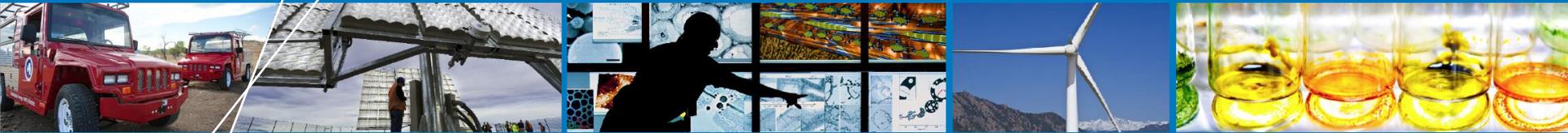


# CSD Safety & Reliability Data



**Forecourt CSD Workshop**  
**Argonne National Laboratory**

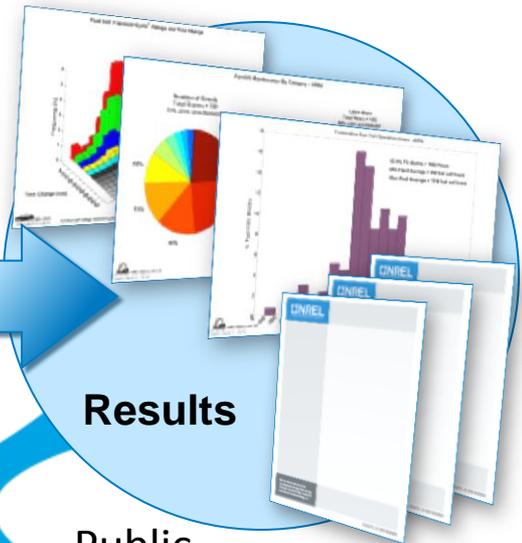
**Kevin Harrison**

**20-Mar-2013**

# Approach – Composite Data Products

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly



DDPs

Confidential

Results

Public

CDPs

## Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months<sup>1</sup>

## Composite Data Products (CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months<sup>2</sup>

1) Data exchange may happen more frequently based on data, analysis, and collaboration  
2) Results published via NREL Tech Val website, conferences, and reports

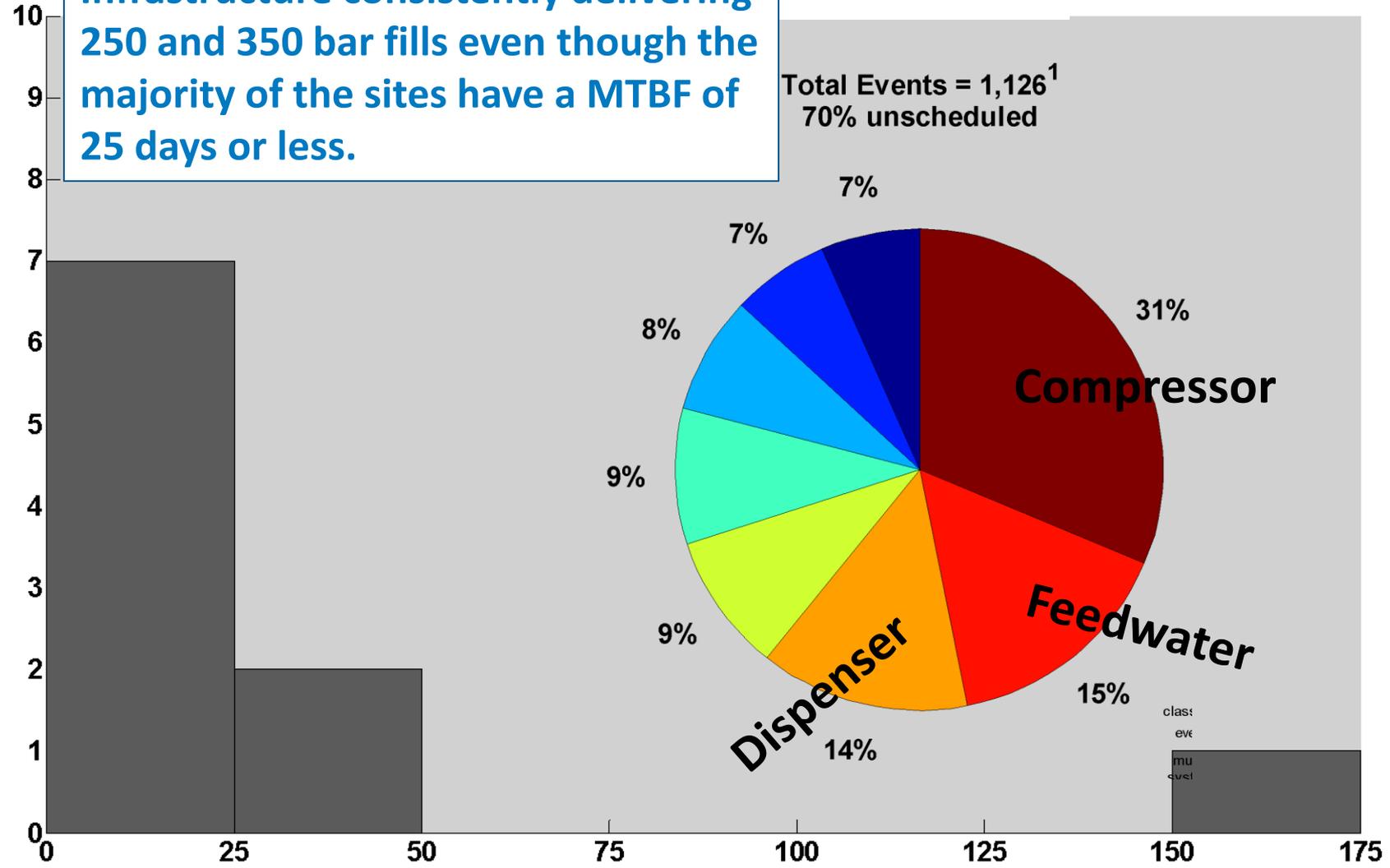
# SITE MTBF (Calendars Days) - Infrastructure



Infrastructure consistently delivering 250 and 350 bar fills even though the majority of the sites have a MTBF of 25 days or less.

Total Events = 1,126<sup>1</sup>  
70% unscheduled

Number of Sites

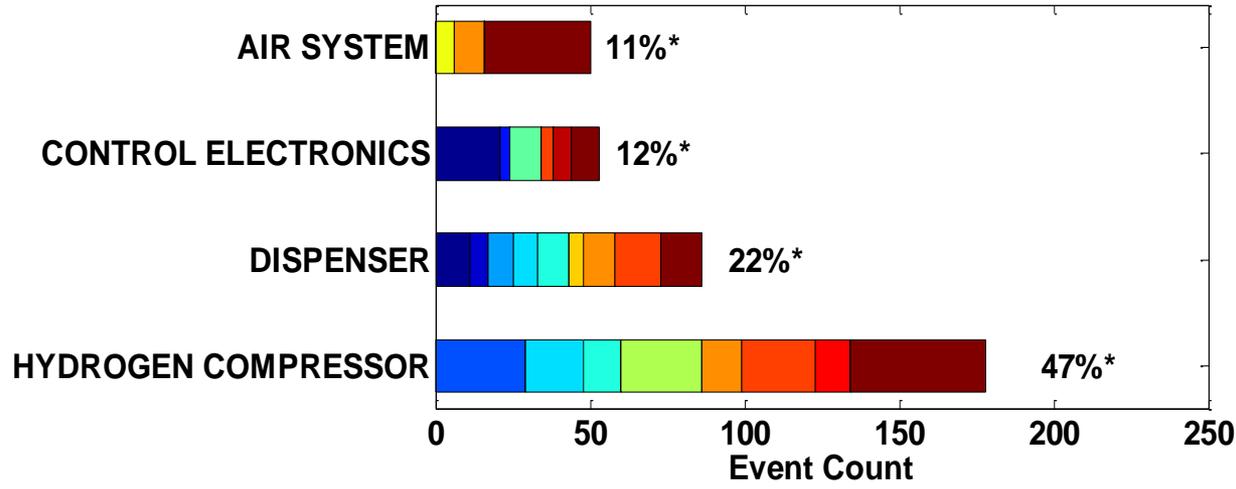


Site Cumulative MTBF (Days)

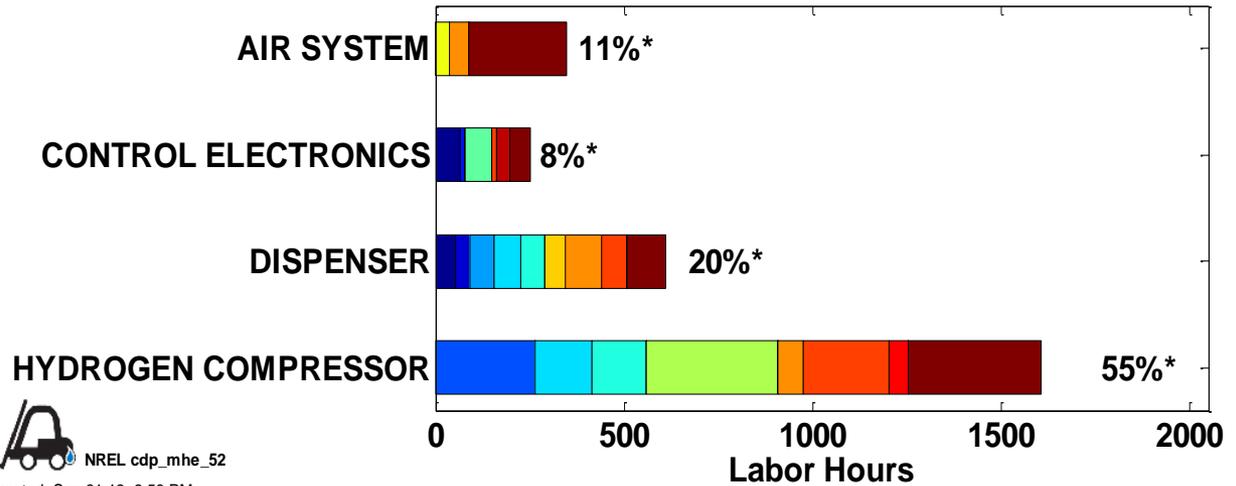
# Infrastructure - Failures for Top 4



## Failure Modes for Top Four Infrastructure Equipment Categories



- DATA ERROR
- DRIVE OFF
- ELECTRICAL SHORT
- EXCESSIVE NOISE
- FAILED CLOSED
- HYDROGEN LEAK
- INSPECT TROUBLE ALARM OR REPORT
- LIGHTNING STRIKE
- METAL FATIGUE
- MOISTURE INFILTRATION
- OPERATOR PROTOCOL
- PRESSURE LOW
- REPLACE FAILED PARTS
- TEMPERATURE HIGH
- UNSPECIFIED ELECTRONICS FAILURE
- MISC



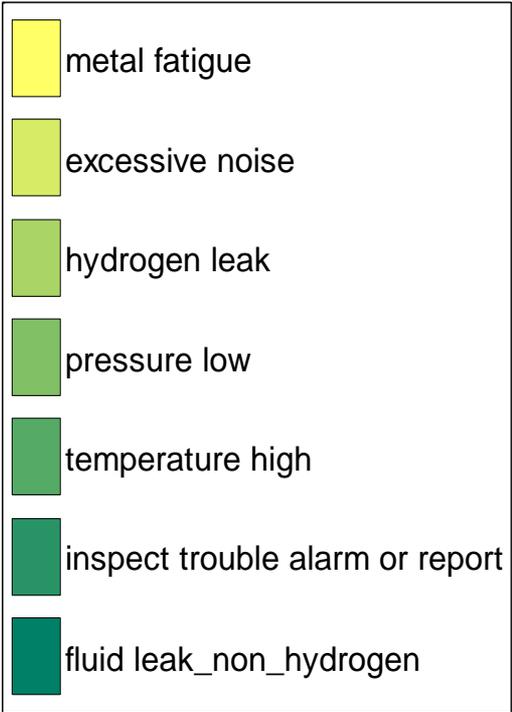
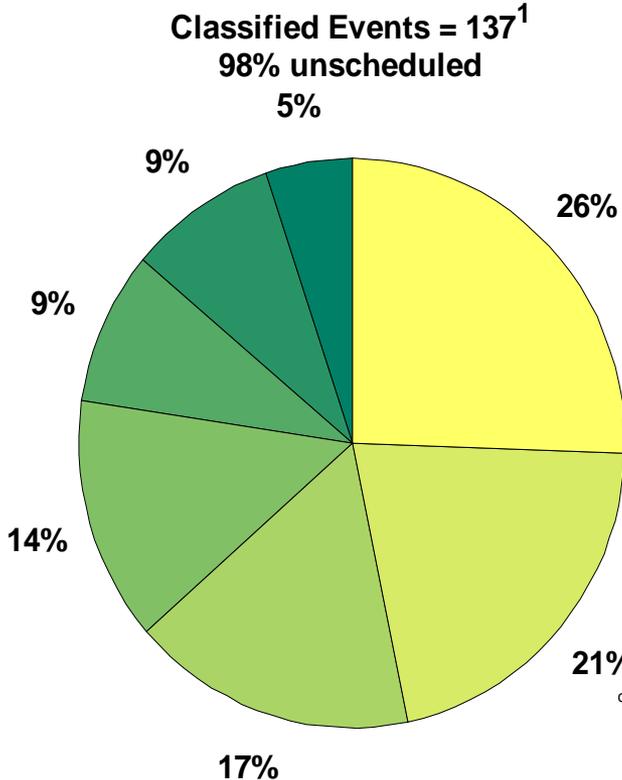
MISC includes the following failure modes: ambient temperature too low, broken wire, cavitation, debris infiltration, failed closed, flow high, flow low, fluid leak\_non\_hydrogen, inspect trouble alarm or report, maintenance error, manufacturing defect, metal fatigue, moisture infiltration, network malfunction, operator protocol, other, pressure high, software bug, vandalism, voltage low, other

\* Percentage of total events or hours, reference CDP 66.

# Hydrogen Compressors - Detailed



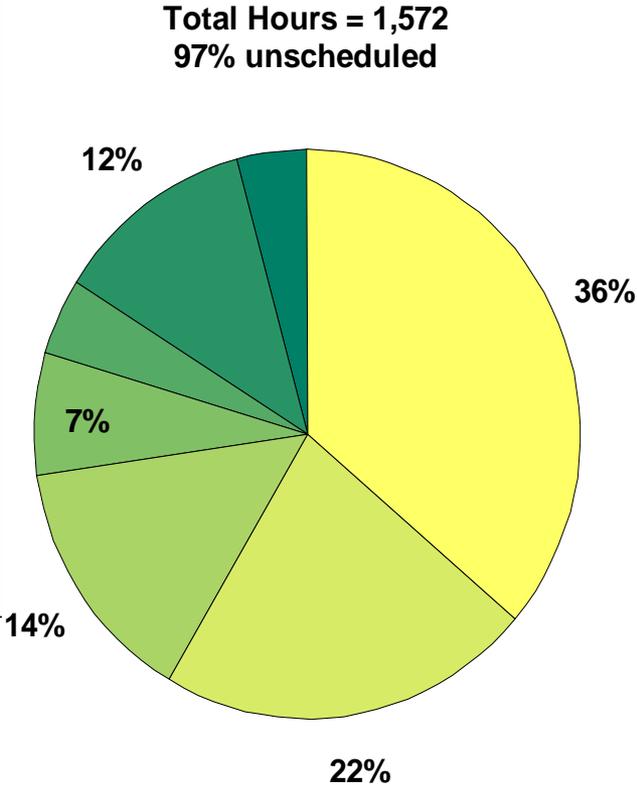
## Hydrogen Compressor Failures By Mode



classified<sup>1</sup> events 137

misc 45

Event Count

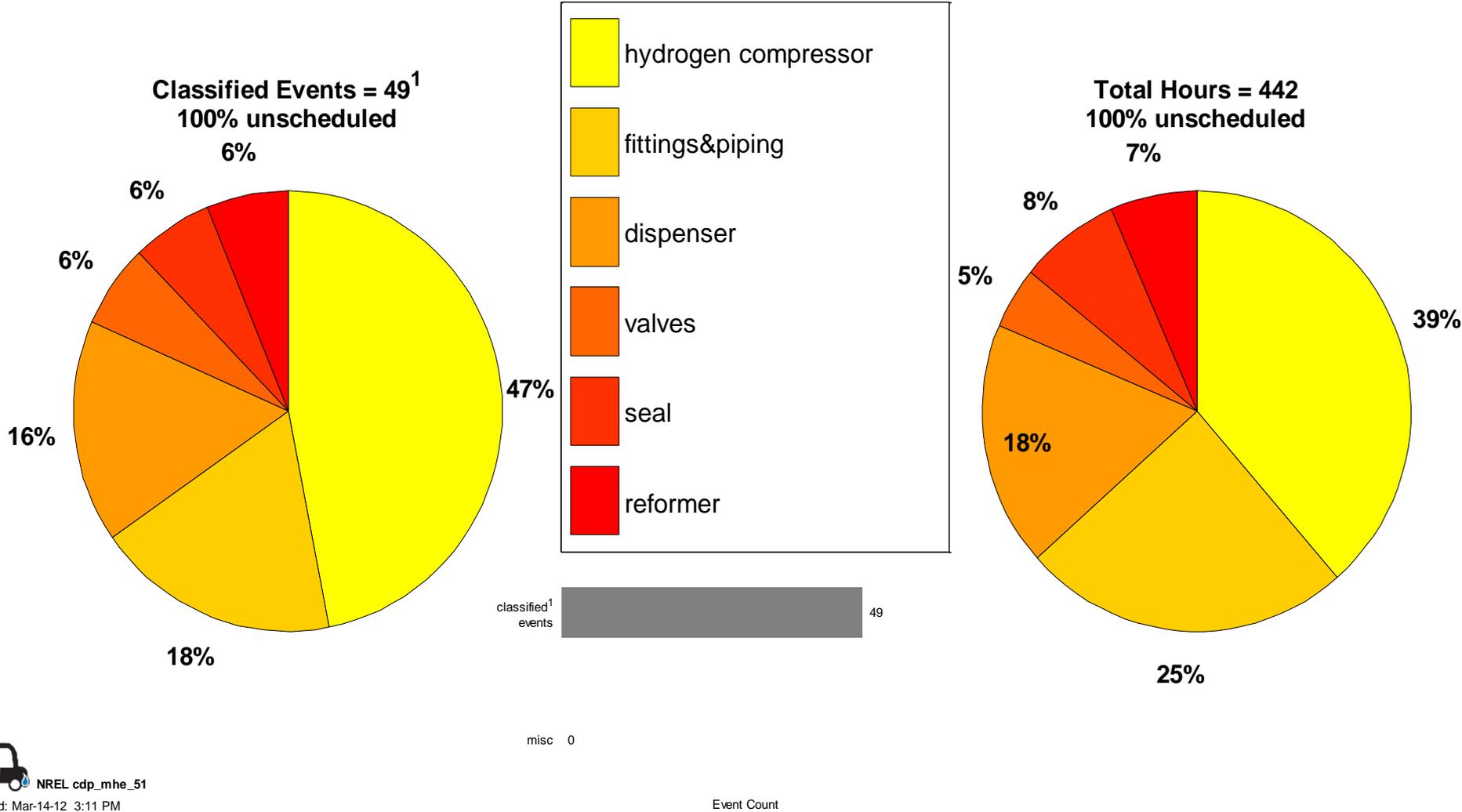


MISC includes the following failure modes: cavitation, debris infiltration, failed closed, flow high, manufacturing defect, moisture infiltration, operator protocol, preventative maintenance, maintenance error, upgrade, replace failed parts, other

# Hydrogen Leaks - Detailed



Hydrogen Leaks By Equipment Category: Infrastructure



# Approach – Process Hazard Analysis

- A PHA was conducted for the installation of 2<sup>nd</sup> H<sub>2</sub> fueling station at NREL (Internally funded)
- Hazards were identified by NODE and analyzed for SEVERITY, LIKELIHOOD to obtain the overall RISK (H, M, L, R)

		LIKELIHOOD						
		A	B	C	D	E	F	
SEVERITY	Category	Descriptive Word	Frequent	Reasonably Probable	Occasional	Remote	Extremely Remote	Impossible
	I	Catastrophic						
	II	Critical						
	III	Marginal						
	IV	Negligible						

# PHA Weighted Results

- Each node was analyzed for process upset conditions (pressure high, flow low, etc...)
- In the context of safeguards, the consequences were ranked by SEVERITY and LIKELIHOOD to arrive at a RISK level
- High risks were weighted by 4, Medium by 3, and so on

Node Description	RISK				Node Total Risk
	High	Medium	Low	Routine	
Compressor	0	0	7	9	23
Hose	0	2	3	0	12
Nozzle	0	0	5	1	11
Cascade Tanks	0	0	2	5	9
Control Electronics	0	0	2	4	8
Air System	0	0	0	5	5
Cryo Storage	0	0	0	1	1

# RD&D Challenges

---

## **Compressor reliability (Cost)**

- Lifetime of diaphragms, CV and seals

## **Hose reliability (Safety, Cost)**

- Improve lifetime to avoid frequent hose replacement

## **Nozzle (Cost)**

- Lifetime of diaphragms, CV and seals

# More information available

- [www.nrel.gov/hydrogen/proj\\_tech\\_validation.html](http://www.nrel.gov/hydrogen/proj_tech_validation.html)
- or search for “NREL CDP”

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

## National Fuel Cell Electric Vehicle Learning Demonstration Final Report

K. Wipke, S. Sprik, J. Kurtz, T. Ramsden, C. Ainscough, G. Saur

*EVS26  
Los Angeles, California, May 6-9*

### Final Results from U.S. FCEV Learning Demonstration

Keith Wipke<sup>1</sup>, Sam Sprik<sup>2</sup>, Jennife Kurtz<sup>3</sup>, Todd Ramsden<sup>4</sup>, Greivevive Saur<sup>5</sup>  
<sup>1</sup>National Renewable Energy Laboratory, 1417 Cole Blvd., Golden, CO 80401

**Abstract**  
The Controlled Hydrogen Fleet and Infrastructure Demonstration and the National Fuel Cell Electric Vehicle Learning Demonstration, is a 7.5 year project started in 2004 and concluded in late 2011. The purpose of this project was to validate the performance of fuel cell electric vehicles (FCEVs) and hydrogen refueling infrastructure. The DOE's National Renewable Energy Laboratory (NREL) analyzed all of the raw technical data collected by the industry partners over its seven-year duration. This paper reviews highlights from the project and draws conclusions about the demonstrated status of the fuel cell vehicle and hydrogen refueling infrastructure technology. Through September 2011, 183 fuel cell electric vehicles were deployed, 25 project refueling stations were placed in use, and no fundamental safety issues were identified. We have analyzed data from more than 500,000 individual vehicle trips covering 3.5 million miles traveled and more than 150,000 kg of hydrogen produced or dispensed. Public analytical results from this project are in the form of composite data products (CDPs), which aggregate individual performance to protect the intellectual property and the identity of each company while still publishing overall status and progress. Ninety-nine of these CDPs have been generated for public use and posted on NREL's technology validation website. The results indicate that fuel cell vehicle technology continues to make rapid progress toward commercial readiness and that the refueling infrastructure technology is ready to provide a convenient, timely fuel fill and long range experience consistent with expectations of gasoline vehicle customers.

**Keywords:** hydrogen, fuel cell, demonstration, ZEP, core mission vehicle

**1 Introduction**  
This paper discusses key analysis results based on data from early 2007 through September 2011 from the U.S. Department of Energy's (DOE's) Controlled Hydrogen Fleet and Infrastructure Validation and Demonstration Project, also referred to as the National Fuel Cell Electric Vehicle Learning Demonstration. The industry partners provided their final project data to NREL in October 2011 and we have now performed analysis across the entire seven-year period. During this time, 183 fuel cell electric vehicles were deployed, 25 project refueling stations were placed in use, and no fundamental safety issues were identified. We have analyzed data from more than 500,000 individual vehicle trips

**DOE Webinar February 6: National Hydrogen Learning Demonstration Status**  
February 01, 2012  
The U.S. Department of Energy (DOE) and its National Renewable Energy Laboratory (NREL) will be hosting a webinar titled "National Hydrogen Learning Demonstration Status" on Monday, February 6 from 12:00 to 1:15 p.m. Eastern Standard Time. During the webinar, NREL researchers will report on progress the lab has made in analyzing fuel cell electric vehicles and hydrogen refueling stations through DOE's National Hydrogen Learning Demonstration. This webinar will also update participants on the metrics used by DOE and industry to evaluate the performance of fuel cell electric vehicles and refueling infrastructure in terms of fuel economy, fuel cell duration, refueling time, and fueling station use.

Beginning in April 2004, the Learning Demonstration tested, demonstrated, and validated fuel cell electric vehicles and hydrogen infrastructure, and evaluated the interaction between the vehicles and infrastructure to optimize complete-system solutions. Four teams took part in the Learning Demonstration, led by auto manufacturers Chevrolet, Daimler, Ford Motor Company, and General Motors Corp. Additionally, Air Products and Chemical, Inc. provided station data through its DOE-funded California Hydrogen Infrastructure Project (CHIP).

The vehicle data was collected from 183 fuel cell electric vehicles spanning 154,000 hours of operation, 3.5 million miles, and more than 500,000 trips. Station data was collected from 25 stations, which produced or dispensed 152,000 kg of hydrogen, fueling the vehicles approximately 33,000 times, in all. The project was funded through DOE awards totaling \$145 million, with an additional \$188 million in co-funding provided by industry partners.

**For More Information and to Register**  
This series of webinars is designed to increase knowledge of fuel cell technologies, applications, identify best practice, state-of-the-art and fuel cell economics and vehicle performance.

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

## National Hydrogen Learning Demonstration Status

Keit  
Jani  
Raim  
Ains  
Saur  
Feb  
DOE  
Web

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC.

**NREL**  
Hydrogen & Fuel Cells Research

Hydrogen & Fuel Cells Research Home

Capabilities  
Projects  
Hydrogen Production & Delivery  
Hydrogen Storage  
Fuel Cells  
Technology Validation  
Fuel Cell Vehicle Learning Demonstration  
Fuel Cell Bus Evaluations  
Fuel Cell Heavy Commercial  
Safety, Codes & Standards  
Analysis  
Education  
Manufacturing  
Research Staff  
Facilities  
Working with us  
Energy Analysis & Tools  
Publications  
Awards & Honors  
News

**Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration**  
The project identifies and tracks the status of technologies as they evolve, assesses the progress of technology readiness, and provides feedback for hydrogen research and development activities. This six-year project through 2010 uses multiple geographic locations and climates with a variety of hydrogen sources, including renewables.

NREL's role is to receive and analyze the technical data from the fuel cell vehicles and the hydrogen refueling infrastructure. Learn more about NREL's role in validation of hydrogen fuel cell vehicles and infrastructure technology. As nations around the world pursue a variety of sustainable transportation solutions, hydrogen fuel cell electric vehicles (FCEVs) present a promising opportunity for American consumers and businesses. FCEVs offer a sustainable transportation option, provide a cost-competitive alternative for dependence on imported oil, and enable global economic leadership and job growth.

**Composite Data Products**  
The raw data for this project is protected in NREL's Hydrogen Secure Data Center. All of the public access results through composite data products (CDPs). The results are presented in the following ways:  
• CDPs by State  
• CDPs by Date  
• CDPs by Number

This page is a repository for NREL's technical analysis results, papers, and presentations generated for this project.

2012

**Fuel Cell**

H2 Tank Level at Fueling

Link to sunburst