

# 2006 DOE Hydrogen Program Annual Merit Review

## Hydrogen Codes and Standards

Jim Ohi

National Renewable Energy Laboratory

May 19, 2006

Project ID# SA1

This presentation does not contain any proprietary or confidential information



## Disclaimer and Government License

This work has been authored by Midwest Research Institute (MRI) under Contract No. DE-AC36-99GO10337 with the U.S. Department of Energy (the “DOE”). The United States Government (the “Government”) retains and the publisher, by accepting the work for publication, acknowledges that the Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for Government purposes.

Neither MRI, the DOE, the Government, nor any other agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the Government or any agency thereof. The views and opinions of the authors and/or presenters expressed herein do not necessarily state or reflect those of MRI, the DOE, the Government, or any agency thereof.



# Overview

<b>Timeline</b>	<b>Barriers</b>
<ul style="list-style-type: none"><li>• Project start date: 10-1-05</li><li>• Project end date: 9-30-06</li><li>• Percent complete: 50</li></ul>	<ul style="list-style-type: none"><li>• Codes and Standards Barriers addressed<ul style="list-style-type: none"><li>– Consensus national agenda on codes and standards (J,A,B,D,L)</li><li>– Limited DOE role in development of ISO standards and inadequate representation by government and industry at international forums (F,G,H,I,K)</li><li>– Current large footprint requirement for hydrogen fueling stations (P,N,M)</li></ul></li></ul>
<b>Budget</b>	<b>Partners</b>
<ul style="list-style-type: none"><li>• Total project funding<ul style="list-style-type: none"><li>– DOE share: \$1.26M</li><li>– Contractor share: \$22K</li></ul></li><li>• Funding received in FY05: \$2.0M</li><li>• Funding for FY06: \$1.28M</li></ul>	<ul style="list-style-type: none"><li>• National H2/Fuel Cells Codes and Standards Coordinating Committee</li><li>• FreedomCAR-Fuel Partnership C&amp;S Technical Team</li><li>• North American H2 Fuel Quality Team</li></ul>



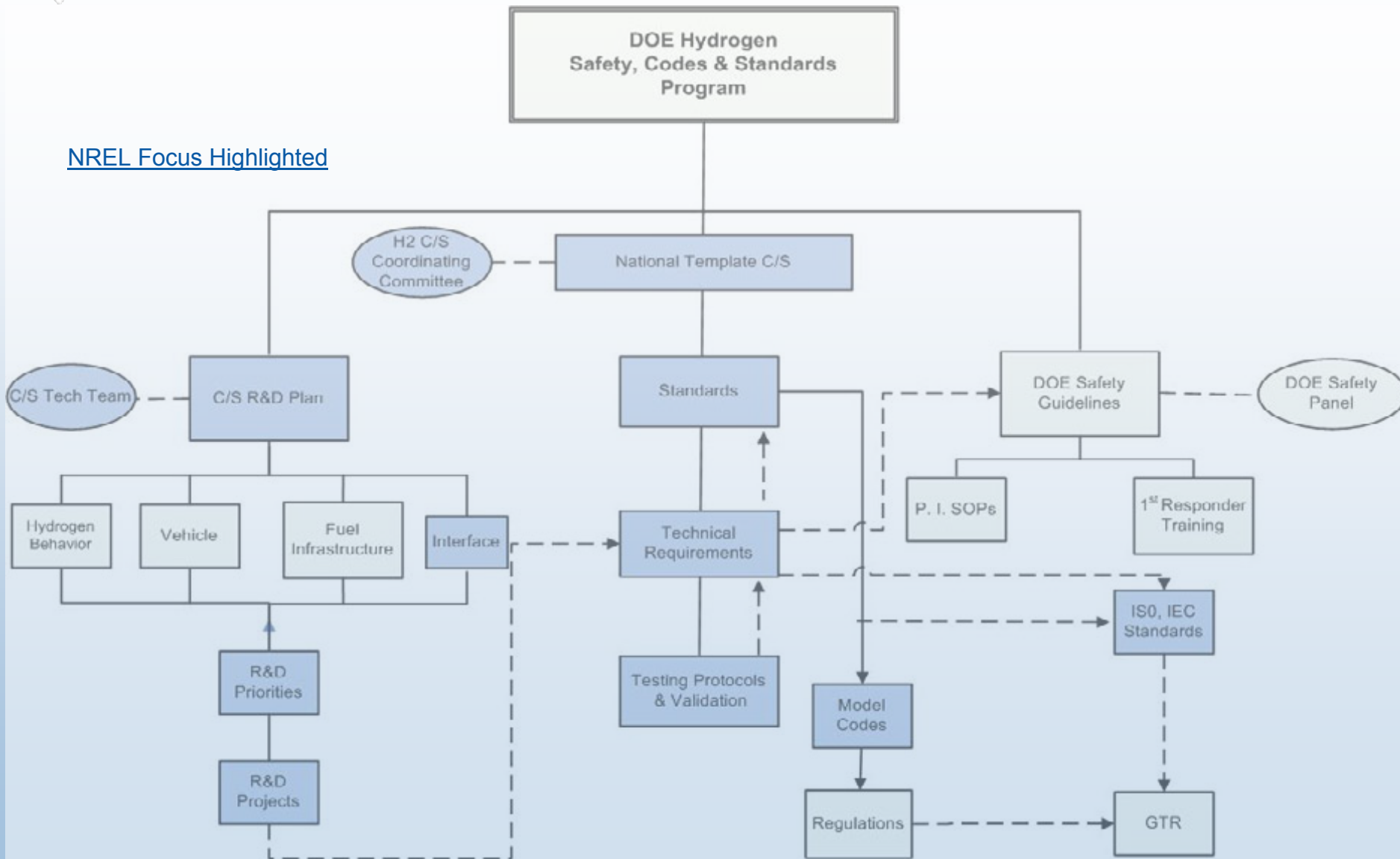
# Objectives

- Strengthen and implement consensus national agenda on domestic and international codes and standards for hydrogen systems in commercial, residential, and transportation applications
- Facilitate harmonization of requirements for hydrogen applications based on consensus R&D
- Enhance DOE's role in development of ISO and other international standards and strengthen representation by government and industry at international forums
- Integrate codes and standards activities from R&D to pre-commercialization



# Approach: Program Structure

NREL Focus Highlighted





# Approach

- Strengthen and implement unified national agenda for codes and standards
  - National templates adopted by consensus of SDO/CDOs
    - accelerate development of priority standards
    - designate and support lead SDO/CDOs
    - facilitate access to standards/model codes through ANSI website
  - Coordinate national/international codes and standards activities
    - National H<sub>2</sub>/Fuel Cells Codes and Standards Coordinating Committee
- Coordinate and conduct R&D through Codes and Standards Tech Team R&D Roadmap
  - Fuel-Vehicle Interface
    - hydrogen fuel quality specifications
    - performance-based component testing and validation
- Harmonize requirements in domestic and international standards
  - Work with and coordinate key participants, e.g., ICC-NFPA, ISO TC197-SAE, IEC TC105-CSA, CGA-CSA/US TAGs



# Technical Accomplishments/Progress

- Unified national agenda for codes and standards
  - Strengthened national consensus through National H2-FC C&S Coordinating Committee created in FY05 by DOE, NHA, USFCC that includes all key SDOs, CDOs, state/federal agencies, other stakeholders
  - Negotiated contracts with all key SDO/CDO to develop essential standards and model codes under significant budget constraints
- R&D to develop defensible standards for hydrogen systems
  - Codes and Standards Tech Team R&D Roadmap implementation
    - completed international guidelines for hydrogen fuel quality (ISO DTS14687-2)
    - prepared R&D/test plan for hydrogen fuel quality
    - facilitate development of better risk-informed codes and standards (with SNL)
- Harmonize requirements in domestic and international standards
  - member of ISO/TC197 WG 12 to prepare hydrogen fuel quality specification
  - member U.S. Technical Advisory Group, ISO/TC197, Hydrogen Technologies
  - work with CGA and CSA to coordinate ISO/TC197 and IEC/TC105
  - conduct semi-annual ISO-IEC “TAG-Team” meetings with NHA, USFCC



# Technical Accomplishments/Progress: Unified National Agenda for Codes and Standards

- Integrated ANSI Hydrogen (and Fuel Cells) Codes & Standards Portal (<http://hcsp.ansi.org>), DOE Hydrogen and Fuel Cells Codes and Standards Matrix and Database ([www.fuelcellstandards.com](http://www.fuelcellstandards.com)), and Hydrogen and Fuel Cell Safety Report ([www.hydrogensafety.info](http://www.hydrogensafety.info))
  - provides comprehensive information regarding published codes and standards documents, national and international codes and standards under development, and information for members of the NHFC4 and other stakeholders
- ASME completed *Design Margin Guidelines for High-Pressure Hydrogen Tanks* and *Properties for Composite Materials in Hydrogen Service* and will develop standards for high-pressure hydrogen tanks for stationary applications and use of non-steel metals and composite materials for high-pressure hydrogen storage tanks





# Technical Accomplishments/Progress: Unified National Agenda for Codes and Standards

- Compressed Gas Association (CGA), Administrator for U.S. Technical Advisory Group (TAG) for ISO TC197 (Hydrogen Technologies) developed website to facilitate consensus positions on proposed international standards, balloting on specific TAG issues
- CSA-America developing performance-based requirements for gaseous hydrogen dispenser systems standards in collaboration with SAE
- Industry Panel on Hydrogen Codes (HIPOC) established
  - neutral forum to develop and submit hydrogen-related code provisions to ICC and NFPA and harmonize provisions in ICC and NFPA codes and standards
- Transition SDO/CDO contracts to DOE-GO competitive solicitation



# Technical Accomplishments/Progress: Unified National Agenda for Codes and Standards

## Hydrogen and Fuel Cell Safety

US Fuel Cell Council



An Online Resource for the National Hydrogen and Fuel Cells Codes & Standards Coordinating Committee  
Produced by the National Hydrogen Association in association with the US Department of Energy and US Fuel Cell Council

- Latest Issue
- Archives
- Meetings/Events
- Next Comm. Meeting
- Issues for Review
- Documents for Review
- Committee Roster
- Members Only
- Technical Resources
- About this Site
- Contact Us

Your email

Join our Mailing List

You are here: Latest Issue

### Latest Issue: April 2006

#### National Hydrogen and Fuel Cells Codes & Standards Coordinating Committee In-Person Meeting

*March 15th, 2006, at 3:00 P.M. Pacific Standard Time in conjunction with the NHA Annual Conference in Long Beach, CA*

*Karen Hall, National Hydrogen Association*

#### MEETING MINUTES (31 March 06, with Corrections)

##### PARTICIPANTS

Coordinating Committee members who participated in the meeting are shown in [Attachment II](#). Other persons that participated are shown in [Attachment III](#).

#### 1. USFCC members were reminded to review and follow the anti-trust guidelines:

[Antitrust Guidelines \(27Kb PDF\)](#)

and

[Memo on Antitrust Guidelines \(24Kb PDF\)](#)

#### 2. Reviewed and approved the agenda.

3. Welcome/Opening Remarks were provided by Russ Hewell at NREL. Due to the later than usual time of this meeting, DOE Program manager Pat Davis was unable to participate.

#### 4. Reviewed and approved the previous minutes.

5. Karen Hall welcomed participants on behalf of the NHA. She reported the NHA's Annual Conference and Hydrogen Expo has been successful so far, full of plenaries, breakout sessions, business meetings, and networking opportunities. There were over 1100 attendees plus 400 attending public

US Fuel Cell Council  
Codes and Standards



Department of Energy  
  
Hydrogen, Fuel Cells, and Infrastructure Technologies Program

Hydrogen Codes & Standards Matrix

ANSI Hydrogen Portal Project

# Technical Accomplishments/Progress: Unified National Agenda for Codes and Standards



## HYDROGEN CODES AND STANDARDS PORTAL

[HOME](#)[SEARCH](#)[RESOURCES](#)[CONTACT](#)[HELP](#)[FEEDBACK](#)

U.S. Department of Energy  
National Renewable Energy Laboratory  
American National Standards Institute  
ANSI eStandards Store

About the Hydrogen Codes and Standards Portal

Hydrogen and Fuel Cells Permitting Guide

Browse by subject:

Vehicle Systems and Refueling Facilities

On-Site Hydrogen Generation and Fuel Cells



## Hydrogen | the standards story

The Hydrogen Codes and Standards Portal is designed to allow easy access to codes, standards and regulations relating to hydrogen used as fuel. You can browse by subject using the [Vehicle Systems and Refueling Facilities](#) or the [On-site Hydrogen Generation and Fuel Cells](#). If you are looking for a specific standard, you can use the [Search](#) page to search by document number or key word.

This site is still under development. As the site grows, other links can be added to sites that have other hydrogen information, such as research sites, education and training links, and certification programs.

### DISCLAIMER

The documents and information provided on this Hydrogen Fuel Cell Portal are provided "AS IS" and "AS AVAILABLE". Such information is directed solely to professionals who have the appropriate degree of experience to understand and interpret the contents and any and all use of or reliance upon the information is at the user's own discretion and at its own risk.

All warranties, express or implied, are disclaimed, including without limitation, any and all warranties concerning the accuracy of the information, its completeness, its fitness or appropriateness for a particular purpose or use, its merchantability and its non-infringement of any third party's intellectual property rights. The U.S. Government (the "Government"), the National Renewable Energy Laboratory (NREL), the Midwest Research Institute (MRI) and the American National Standards Institute (ANSI) expressly disclaim any and all responsibilities for the accuracy of the information and make no representations or warranties regarding the information's compliance with any applicable statute, rule or regulation.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the Government, NREL, MRI, or ANSI. Additionally, the views and opinions (if any) of any author expressed in the information do not necessarily state or reflect those of the Government, NREL, MRI, or ANSI.

### LATEST HEADLINES

Take the Hydrogen Codes and Standards Portal User Survey

President Bush visits California Fuel Cell Partnership to Learn ...

COLUMBIA FUEL CELL CHALLENGE

FUEL OF THE FUTURE

Ballard shares rocket skyward on Bush talk of hydrogen future

Challenges confront 'hydrogen economy,' expert says

Alternative Fuel Stocks Soar on Bush Push

Hybrid cars are so last century

Bush: Hydrogen is the fuel of the future

Enzyme-Powered Fuel Cell Developed

Bio fuel cells could power portable gadgets

Earth Day marked by cleanup teams, and hope for hydrogen fuel ...



# Technical Accomplishments/Progress: Unified National Agenda for Codes and Standards



U.S. Department of Energy  
National Renewable Energy Laboratory  
American National Standards Institute  
ANSI eStandards Store

About the Hydrogen Codes and Standards Portal

Hydrogen and Fuel Cells Permitting Guide



**Browse by subject:**

**Vehicle Systems and Refueling Facilities**

On-Site Hydrogen Generation and Fuel Cells

Click on any links below to browse for standards in a specific category

VEHICLES	INTERFACE	FUEL DELIVERY, STORAGE	FUELING, SERVICE PARKING FACILITY
<ul style="list-style-type: none"> <li>▣ Fuel Cell Vehicle Systems</li> <li>▣ Fuel Delivery Systems</li> <li>▣ Containers</li> <li>▣ Reformers</li> <li>▣ Emissions</li> <li>▣ Recycling</li> <li>▣ Service/Repair</li> </ul>	<ul style="list-style-type: none"> <li>▣ Fuel Specifications</li> <li>▣ Weights/Measures</li> <li>▣ Fueling/Defueling</li> <li>▣ Sensors/Detectors</li> <li>▣ Connectors</li> <li>▣ Communications</li> </ul>	<ul style="list-style-type: none"> <li>▣ Composite Containers</li> <li>▣ Pipelines</li> <li>▣ Equipment</li> <li>▣ Fuel Transfer</li> </ul>	<ul style="list-style-type: none"> <li>▣ Storage Tanks</li> <li>▣ Piping</li> <li>▣ Dispensers</li> <li>▣ On-site H<sub>2</sub> Production</li> <li>▣ Codes for the Built Environment</li> </ul>



# Technical Accomplishments/Progress: Codes and Standards R&D Roadmap Implementation

## Fueling Station-Vehicle Interface

- **Hydrogen Quality: Nozzle to Fuel Cell**
- Feedback Strategies
- Dispenser Protocol and Testing (70 Mpa)
- Fueling Components
- Station Grounding
- *Integrated Systems Design*



# Technical Accomplishments/Progress: Fuel Quality – ISO TS14687-2 Table of Characteristics

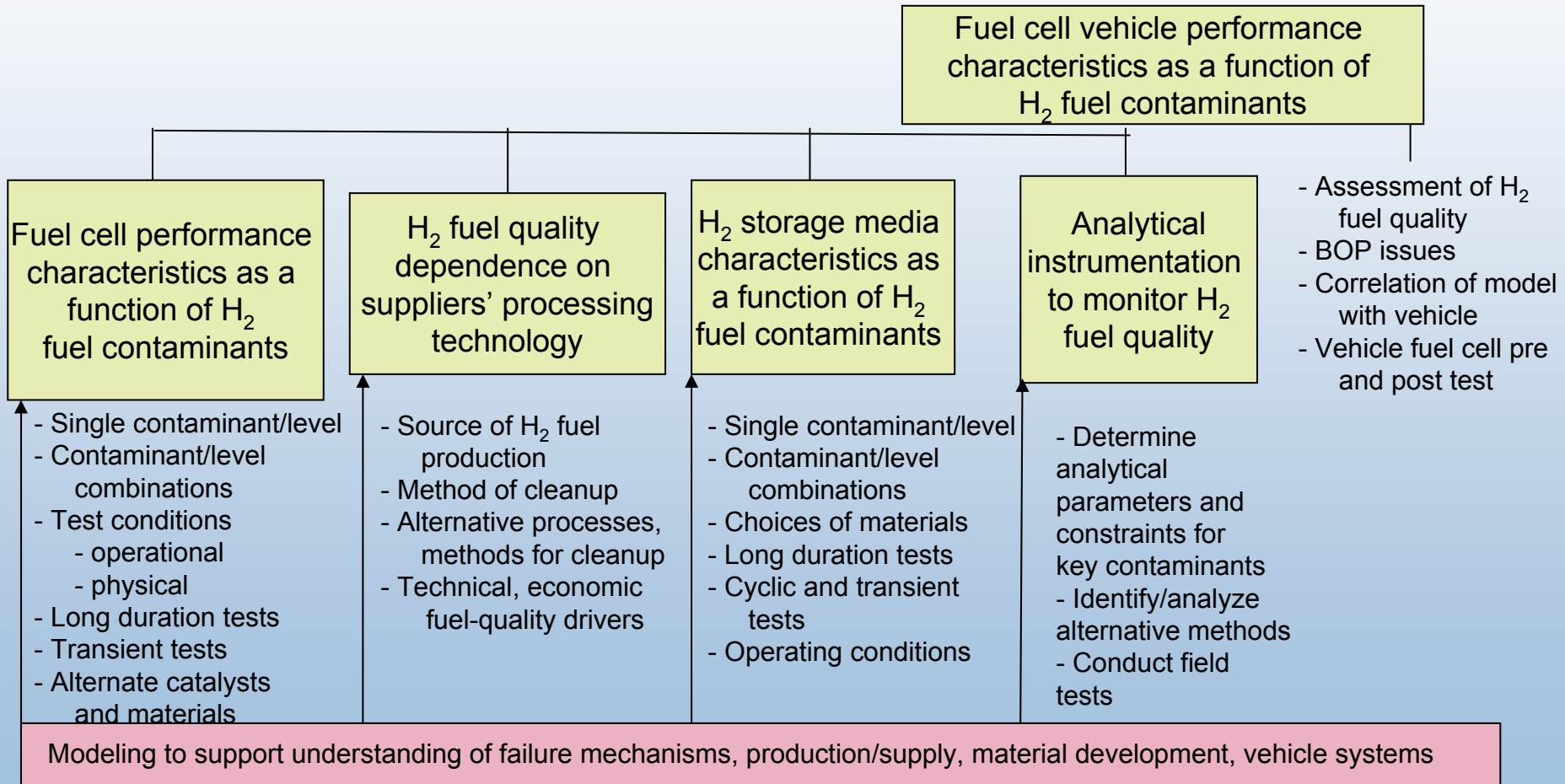
Table 1 — Directory of limiting characteristics

Characteristics (assay)	Type I Grade D	Type II Grade D	Laboratory Test Methods to Consider
Hydrogen fuel index (minimum, %) <sup>a, b</sup>	99,99	99,99	
<i>Para</i> -hydrogen (minimum, %)	NS	95,0	
<b>Non-hydrogen constituents</b> (maximum content)			Dimensions in micromoles per mole unless otherwise stated
Total gases <b>Error! Reference source not found.</b>	100	100	
Water (H <sub>2</sub> O)	5	5	ASTM D6348, D5454, (D1946 & D5466) <sup>g</sup> JIS K0225
Total hydrocarbons <sup>c</sup> (C <sub>1</sub> basis)	2	2	EPA T012, T015, ASTM (D1946 & D5466) <sup>g</sup> , D6968, JIS K0114
Oxygen (O <sub>2</sub> )	5	5	ASTM (D1946 & D5466) <sup>g</sup> , JIS K0225
Helium (He), Nitrogen (N <sub>2</sub> ), Argon (Ar)	100	100	ASTM (D1946 & D5466) <sup>g</sup> , JIS K0114
Carbon dioxide (CO <sub>2</sub> )	2	2	ASTM (D1946 & D5466) <sup>g</sup> , JIS K 0114, K 0123
Carbon monoxide (CO)	0,2	0,2	EPA 25C, ASTM (D1946 & D5466) <sup>g</sup> , JIS K 0114, K 0123
Total sulfur compounds <sup>d</sup>	0,004 <sup>f</sup>	0,004 <sup>f</sup>	ASTM (D1946 & D5466) <sup>g</sup> , D5504, JIS K 0127
Formaldehyde (HCHO)	0,01	0,01	EPA Method 11, NIOSH 2541, EPA T015, ASTM (D1946 & D5466) <sup>g</sup> , JIS K 0114, K 0124, K 0123
Formic acid (HCOOH)	0,2 <sup>f</sup>	0,2 <sup>f</sup>	ASTM (D1946 & D5466) <sup>g</sup> , JIS K 0123, K 0127
Ammonia (NH <sub>3</sub> )	0,1 <sup>f</sup>	0,1 <sup>f</sup>	ASTM (D1946 & D5466) <sup>g</sup> , EPA T015, JIS K 0127
Total halogenated Compounds	0,05	0,05	EPA 200.7, JIS K101
Max Particulates Size <sup>e</sup>	10 μm	10 μm	SCAQMD Method 301-91
Max Particulates Concentration <sup>e</sup>	1 μg/L @ NTP	1 μg/L @ NTP	Gravimetric (EPA IO 3.1)



# Technical Accomplishments/Progress: Fuel Quality – R&D/Testing Approach Defined

Collect, evaluate, and report assemblage of data and information  
Recommend H<sub>2</sub> fuel quality specifications





# Technical Accomplishments/Progress: Fuel Quality – Effects of Non-hydrogen Constituents on PEM Fuel Cells and Vehicle Systems Defined

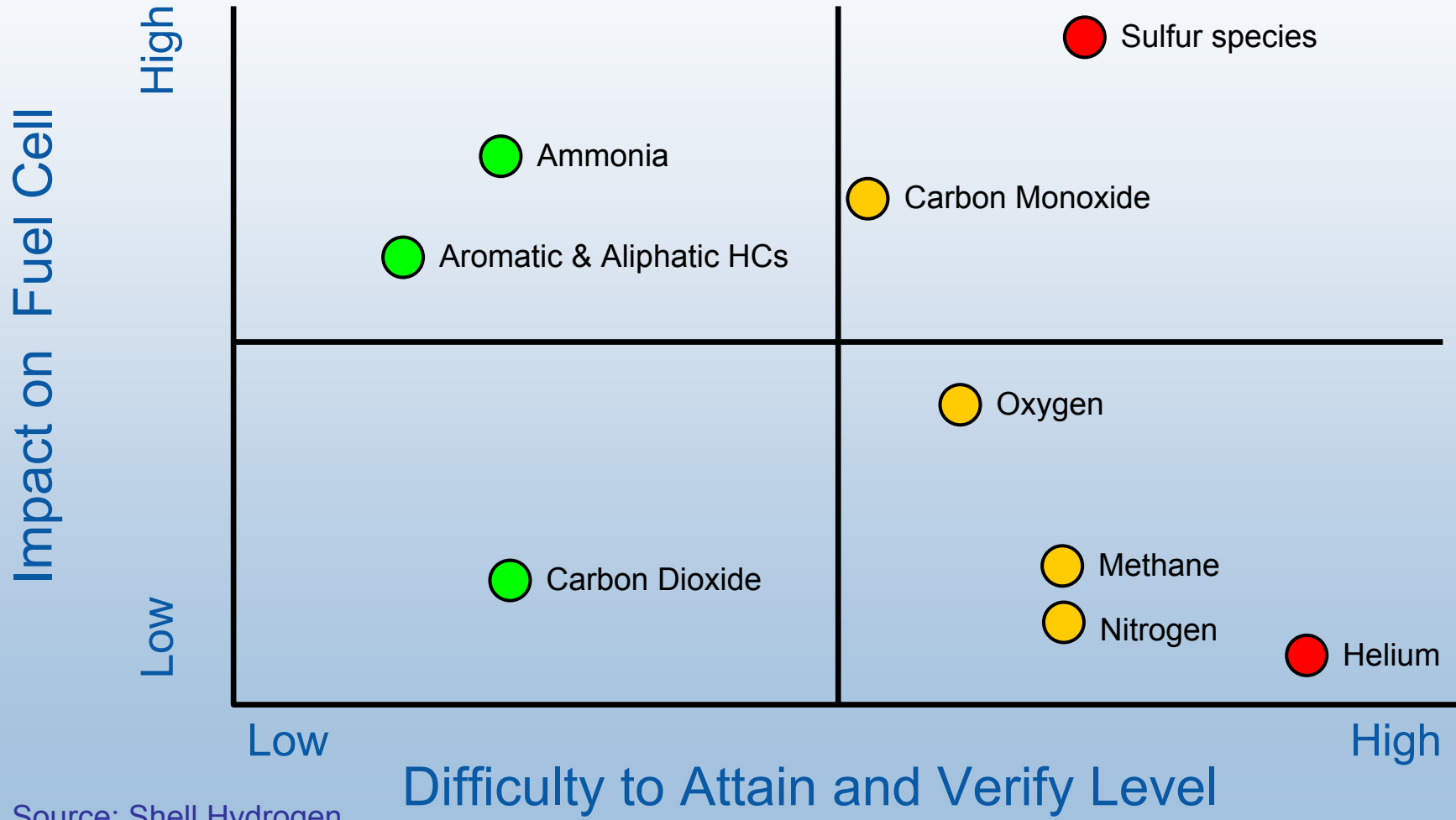
Species	FC Stack	BOP	Storage
Inert gasses (Helium, Argon, Nitrogen)	H <sub>2</sub> dilution effect, affects system efficiency	Will affect purging rate and blowers	Believed to affect cycle life of reactive storage media
Hydrocarbons	Aromatics, acids, aldehydes, etc., degrade performance	Unknown	May affect cycle life of reactive storage media
Oxygen	Tolerant to > 500 ppm	May form ice	Believed to affect cycle life of reactive storage media
Carbon Monoxide	Reacts, degrades performance (reversible)	No effect	Believed to affect cycle life of reactive storage media
Carbon Dioxide	Tolerant at 100 ppm – limited CO back shifting	No effect	Believed to affect cycle life of reactive storage media

Source: SAE





# Technical Accomplishments/Progress: Fuel Quality – Specification Tradeoffs Defined



Source: Shell Hydrogen

# Technical Accomplishments/Progress: Hydrogen Purification Drivers (PSA)

Species	Adsorption Force	ISO TC 197 WG 12 (14687) Draft Spec	ATR Mol %	Purification Ratio for ATR	SMR Mol %	Purification Ratio for SMR	OVERALL EFFECT
Helium (He)	Zero	100 ppm (total inert)	500 ppm	5	500 ppm	5	<b>NOT POSSIBLE</b>
Hydrogen (H2)	Weak	99.99%	40-45%		75-80%		Impacts PSA recovery & Capital Cost
Oxygen (O2)		5 ppm	50 ppm	10	-	-	Impacts PSA recovery & Capital Cost
Argon (Ar)		100 ppm (total inert)	500 ppm	5	500 ppm	5	Impacts PSA recovery & Capital Cost
Nitrogen (N2)		100 ppm (total inert)	34-38%	3800	1000 ppm	10	Impacts PSA recovery & Capital Cost
Carbon Monoxide (CO)		0.2 ppm	0.1 -1 %	50000	0.1-4%	200000	Impacts PSA recovery & Capital Cost
Methane (CH4)		2 ppm (incl THC)	0.5 – 2%	10000	0.5 – 3%	15000	Impacts PSA recovery & Capital Cost
Carbon Dioxide (CO2)		2 ppm	15-17%	85000	15 -18%	90000	Relatively easier to remove
Total HC's		2 ppm (incl CH4)	0.1 %	500	0.5%	2500	Relatively easier to remove
Ammonia	Strong	0.1 ppm	Low ppm		Low ppm		Relatively easier to remove
Total Sulfur	Strong	0.004 ppm					Relatively easier to remove
Halogenates	Strong	0.05 ppm					Relatively easier to remove
Water (H2O)	Strong	5 ppm	Dew Point		Dew Point		Relatively easier to remove

Source: Chevron



# Technical Accomplishments/Progress: Fuel Quality – Critical Constituents Defined

- To date, the North American team has identified the following as critical constituents around which near-term R&D and testing should be focused:
  - CO
  - S compounds
  - He
  - CH<sub>4</sub> and inerts
  - NH<sub>3</sub>
  - Particulate Matter (<10 $\mu$  diameter)

This list may change and other critical constituents may be identified as R&D and testing proceed



# Technical Accomplishments/Progress: Fuel Quality – 5-year R&D/Testing Plan Defined

Topic of Investigation	2006	2007	2008	2009	2010
<b>I. Consensus Testing Strategy</b>					
A. Fuel cell-OEMs/fuel providers select n critical species from Table 1 based on key technical/economic drivers	■				
B. Develop R&D/test plan with WG12	■				
C. Coordinate activities, revise plan annually	■	■	■	■	■
D. Derive optimal balance bet. fuel cell performance and fuel cost				■	■
<b>II. Fuel Cell Tests ('standard' MEA)</b>					
A. Conduct failure mechanism tests w/re concn. at const. load, RH, T & P with critical constituents (CO, H2S, etc.)	Determine mechanism	Identify regeneration alternatives	Alternate materials		
B. Conduct long-term tests (const. physical conditions) and const. & variable loads with critical constituents (CO, H2S, etc.)	Aging/const load	Aging/variable load	Aging w/regen		
C. Conduct tests with selected combinations of critical constituents (CO, H2S, etc.) and concentrations	Determine mechanisms	Identify regeneration alternatives	Alternative materials use (low cat. loading, etc.)	Commercial Materials	
D. Conduct "Simulated Drive Cycle" tests with H <sub>2</sub> + critical constituents as fuel		Operations with limited contaminants and limits on conditions (load,SD/SU)	Operations with 'H <sub>2</sub> Fuel' & typical conditions		
E. Investigate performance/cost trade offs re: critical constituents			■	■	
<b>III. H<sub>2</sub> Fuel Provider Integration</b>					
A. Define H <sub>2</sub> fuel quality variations based on current cleanup procedures (relative to critical constituent limits)	■				
B. Define contaminant species/ concentration variations as a function of planned H <sub>2</sub> sources	■				
C. Investigate H <sub>2</sub> cleanup alternatives commensurate with fuel cell tests	■				
D. Conduct cost trade-offs re: critical constituents			■	■	
<b>IV. Analytical Protocol/Instrumentation</b>					
A. Evaluate adequacy of Table 1 info., set priorities based on IA	■				
B. Modify ASTM standards to measure critical constituents as needed	Determine variations to current practice	Investigate and incorporate required alternatives to SOP			
C. Validate test methodology and requirements for critical constituents	Identify key species required to be monitored		Finalize species and concns to be monitored		
D. Assess cost trade-offs, esp. in-line measurement		■	■		
<b>V. OEM Engine/Vehicle Tests</b>					
A. H <sub>2</sub> Fuel with Priority Constituents		Correlate small scale fuel cell tests with large scale	Assemble and evaluate demo and fleet vehicle operations with H <sub>2</sub> → fuel quality	Test and demonstrate vehicle/engine dyno tests with	
<b>VI. Advance Storage Materials</b>					
A. Track Development of Adv. Materials		■	■	■	■



# Technical Accomplishments/Progress: Safety Bibliographic Database

U.S. DEPARTMENT OF ENERGY hydrogen.energy.gov

Hydrogen Program

U.S. DEPARTMENT OF ENERGY

hydrogen.energy.gov

Hydrogen Safety Bibliographic Database Home Page

## Hydrogen Safety Bibliographic Database — Search

This searchable database provides references for information on hydrogen safety. You can search for documents by title/abstract/keyword, author, source, publication year, and document type. To perform a search, enter search terms in one or more boxes. Entering search terms in more than one box allows you to narrow your results.

<b>Title/Abstract/Keyword :</b>	<input type="text" value="contains all"/>	<input type="text"/>
<b>Author :</b>	<input type="text" value="contains all"/>	<input type="text"/>
<b>Source :</b>	<input type="text" value="contains all"/>	<input type="text"/>
<b>Publication Year :</b>	<input type="text" value="-"/>	<input type="text"/>
<b>Document Type:</b>	<input type="text" value="All Types"/>	<input type="text"/>

---

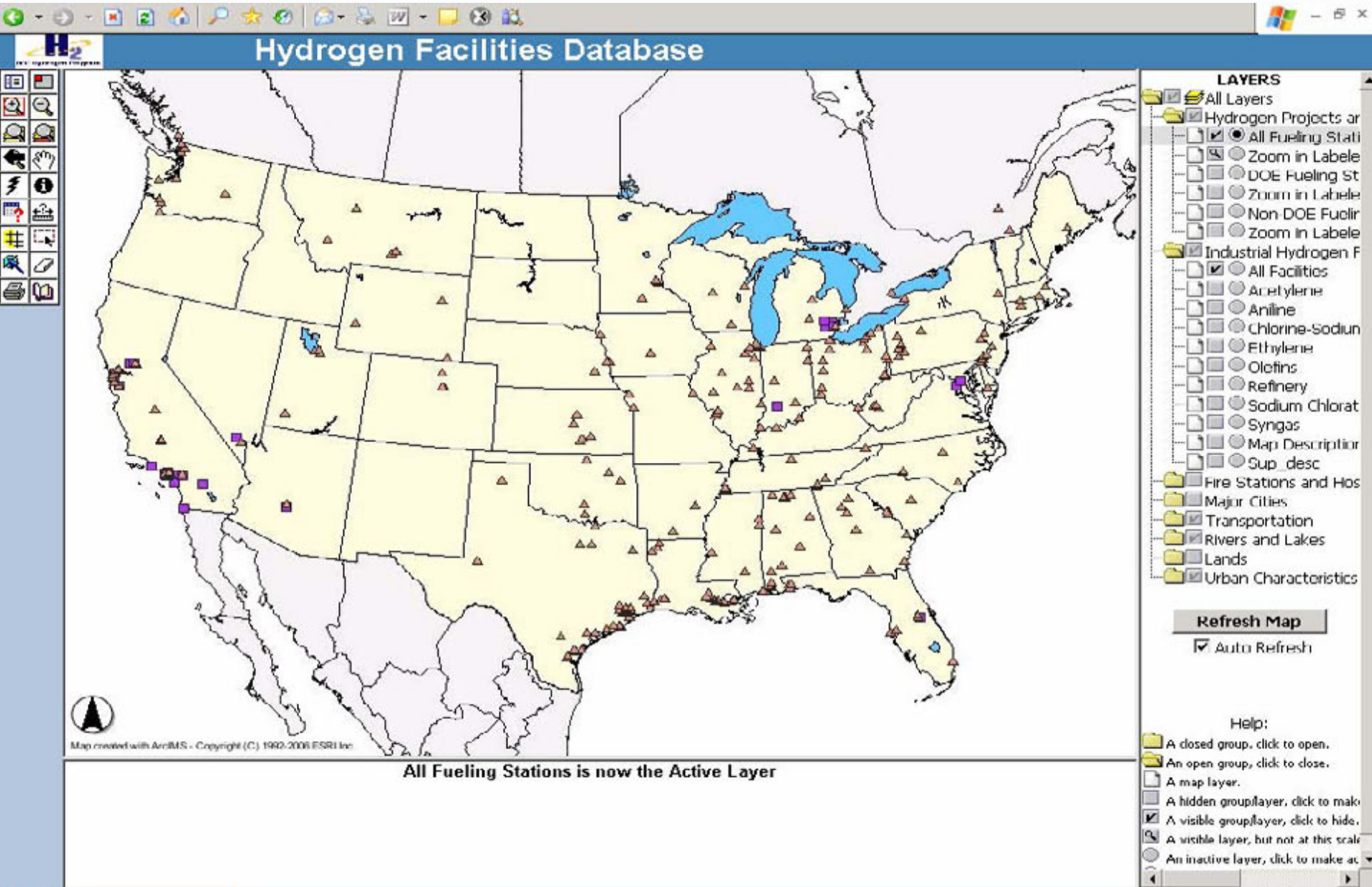
**Sort By:**       **Sort Direction:**       **Field Connector:**

---

[Search Help](#)

# Technical Accomplishments/Progress: Hydrogen Facilities Database





# Future Work

- Fuel Quality (FY06-07)
  - coordinate R&D and testing in parallel with preparation of international standard
  - focus R&D/testing on critical constituents identified as cost and technology drivers by consensus of fuel providers and fuel cell and automobile OEMs
    - cell testing
    - fuel cell system performance and durability trade-offs
    - fuel production, purification, delivery, options and cost trade-offs
    - sampling, analytic methodology, and instrumentation needs
  - develop consensus on critical analytical methods and procedures needed to verify recommended maximum levels of contaminants
  - integrate findings, results with DOE H2 Quality Working Group
- Component Testing and Validation (FY06-07)
  - harmonize performance-based test protocols and validation of technical requirements in domestic and international hydrogen standards, codes, and regulations
    - streamline testing/validation through computer-aided engineering (CAE), Design of Experiments, and other statistical techniques
- Sensor Testing and Validation (FY07)
  - sensitivity, accuracy, selectivity, durability in laboratory and field
  - develop criteria, test procedures relevant to integrated engineering and design approach
  - measure performance dependence on temperature, humidity, exposure to outdoor air



# Summary

- Strengthened consensus codes and standards agenda through National H2-FC C&S Coordinating Committee
  - contracts with all key SDO/MCO to develop essential standards and model codes under significant budget constraints
- Established and coordinated North American team of experts to help prepare and submit draft ISO Technical Specification for hydrogen fuel quality for PEMFC road vehicles
  - high priority for FreedomCAR- Fuel Partnership C&S Tech Team
- Created online hydrogen safety bibliographic database for DOE
  - fulfills NAS recommendation
- Created online Geographic Information System (GIS) hydrogen facility database
  - enables timely and informed response to hydrogen incidents
- Applying risk assessment techniques to develop better risk-informed codes and standards (with SNL)
  - linked to IEA Annex 19 (Hydrogen Safety)





# Supplemental Slides

The following slides are for the purposes of the reviewers only.



# Responses to Previous Year Reviewers' Comments

- “Accelerate efforts on hydrogen quality specifications;”  
“focus on fuel quality, data collection, and underlying R&D”
  - final draft of ISO specification submitted, ISO requirements harmonized with SAE
  - fuel quality incorporated in R&D Roadmap, designated as high priority by Codes and Standards Tech Team
  - the North American team has developed 5-year and 1-year R&D plans for testing, data collection



# Responses to Previous Year Reviewers' Comments

- “Move more budgets toward codes and standards R&D and decrease general contributions made to trade organizations”
  - significant R&D budgets planned for integrated safety engineering, component testing and validation, sensor testing and validation eliminated due to funding reductions
  - R&D focus placed on fuel quality testing
  - less than 10% of budget going to an industry association (provided 20% cost-share) to support codes and standards coordination and provide central communication for C&S issues



# Responses to Previous Year Reviewers' Comments

- “More attention to residential and commercial systems is desirable”
  - supporting revision of ICC model codes relevant to residential and commercial buildings
  - supporting revision of NFPA model codes and standards for fueling stations
  - supporting R&D to establish scientific foundation for setbacks for hydrogen and fuel cell applications in telecommunication facilities



# Publications and Presentations

## Patents:

Two submitted for hydrogen safety sensor, prospective patents licensed to industrial firm

## Papers:

- Overview Paper, Hydrogen Energy Cycle, MRS Symposium on Hydrogen; Cambridge, MA
- Risk Assessment for Hydrogen Codes and Standards, 1st International Conference on Hydrogen Safety; Pisa, Italy
- DOE Hydrogen Codes and Standards Program, SAE Congress; Detroit, MI

## Presentations:

- Fuel quality R&D and Testing, ISO TC197 WG12; Palm Springs, CA
- DOE Hydrogen Codes and Standards Program, SAE Congress; Detroit, MI
- Hydrogen Fuel Quality R&D Needs, Codes and Standards Tech Team; Washington, D.C.
- North American Consensus for Fuel Quality Requirements, ISO TC197 WG12; Kyoto, Japan
- Fuel Quality R&D Plan, Fuel Cell Tech Team; Detroit, MI
- Hydrogen Fuel Quality, National H2/FC C&S CC and US TAGs; Detroit, MI



# Critical Assumptions

- Synchronization of Codes and Standards Development with R&D
  - better synchronization of codes and standards development with the R&D will establish a sound technical and scientific basis for requirements incorporated in codes and standards
  - scientific and technical basis requirements difficult to trace at times; SDOs and MDOs devoting significant efforts to update requirements using the results of R&D supported by DOE and industry
- Performance-Based preferred over Design-Based, or Prescriptive, Standards
  - specifies tests component, subsystem, or system must pass without regard to materials made of or how designed
  - requirements for stationary applications will most probably remain prescriptive, requirements for vehicular applications should, to extent possible, be performance-based
- Coordinating National and International Codes and Standards Development
  - many major stakeholders involved in codes and standards operate in global markets and clearly recognize need for close coordination and integration of national codes and standards development and international efforts to protect U.S. economic interests
  - DOE will facilitate harmonization of requirements, including uniform application of results from R&D efforts in formulating safety requirements, and minimize duplications of effort



# Technical Accomplishments/Progress: National Template for Vehicle Systems and Refueling Facilities

## Vehicles

**Controlling Authority:**  
**DOT/NHTSA** (Crashworthiness)  
**EPA** (Emissions)

---

**Standards Development:**  
**General FC Vehicle Safety:** SAE  
**Fuel Cell Vehicle Systems:** SAE  
**Fuel System Components:** CSA  
**Containers:** SAE  
**Reformers:** SAE  
**Emissions:** SAE  
**Recycling:** SAE  
**Service/Repair:** SAE

## Interface

**Fuel Specs:** SAE  
 ASTM, API  
**Analytical Methods:** ASTM  
**Wts/Measures:** NIST, API,  
 ASME  
**Fueling:** SAE, CSA  
**Sensors/Detectors:** UL,  
 NFPA, SAE, CSA  
**Connectors:** SAE, CSA  
**Communications :** SAE  
 UL, CSA, API, IEEE

## Fuel Delivery, Storage

**Controlling Authority:**  
**DOT/PHMSA:** (Over-road  
 Transport, Pipeline Safety)

---

**Standards Development:**  
**Composite Containers:** ASME  
 CSA, CGA, NFPA  
**Pipelines:** ASME, API, CGA,  
 AGA  
**Equipment:** ASME, API, CGA,  
 AGA  
**Fuel Transfer:** NFPA, API

## Fueling, Service

## Parking Facility

**Controlling Authority: State, Local Govt.**  
 Zoning, Building Permits

---

**Standards Development:**  
**Storage Tanks:** ASME, CSA, CGA, NFPA,  
 API  
**Piping:** ASME, CSA, CGA, NFPA  
**Dispensers:** CSA, UL, NFPA,  
**On-site H2 Production:** CSA, UL, CGA, API  
**Codes for the Environment:** ICC, NFPA

Lead SDO underlined



# Technical Accomplishments/Progress: National Template for Stationary and Portable Systems

**Controlling Authority:**  
**OSHA, Emissions – EPA**  
**Pipeline: DOT/PHMSA**  
**State, Local Government**  
**Zoning, Building Permits**

**Standards Development:**  
**Electrolyzers: UL, CSA**  
**Reformers: UL, CSA, API**  
**Performance Test**  
**Procedures: ASME, CSA**  
**Chemical Hydrides: UL,**  
**CSA, NFPA**

**Installation Piping: ASME, CSA, CGA,**  
**NFPA, ICC**  
**Storage: ASME, CGA, CSA, API, NFPA**  
**Compressors Safety Certification: CSA, UL**  
**Compressor Design, Performance &**  
**Safety: API**  
**Sensors/Detectors: UL, CSA, NFPA**  
**Fuel specifications: CGA, SAE, API, ASTM**  
**Weights/Measures: NIST, API, ASME**  
**Dispensers: NFPA, SAE, CSA, UL, API**  
**Non-vehicle Dispensing: CGA**  
**Codes for Built Environment: ICC, NFPA,**  
**CGA, ASHRAE**  
**Interconnection: IEEE , UL, NFPA**

## Interface

**Controlling Authority:**  
**OSHA,**  
**State, Local Government**  
**Zoning, Building Permits**

**Standards Development:**  
**H2 ICEs: UL, CSA**  
**H2 Fueled Turbines: API,**  
**CSA, UL, ASME**  
**FC Systems: CSA, ASME, UL**  
**FC Installation: NFPA**  
**FC Performance Test**  
**Procedures: ASME, CSA,**  
**NHA-GTI**

Hydrogen  
Generator

**Controlling Authority: CPSC, DOT/PHMSA, OSHA,**  
**EPA (Methanol),**  
**State, Local Govt. (Zoning, Building Permits)**

**Standards Development:**  
**Handheld Systems: UL, CSA**  
**Portable Systems: CSA, UL, CGA**  
**Handheld Fuel Containers: UL, CSA, CGA**  
**Portable Fuel Containers: CGA, CSA, ASME**  
**H2 Fuel Specifications: CGA, SAE**  
**Performance Test Procedures: NHA-GTI, ASME, CSA**

Stationary  
Fuel Cells

Portable  
Fuel Cells

Leads will change  
depending on type of  
environment.





# Technical Accomplishments/Progress: Fuel Quality – North American Team Established

- Bhaskar Balasubramanian, John Lemen, Chevron (C&STT, HPTT)
- Bob Boyd, BOC Gases (ASTM, SAE)
- Bill Collins, UTC Fuel Cells (ISO/TC197 WG12, USFCC, SAE)
- Raul Dominguez, SCAQMD (ASTM D03)
- Tony Estrada, PG&E (ASTM, SAE, ISO/TC197 WG12)
- Karen Hall, NHA (ISO TC197 and WG12)
- J.P. Hsu, Smart Chemistry (ASTM)
- Tom Joseph, Air Products (CGA, NFPA, ISO TC197)
- Jim Ohi, NREL (DOE HFCIT, C&STT)
- Rick Rocheleau, University of Hawaii (ISO/TC197 WG12, DOD)
- Leon Rubinstein, Patrick Kilough, Shell Hydrogen (HPTT, SAE, ASTM D03)
- Jesse Schneider, Daimler-Chrysler (C&STT, SAE, ISO/TC197 WG12)
- Joe Schwartz, Praxair (CGA, NFPA)
- Jim Simnick, BP (ASTM, HPTT)
- Mike Steele, Fred Wagner, GM (C&STT, FCTT, SAE)
- Tommy Rockward, Francisco Uribe, LANL (FCTT, USFCC/SCTRR)
- Spenser Quong, Quong and Associates (ASTM, CaFCP)
- Gerald Voecks, consultant to NREL (ISO/TC197 WG12)
- Silvia Wessel, Ballard Power Systems (ISO/TC197 WG12, CaFCP, USFCC)
- Doug Wheeler, consultant to University of Hawaii (ISO/TC197 WG12)
- Robert Wichert, USFCC (ISO and TC197 WG12, IEC)