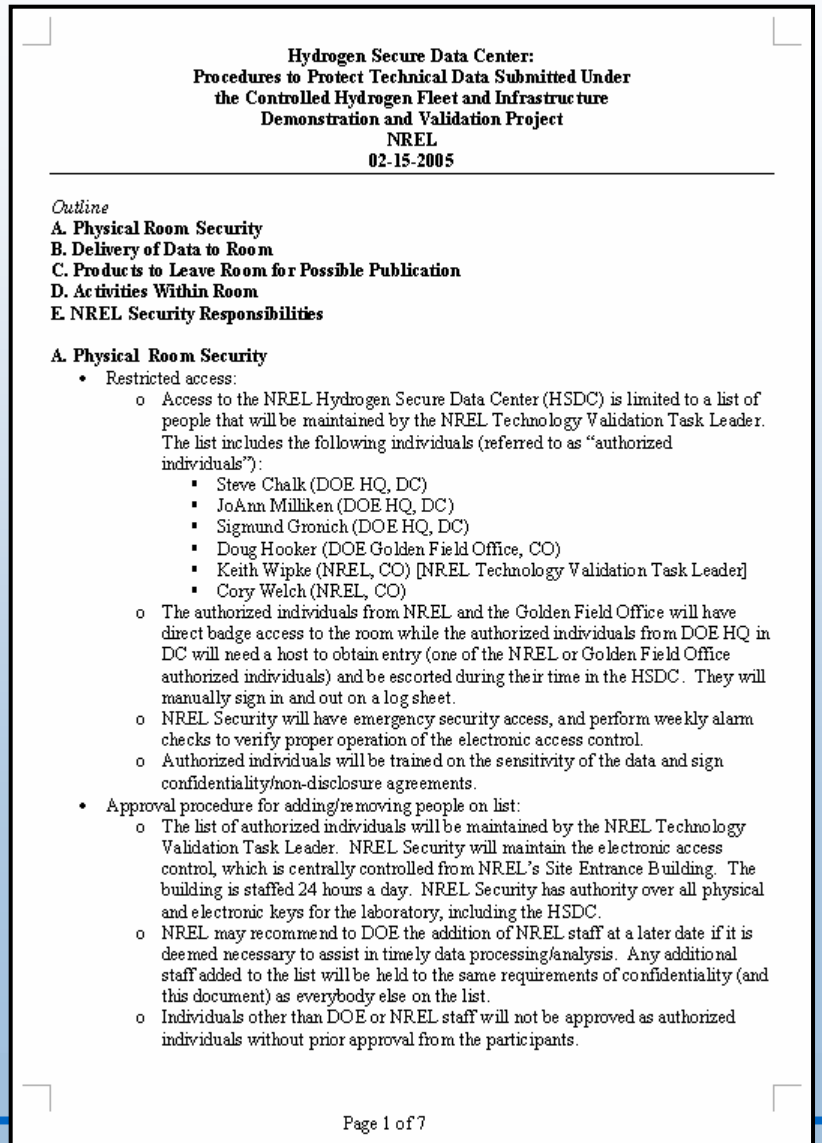
Audible alarm

PIN reader badge scanner

1350 lb. safe for backups

paper shredder

Accomplishments: Obtained Agreement with Industry Partners on Data Handling and Security



Hydrogen Secure Data Center:
Procedures to Protect Technical Data Submitted Under the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project
NREL
02-15-2005

Outline

A. Physical Room Security
B. Delivery of Data to Room
C. Products to Leave Room for Possible Publication
D. Activities Within Room
E. NREL Security Responsibilities

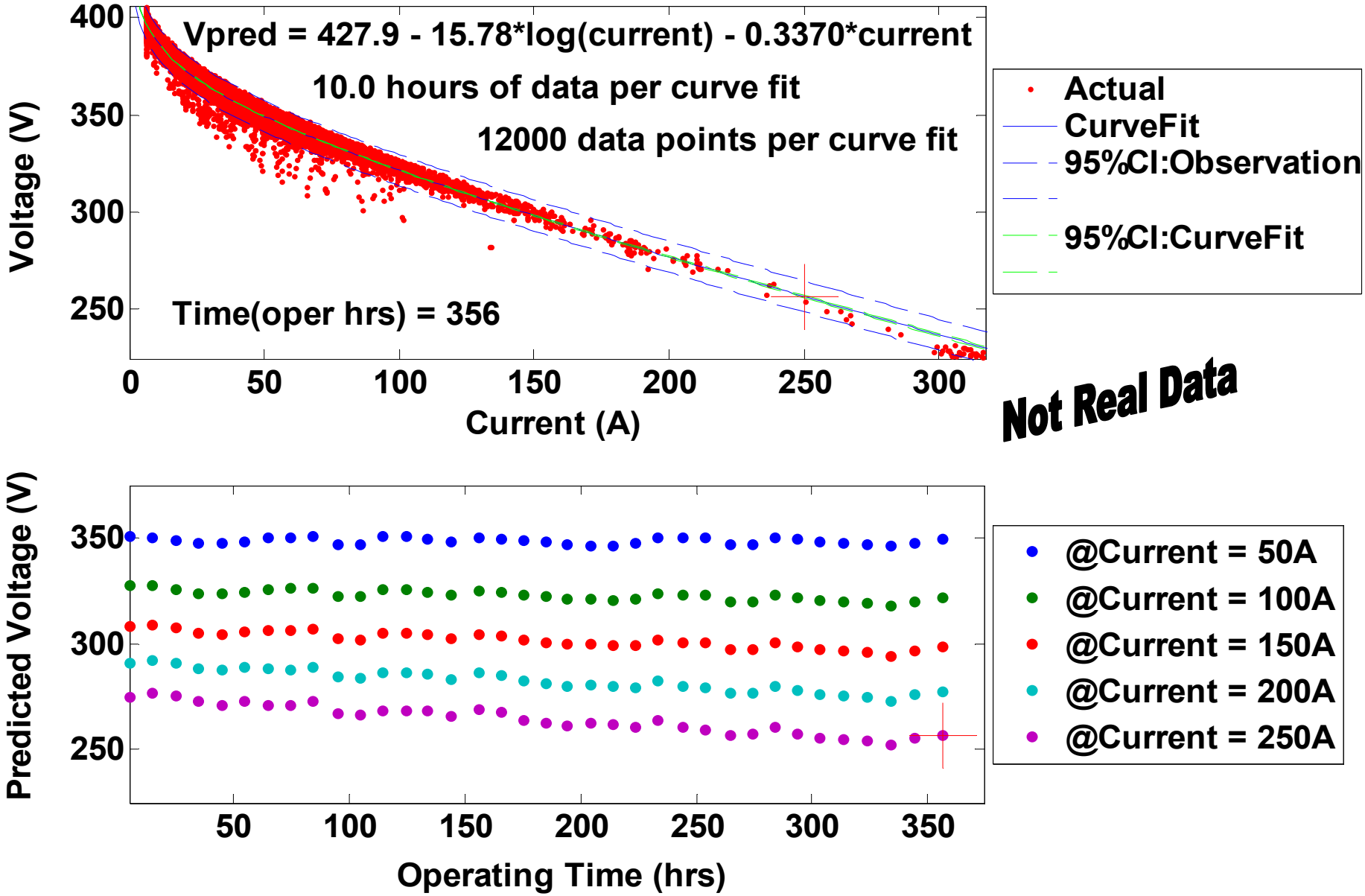
A. Physical Room Security

- Restricted access:
  - Access to the NREL Hydrogen Secure Data Center (HSDC) is limited to a list of people that will be maintained by the NREL Technology Validation Task Leader. The list includes the following individuals (referred to as "authorized individuals"):
    - Steve Chalk (DOE HQ, DC)
    - JoAnn Milliken (DOE HQ, DC)
    - Sigmund Gronich (DOE HQ, DC)
    - Doug Hooker (DOE Golden Field Office, CO)
    - Keith Wipke (NREL, CO) [NREL Technology Validation Task Leader]
    - Cory Welch (NREL, CO)
  - The authorized individuals from NREL and the Golden Field Office will have direct badge access to the room while the authorized individuals from DOE HQ in DC will need a host to obtain entry (one of the NREL or Golden Field Office authorized individuals) and be escorted during their time in the HSDC. They will manually sign in and out on a log sheet.
  - NREL Security will have emergency security access, and perform weekly alarm checks to verify proper operation of the electronic access control.
  - Authorized individuals will be trained on the sensitivity of the data and sign confidentiality/non-disclosure agreements.
- Approval procedure for adding/removing people on list:
  - The list of authorized individuals will be maintained by the NREL Technology Validation Task Leader. NREL Security will maintain the electronic access control, which is centrally controlled from NREL's Site Entrance Building. The building is staffed 24 hours a day. NREL Security has authority over all physical and electronic keys for the laboratory, including the HSDC.
  - NREL may recommend to DOE the addition of NREL staff at a later date if it is deemed necessary to assist in timely data processing/analysis. Any additional staff added to the list will be held to the same requirements of confidentiality (and this document) as everybody else on the list.
  - Individuals other than DOE or NREL staff will not be approved as authorized individuals without prior approval from the participants.

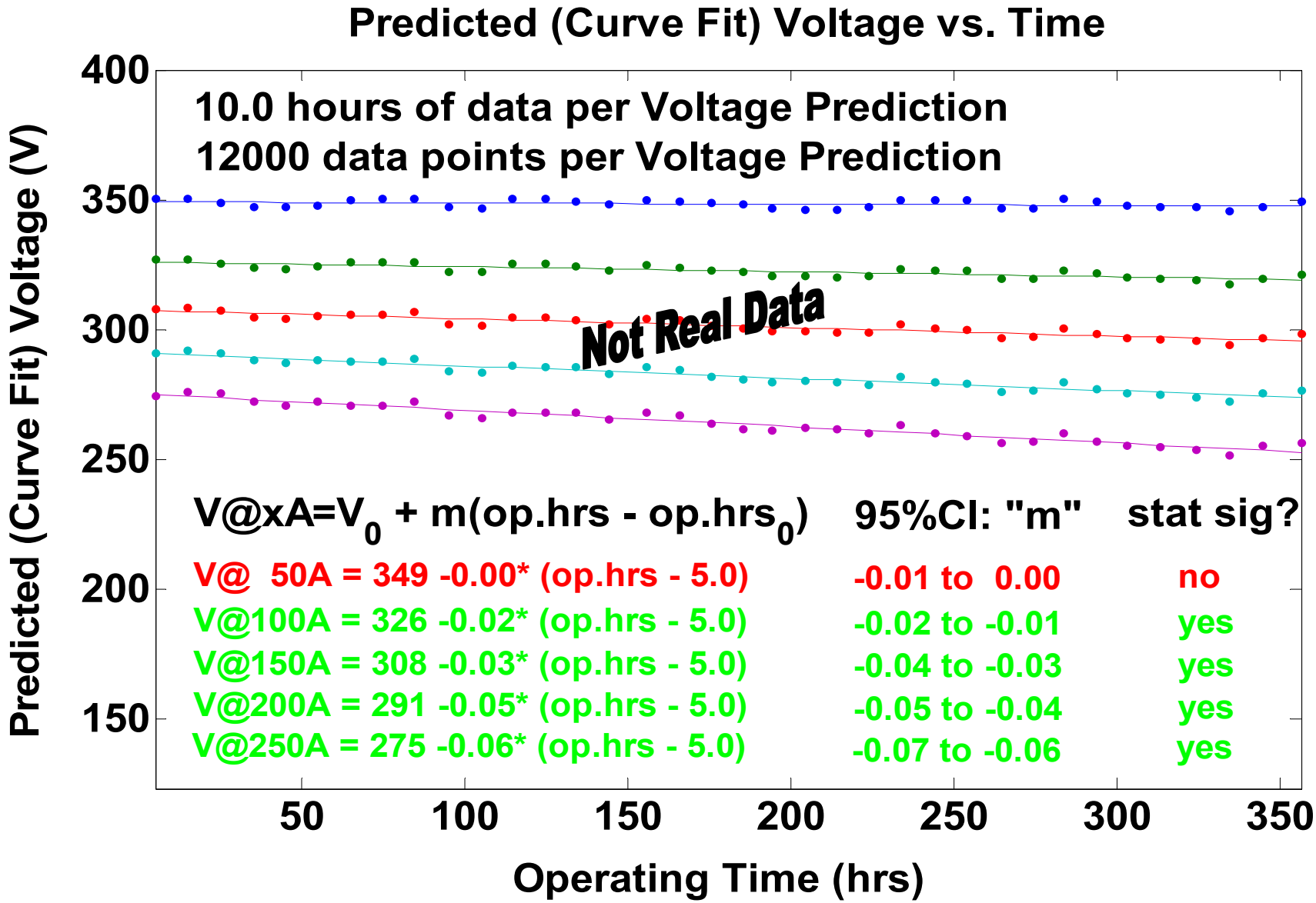
Page 1 of 7

- NREL Created 7-Page Security Document
- Major Section Headings:
  - A. Physical Room Security
  - B. Delivery of Data to Room
  - C. Products to Leave Room for Possible Publication
  - D. Activities Within Room
  - E. NREL Security Responsibilities

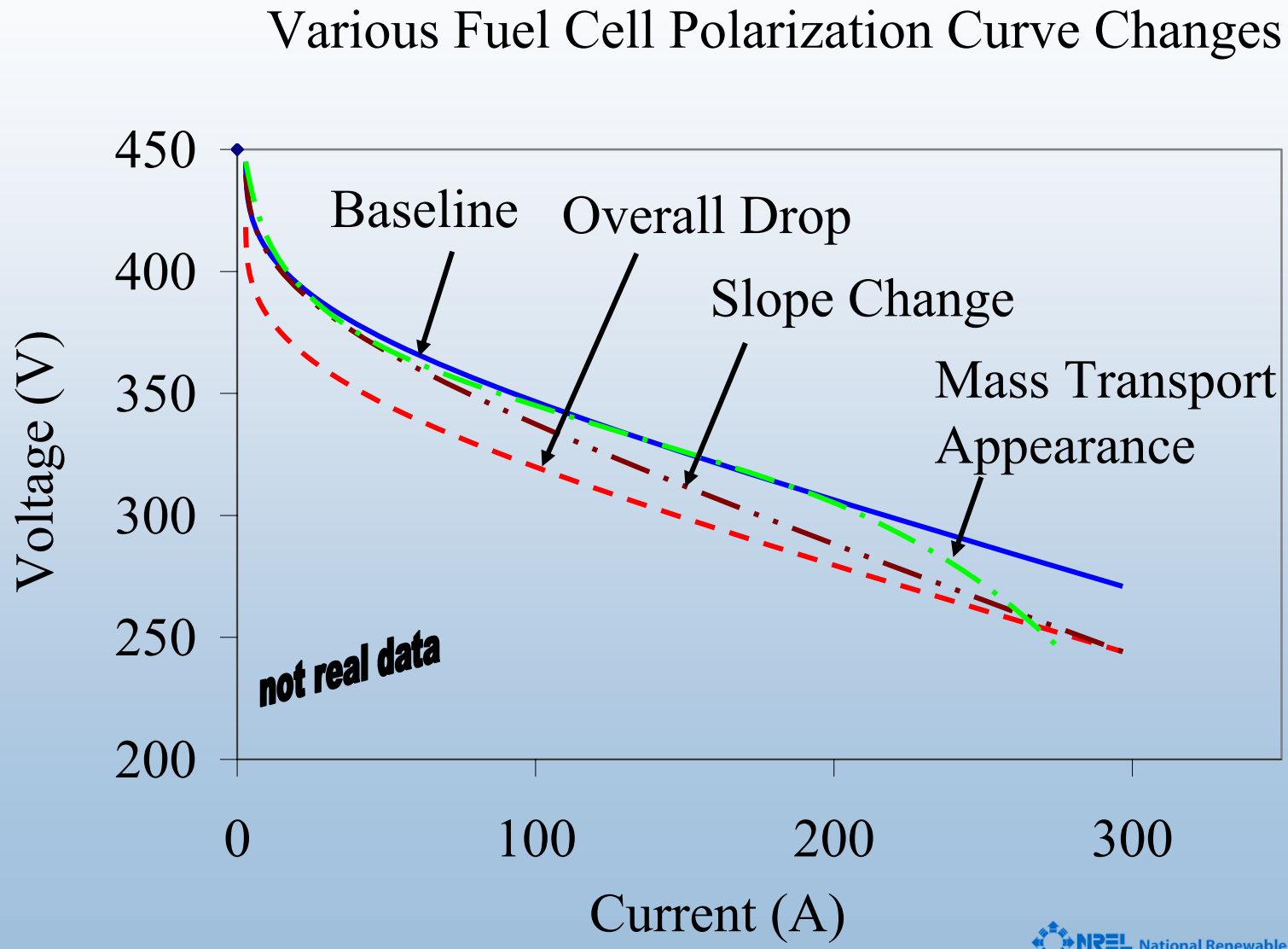
Accomplishments: Automated Analysis Created for Analyzing Stack Current/Voltage Degradation



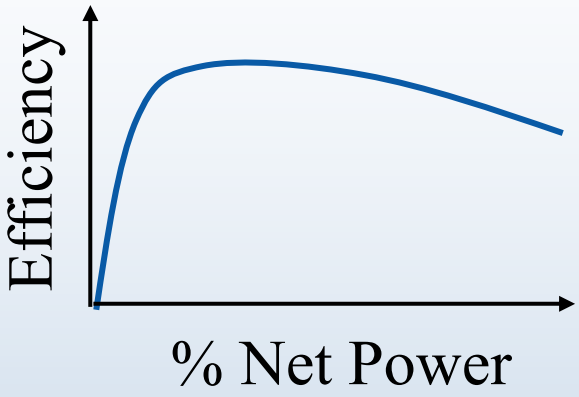
Accomplishments: Automated Analysis Created for Analyzing Stack Current/Voltage Degradation (cont.)

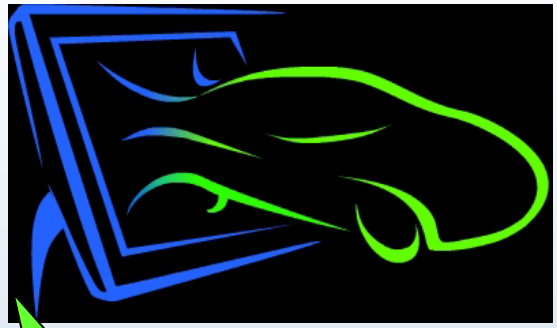


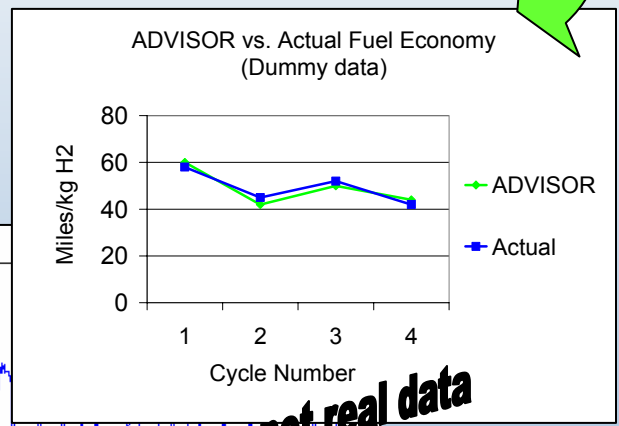
Analyzing Shape of Polarization Curve Changes May Lead to Understanding of Modes of FC Degradation

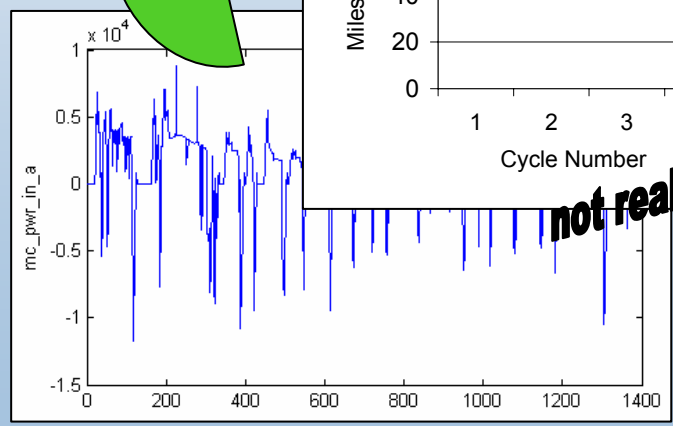


Accomplishments: Initial Data Used to Begin Validation of HSDC ADVISOR in Data Room





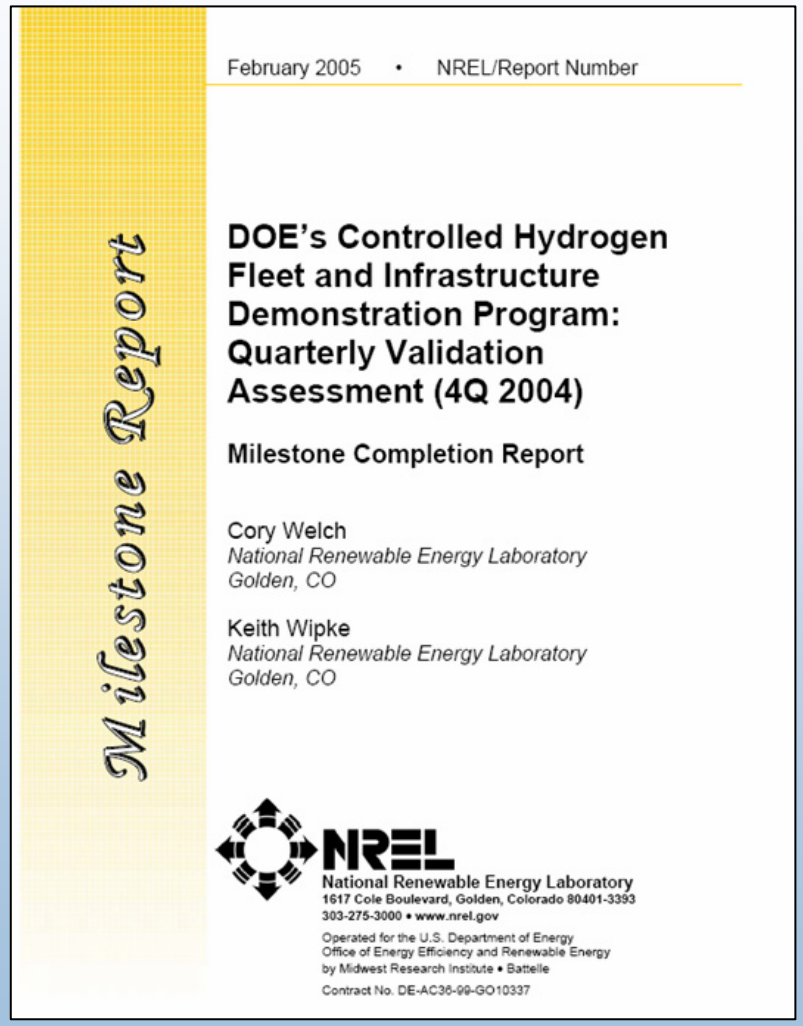




not real data

Vehicle, Power Plant Parameter Summary *Include parameters for each vehicle and power plant*	
Report Date	*insert report date*
Automaker	*insert automaker*
Parameter	**Units**
veh_CD (1)	dimensionless
veh_FA (1)	m2
Vehicle Mass (1)	kg
veh_front_wt_frac (1)	dimensionless
veh_cg_height (1)	m
veh_wheelbase (1)	m
Fuel Cell System	
c. Power Rating (net)	kW
Propulsion Battery or Capacitor	
c. Maximum Rated Ampere-Hour Capacity	Ampere*hrs
Electric Propulsion Motor	
b. Peak Power Rating	kW

Accomplishments: Completion of 1st Quarterly Technology Validation Assessment Report



Milestone Report

February 2005 • NREL/Report Number

DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration Program: Quarterly Validation Assessment (4Q 2004)

Milestone Completion Report

Cory Welch
National Renewable Energy Laboratory
Golden, CO

Keith Wipke
National Renewable Energy Laboratory
Golden, CO

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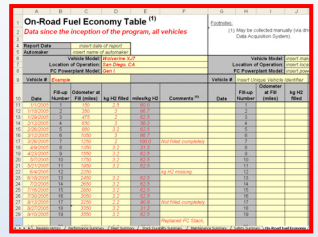
Contract No. DE-AC36-99-GO10337

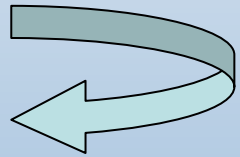
Table of Contents

- Proprietary version of Quarterly Reports may not be removed from the room
- Non-proprietary (composite data) versions may also be created

Interactions and Collaborations

- Participated in project kick-off meetings with all 4 industry teams
- Participated in detailed discussions with industry to reach agreement on data reporting templates and data handling
- Performed industry site visits to review vehicle dynamometer test facilities and test procedures
- Analyzed data from one team and provided analysis results back to originating OEM
- Interacted with relevant codes and standards teams
- Participated in CA H2 infrastructure planning teams


On-Road Fuel Economy Table (1)
Data since the inception of the program, all vehicles



Responses to Previous Year Reviewers' Comments

- Q: "Is GIS assessment critical at this time given funding constraints?"
  - The GIS work has been completed and transitioned to cross-cut analysis activity (see poster TVP14 for details)

- Q: "Editorial and interpretive techniques used behind firewalls unclear and seemingly subjective." and "Tech transfer process is well thought out but more detail on how data is handled would be interesting."
  - Hydrogen Secure Data Center (HSDC) opened and 6-page data handling/security procedures document finalized
  - Presented 2 papers at NHA and EVS-21 to discuss examples of specific analytical techniques that will be employed
  - Developed clear composite data products examples (25) to articulate public outputs from project

- Q: "Will reporting of composite data only dilute value to rest of community of the largest of all the H2/FC projects?"
  - After considering all options, we found this was the best solution to:
    - Protect industry partners' intellectual property (IP)
    - Allow NREL to perform valuable analysis on raw data for DOE
    - Provide a public outlet for progress of the project

Future Work

- Remainder of FY05
  - Complete auto OEM site visits and reviews 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 and validate models
  - Compare results to DOE targets
  - Prepare composite data products and write quarterly Validation Assessment Reports
- FY06 and beyond:
  - Annually compare technical progress to program objectives
  - Actively feed findings from project back into HFCIT program R&D activities (ensure it is a “learning demonstration”)
  - Provide public outputs to report on technology and project progress

Project Safety

- Safety an important part of Controlled Fleet & Infrastructure project Cooperative Agreements.
  - NREL's role in this project is analytical, so typical office environment safety measures are being followed.
  - Industry partners have responsibility for ensuring the safety of their hydrogen vehicles and refueling infrastructure.
- Industry is including the following aspects in each of their projects:
  - Failure Modes and Effects Analysis (FMEA) on the project
  - Safety assessment
  - Risk Mitigation Plan
  - Measuring and monitoring safety performance
  - Communication Plan, including reportable accidents, management response, and independent reviews
- All projects are using "Guidance for Safety Aspects of Hydrogen Projects" for reference

Publications and Presentations

- 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)
- Welch, C., "Composite Data Products for the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," November 2004. (NREL document)
- Welch, C., Wipke, K., "DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project: Quarterly Validation Assessment (4Q 2004), February 2005. (publication only)
- Wipke, K., "Hydrogen Secure Data Center: Procedures to Protect Technical Data Submitted Under the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," February 2005. (NREL document)
- 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)
- 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)
- Welch, C., "Data Templates for Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" April 2005. (6 NREL Excel spreadsheets)