

# PROCEEDINGS NATIONAL HYDROGEN ENERGY ROADMAP WORKSHOP

WASHINGTON, DC, APRIL 2-3, 2002



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Table of Contents

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INTRODUCTION

1. OPENING PLENARY SESSION.....	1
2. HYDROGEN PRODUCTION BREAKOUT SESSION.....	5
3. HYDROGEN DELIVERY BREAKOUT SESSION .....	12
4. HYDROGEN STORAGE BREAKOUT SESSION .....	20
5. HYDROGEN ENERGY CONVERSION BREAKOUT SESSION .....	27
6. HYDROGEN APPLICATIONS BREAKOUT SESSION .....	33
7. HYDROGEN OUTREACH AND EDUCATION BREAKOUT SESSION .....	41
8. HYDROGEN SYSTEMS INTEGRATION BREAKOUT SESSION .....	50
9. CLOSING PLENARY SESSION .....	56
10. LIST OF PARTICIPANTS .....	64

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# INTRODUCTION

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On April 2-3, 2002, more than 200 participants representing hydrogen energy industries, academia, environmental organizations, federal and state government agencies, and National Laboratories met for a National Hydrogen Energy Roadmap Workshop in Washington, DC. (A list of the participants can be found at the end of this document.) During the workshop they discussed the actions that need to be taken in order to reach the hydrogen vision that was identified during the National Hydrogen Vision Meeting in November 2001. The intent was to identify the most important barriers and needs that should be addressed in order to achieve the vision, the time frames for the top priority research and development and other efforts, and the respective roles of industry, government, universities, and National Laboratories in dealing with these issues.



This document is a summary of the proceedings from that meeting. It captures the comments and ideas that were exchanged, and summarizes the major themes that were expressed throughout the workshop. There will be a forthcoming national roadmap document that will be released shortly.

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# SECTION 1

## OPENING PLENARY SESSION

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### Welcome and Opening Remarks

*Robert Dixon, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy*

- Welcome to the National Hydrogen Roadmap workshop. We appreciate the time you've taken out of your busy schedules to be here with us today. Thank you.
- I would like to introduce Under Secretary of Energy Robert G. Card. Mr. Card is going to provide some opening remarks. Mr. Card attended the National Hydrogen Vision Meeting held in November and is a strong supporter of our efforts in this arena.



*Robert Card, Under Secretary, U.S. Department of Energy*

- Welcome. Thank you in advance for your hard work and participation in this Roadmap meeting.
- Science and energy research functions are driven by this process...not paper pushing.
- Since the National Hydrogen Vision Meeting in November, we have announced the FreedomCAR initiative.
- Since the November meeting, I have become more familiar with the technology; I recently had the opportunity to visit a hydrogen pipeline.
- We need to keep the investment criteria in mind. We are now beginning the FY04 budgeting process. We need to ask the following questions: 1) How many tons of carbon are we going to displace? What will be the cost?
- When considering hydrogen, we need to keep price competitiveness in mind. We must also remember that hydrogen is a long-term resource.
- Current issues for the Administration include climate change, energy supply, and energy security. In addition, there are many other budget issues under consideration.
- The outputs of the November Vision Meeting were instrumental in our decision to launch the FreedomCAR initiative. I would like to see something similar to the FreedomCAR initiative come out of this National Hydrogen Energy Roadmap Workshop.



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## Legislative Update on Hydrogen-related Legislation

*Jeff Serfass, President, National Hydrogen Association*

- Hydrogen Future Act – Amendments to Matsunaga Hydrogen R, D&D Act of 1990.
- House Energy Bill: HR 4, §2205, Hydrogen Research and Development, \$40-60 million for R&D from 2002-2006, \$20-40 million for demonstrations; advisory committee by National Academies of Science and Engineering
- Senate Energy Bill: Energy Policy Act of 2002, Title XII, Subtitle B, §1223, Hydrogen R&D, \$65-80 million for R&D from 2003-2006, \$25-40 million for fuel cell and hydrogen demonstrations; includes E&O, villages and foreign economic development; interagency task force to plan for development and demonstrations in Federal buildings and buses/fleets
- Agriculture bill S. 1731: Energy Title, §388H, Hydrogen and Fuel Cell Technologies Program; includes demonstration of hydrogen technologies and fuel cell technologies in farm, ranch, and rural applications; includes studies of technical, environmental, and economic viability in farm, ranch, and rural applications, of innovative hydrogen and fuel cell technologies not ready for demonstration; \$5 million per year through 2006
- Energy Tax Incentives Act of 2002 S. 1979: Title II, Alternative Motor Vehicles and Fuels Incentives, \$4 thousand for fuel cell cars, \$10-40 thousand for larger vehicles, economy adders, \$1-30 thousand for refueling property
- More Fuel Cell Titles: Energy Bills—Fuel Cell Bus Development and Demonstration Program, Clean Green School Bus Act, Alternative Fuel Vehicle Act, Federal Cost Sharing in Demos and Fuel Infrastructure
- 2003 Appropriations?: EE Hydrogen Research \$39.9 million, + 37%, EE Transportation \$275.7 million, -9% with \$150 million redirection from FreedomCAR, Fuel Cell research throughout DOE—EE Transportation \$50 million, EE Buildings \$75. million, EE Power Generation \$49.5 million (-15%), FE Carbon Sequestration \$54 million, +67%, EE Biomass, and other Renewables

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## Presentation on the Integration of Activities at the Department of Energy

*Steve Chalk, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy*

- We need a “business case” for expanding the use of hydrogen.
- The Department’s current research on hydrogen production, storage, conversion, etc. will impact the next 20 years
- I’m hoping that this and other meetings will help guide us in the right directions.



## Presentations on the Purpose and Goals of the Vision and Roadmap Process, and this Workshop

*Tex Wilkins, Roadmap Leader, U.S. Department of Energy*

- We have more than 200 people here today representing about 100 organizations.
- We all need roadmaps. For example, the Declaration of Independence was a roadmap that was written more than 200 years ago.
- As you know, the Hydrogen Vision meeting was held in November. Fifty-three people attended that meeting, and out of it came the Hydrogen Vision document.
- Today we have six areas that we will be focusing on: production, delivery, storage, energy conversion, applications, and public education and outreach. There will also be an integration group whose job it will be to incorporate all of the important ideas from each of the six areas.
- Roadmap chapters will ultimately be written by industry and university representatives. We envision that each chapter will be 4-5 pages and hope for a good draft by the end of May and a final draft sometime in June.
- Now I would like to introduce the roadmap leaders:
  - Energy Conversion - *Mike Davis, Avista Labs*
  - Delivery - *Art Katsaros, Air Products & Chemicals*
  - Applications - *Frank Balog, Ford Motor Company*
  - Storage - *Alan Niedzwiecki, Quantum Technologies*
  - Production - *Gene Nemanich, Chevron Texaco Technology Ventures*
  - Public Education and Outreach - *Jeff Serfass, National Hydrogen Association*
  - Systems Integration - *Joan Ogden, Princeton University*





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*Rich Scheer, Energetics, Inc.*

- We really appreciate your being here and we've developed a facilitation game plan that should keep you very busy over the next two days.
- Recently there have been several U.S. Department of Energy-sponsored meetings related to H<sub>2</sub> and fuel cells: the Hydrogen Vision meeting, the Fuel Cell Report to Congress meeting, and the Fuel Cells for Building meetings. In your deliberations over the next several days it is important that you try to tie all of these events together. Many of you were involved in those other meetings. Please remember that you are not here to "reinvent the wheel."



# SECTION 2

## HYDROGEN PRODUCTION BREAKOUT SESSION

- **Barriers:** What are the barriers that interfere most with achieving the vision?
- **Needs:** What are the most important needs to undertake between now and 2030 to address the barriers and achieve the vision?
- **Top needs and next steps:** What are the top priority needs, including their milestones and dates, primary funding entities, and next steps to addressing them?

### Participants:

NAME	ORGANIZATION
Mark Ackiewicz	Technology & Management Services, Inc.
Arvind Atreya	University of Michigan
David Bartine	Kennedy Space Center
Gottfried Besenbruch	General Atomics
Mel Buckner	Savannah River Technology Center
Wilson Chu	Johnson Mathey Fuel Cells
Anthony Cugini	National Energy Technology Laboratory
Gregory Dolan	Methanol Institute
Kellye Eversole	Eversole Associates
Alexander Fridman	University of Illinois
Leo Grassilli	Department of the Navy, ASN (I&E)
Neville Holt	Electric Power Research Institute
Alan Johnson	ZECA Corporation
Dan Keuter	Entergy Nuclear, Inc.
Joe Klimek	Startech Environmental Corporation
Ravi Kumar	General Electric
Jay Laskin	Teledyne Energy Ssystems, Inc.
William Lewis	ExxonMobil Refining & Supply Co.

### Participants:

NAME	ORGANIZATION
Ted Lima	Hamilton Sundstrand
Gary McDow	Air Liquide America
Gene Nemanich	ChevronTexaco Technology Ventures
Edson Ng	QuestAir Tehnologies, Inc.
Michael Nicklas	Innovative Design
Richard Noceti	National Energy Technology Laboratory
Manuel Pacheco	PDVSA-Citgo
Ken Schultz	General Atomics
Surindar Singh	Alberta Energy Research Institute
Andrew Stuart	Stuart Energy Systems
Chris Sutton	Air Products & Chemicals Inc.
Satish Tamhankar	BOC Group
David Tsay	Ztek Corporation, West Coast Office
John Turner	National Renewable Energy Laboratory
Robert Walker	Wexler & Walker Public Policy Associates
Kyle Wetzel	K. Wetzel & Co. Inc.

**FACILITATOR:** Ross Brindle, Energetics, Inc. (assisted by Tracy Carole)





## RD&D NEEDS – PRODUCTION (1 of 2)

(⊕ = Most Critical to Realizing the Vision; ◆ Most Critical Near-Term Need)

Time Frame: (N =2002 = -2010; M = 2010-2020; L = 2020-2030+)

Lead (capital letters) and Supporting (lower-case letters) Roles: (I = Industry; G = Government; U = Universities; NL = National Labs)

ELECTROLYSIS	THERMAL CYCLES	CARBON/WATER	ADVANCED PRODUCTION TECHNIQUES	CROSSCUTTING PROCESS TECHNOLOGIES
<ul style="list-style-type: none"> <li>• Higher efficiency, lower cost electrolysis (N; I) ⊕⊕⊕⊕⊕⊕</li> <li>• Develop 900°C electrodes and membranes for use with present nuclear off-peak ◆</li> <li>• Develop techniques to use seawater as feedstock for electrolysis (desalination or direct feed)</li> </ul>	<ul style="list-style-type: none"> <li>• Demonstrate hydrogen production from nuclear power by thermochemical process ⊕⊕⊕⊕⊕⊕⊕⊕⊕◆◆</li> <li>◆◆ (N; I, NL, g u)</li> <li>• sulfur and iodine PDU, research other cycles ⊕⊕◆◆◆◆</li> <li>• Address kinetics and materials questions ⊕⊕◆◆◆◆</li> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>• Develop economic, scalable carbon capture and sequestration techniques (N-L; I, nl, u, g) ⊕⊕⊕⊕⊕◆</li> <li>• reduce cost of CO<sub>2</sub> capture by 2/3 or more ⊕⊕⊕⊕⊕</li> <li>• membranes, catalysts, mineral carbonation, and pilots are needed ⊕⊕⊕⊕◆◆</li> <li>• Distributed production via small-scale reformers (N; I, U, NL, g) ◆◆◆◆◆◆</li> <li>• Improved and integrated refinery processes for hydrogen production (N-L; I) ⊕⊕⊕⊕◆◆</li> <li>• Develop improved gasification processes (N; I, U, NL, g) ⊕⊕⊕◆</li> <li>• fuel flexibility for feedstocks ⊕⊕⊕⊕⊕</li> <li>• Hot gas clean-up for coal</li> <li>• Develop methods for higher oxygen concentration to influence CO<sub>2</sub> purity during carbon sequestration</li> </ul>	<ul style="list-style-type: none"> <li>• Research on hi-temperature direct conversion of water to hydrogen (thermal, solar, electric) – need rapid separation technologies on nano-scale time frames (M-L; NL, U, g) ⊕⊕⊕⊕⊕⊕⊕⊕◆</li> <li>• More research into advanced “carbon-free” production processes ⊕⊕⊕⊕⊕</li> <li>• genetic engineering of biological-based photolytic processes ⊕</li> <li>• Develop lower-cost materials with longer lifetimes for semiconductor-based photolytic processes ⊕</li> <li>• develop nanotechnology production and storage capabilities ⊕⊕⊕</li> <li>• Develop and demonstrate methods to produce hydrogen by heat directly</li> <li>• nuclear – radiolysis</li> <li>• solar – plasma</li> </ul>	<ul style="list-style-type: none"> <li>• Improved separation and purification methods and materials ⊕⊕⊕⊕⊕⊕⊕⊕⊕⊕⊕⊕⊕◆◆◆◆◆◆</li> <li>◆</li> <li>• membrane separation of carbon and water</li> <li>• economical, scalable hydrogen separation at desired purity</li> <li>• Design for hi-volume mass production ⊕⊕⊕⊕</li> <li>• Production from lowest cost feedstocks ⊕⊕⊕◆◆</li> <li>• Eliminate use of precious metals ⊕⊕⊕⊕</li> <li>• Interconvertability of hydrocarbons and hydrogen ⊕⊕⊕⊕</li> <li>• use carbon as a hydrogen carrier</li> <li>• on-board reformers; use CO<sub>2</sub> in atmosphere</li> <li>• Develop analysis tools to understand different production schemes ⊕⊕</li> <li>• Develop improved materials (catalysts, hi-temperature, containment) ⊕⊕</li> <li>• Develop direct hydrogen production processes with minimal steps ⊕</li> <li>• Develop hydrogen detection technology</li> <li>• Apply low-cost processes (e.g., semiconductor processes) to hydrogen generation and production</li> </ul>



### NINE MOST WANTED - PRODUCTION

TOP-PRIORITY NEED	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<ul style="list-style-type: none"> <li>• Technical demonstration by process that can show the potential for technical and economic viability</li> </ul>	<ul style="list-style-type: none"> <li>• Codes and standards that apply to all production processes, including safety</li> <li>• Demonstration projects to take place in public venues to promote public acceptance</li> </ul>	<ul style="list-style-type: none"> <li>• 2 years: establish codes and standards across all production techniques</li> <li>• 5 years: at least one demonstration “fair” in each major metro area</li> </ul>	<ul style="list-style-type: none"> <li>• Industry, related industrial organizations</li> <li>• Government co-funding</li> </ul>	<ul style="list-style-type: none"> <li>• Establish venue for government and industry to work together</li> <li>• Begin working with local governments to break down barriers to implementing demonstration projects</li> </ul>
<ul style="list-style-type: none"> <li>• Develop economic, scalable carbon capture and sequestration techniques</li> </ul>	<ul style="list-style-type: none"> <li>• Cost reduction for capture</li> <li>• New methods for low-concentration capture</li> <li>• Demonstration</li> <li>• Validation for performance</li> </ul>	<ul style="list-style-type: none"> <li>• 2007: Demonstrate geological sequestration</li> <li>• 2010: Demonstrate mineral sequestration</li> <li>• 2010: Demonstrate three technologies</li> <li>• 2010: Reduce cost of high-concentration capture by 50%</li> <li>• 2020: Consider demonstrating ocean sequestration</li> <li>• 2030: Demonstrate low-concentration capture</li> </ul>	<ul style="list-style-type: none"> <li>• Government – DOE support, low-concentration capture</li> <li>• Industry – high-concentration capture</li> <li>• Sequestration – Work: NL:I 50:50; Funding: G:I 75:25</li> <li>• High-concentration capture – work: NL:I 50:50; Funding: I:G 60:40</li> <li>• Low-concentration capture – work: NL:U 50:50; Funding: G:I 75:25</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct demonstrations of sequestration techniques</li> </ul>
<ul style="list-style-type: none"> <li>• Develop improved separation and purification methods and materials</li> </ul>	<ul style="list-style-type: none"> <li>• Economical gas separation technologies that are appropriate to hydrogen application and production method</li> </ul>	<ul style="list-style-type: none"> <li>• 2007: demonstrate hydrogen separation from mixed gas at 30% below current cost</li> <li>• 2007: demonstrate oxygen separation from air at 30% below current cost</li> <li>• 2015: demonstrate both at 50% lower cost</li> </ul>	<ul style="list-style-type: none"> <li>• Federal 80:20 for long-term research; 50:50 for demonstrations</li> <li>• Private, as desired</li> </ul>	<ul style="list-style-type: none"> <li>• Designate “gas separations technologies” as a separate program area equivalent in stature to hydrogen generation</li> <li>• Define performance targets for each application and production method</li> </ul>

## NINE MOST WANTED - PRODUCTION

TOP-PRIORITY NEED	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<ul style="list-style-type: none"> <li>• Demonstrate hydrogen production from nuclear power by thermochemical process</li> </ul>	<ul style="list-style-type: none"> <li>• Utilities and refineries are risk-adverse. We need technical demonstration that thermochemical hydrogen production really works</li> <li>• Temperature greater than 800° C, integrated loop, continuous operation (greater than weeks)</li> </ul>	<ul style="list-style-type: none"> <li>• 2005: integrated laboratory loop of S-I cycle (\$6M)</li> <li>• 2007: measure kinetics, materials, for Ca-Br cycle (\$2M)</li> <li>• 2004: chemical data for HI-I<sub>2</sub>-H<sub>2</sub>O equilibrium (\$1M)</li> <li>• 2010: pilot plant (100 m<sup>3</sup>/hr) non-nuclear simulation (\$30-50M)</li> <li>• 2012: pilot plant using NP 2010 (\$20M)</li> </ul>	<ul style="list-style-type: none"> <li>• 2002-2010: DOE and some industry support</li> <li>• 2010-2012: (using 5% of NP 2010) 50:50 industry: government</li> <li>• 2012-2015 (using 100% NP 2010): 50:50 cost share</li> <li>• 2015+: Industry</li> </ul>	
<ul style="list-style-type: none"> <li>• Advanced direct production techniques</li> <li>• biological</li> <li>• photolytic</li> <li>• nanotechnology</li> <li>• nuclear</li> <li>• solar</li> <li>• hi-temperature</li> </ul>	<ul style="list-style-type: none"> <li>• Biological (dark process using biomass feedstock) – identify organisms for doing conversion, genomics for improved feedstock and microbes</li> <li>• Biological (solar) – genomics to understand the water splitting reaction center and the efficiency of conversion</li> <li>• Hi-temp direct (solar or nuclear) – separation technology fro hydrogen/oxygen separation at high temperatures (nanotechnology membranes)</li> <li>• Photolytic (semiconductor-based) – identification of materials for longer lifetimes (corrosion); quantum dots (nanotech)</li> </ul>	<ul style="list-style-type: none"> <li>• Biological – 2007: basic sequencing; 2020; functional control</li> <li>• Hi-temp – 2012: develop low-cost membranes for separation</li> <li>• Photolytic – 2012: materials identification</li> </ul>	<ul style="list-style-type: none"> <li>• Biological – NIH, DOE, NSF, USDA</li> <li>• Hi-temp – DOE, NSF, Industry, DOC</li> <li>• Photolytic – DOE, NSF, Industry</li> </ul>	<ul style="list-style-type: none"> <li>• Prioritize research needs by DOE, NSF, etc.</li> <li>• Support basic research to develop computational capabilities in support of these technologies</li> </ul>
<ul style="list-style-type: none"> <li>• Develop improved gasification processes; enable fuel flexibility for feedstock</li> </ul>	<ul style="list-style-type: none"> <li>• Cheaper oxygen, integration</li> <li>• Mixed feedstock handling (e.g., biomass, potcoke)</li> <li>• High-efficiency integration (heat management, IGCC)</li> <li>• Cheaper syngas production</li> </ul>	<ul style="list-style-type: none"> <li>• 2005: feedstock flexibility</li> <li>• 2005: optimization for cost reduction</li> <li>• 2005-2010: system integration</li> <li>• 2010: cheaper oxygen demonstration</li> <li>• 2020: integration with carbon sequestration (total system)</li> </ul>	<ul style="list-style-type: none"> <li>• Government-industry cost share</li> </ul>	<ul style="list-style-type: none"> <li>• Continue R&amp;D with expanded scope (include other feedstocks)</li> </ul>

## NINE MOST WANTED - PRODUCTION

TOP-PRIORITY NEED	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<ul style="list-style-type: none"> <li>Integrated environmental policy to reward non-polluters and/or tax polluters based on cap and trade system</li> </ul>	<ul style="list-style-type: none"> <li>Integrated environmental policy (electric utilities, transportation, industrial, commercial, residential)</li> <li>Set national cap for major pollutants: NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub>, etc., issue credits to match caps, and allow trading of credits</li> </ul>	<ul style="list-style-type: none"> <li>2004: national legislation is in place</li> <li>2010: legislation is implemented</li> </ul>	<ul style="list-style-type: none"> <li>This policy can be a fund-generator. Funds collected can be directed to support energy R&amp;D that reduced pollution, including hydrogen infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>Draft legislation</li> </ul>
<ul style="list-style-type: none"> <li>Higher-efficiency, lower-cost electrolysis</li> </ul>	<ul style="list-style-type: none"> <li>Electrolysis improvements include:</li> <li>lower life-cycle hydrogen costs for application-specific uses considering the supply and source of electricity by improving efficiency, capital costs, and maintenance, etc. of complete system</li> </ul>	<ul style="list-style-type: none"> <li>By 2010, for each target application:</li> <li>improve efficiency</li> <li>improve capital cost</li> <li>improve total life-cycle costs</li> <li>optimize</li> </ul>	<ul style="list-style-type: none"> <li>Primary funding by industry</li> <li>Goal-setting study by government assist</li> </ul>	<ul style="list-style-type: none"> <li>For the major use/applications (e.g., transportation, stationary power, etc.) establish acceptable value of hydrogen</li> <li>Establish price/value goals for electrolysis</li> <li>Based on above, identify methods of achieving price and thus improvement needed</li> <li>By 2002</li> </ul>
<ul style="list-style-type: none"> <li>Distributed production using small-scale reformers</li> </ul>	<ul style="list-style-type: none"> <li>Reduce cost</li> <li>Improve reliability and safety</li> <li>Develop codes and standards</li> <li>Fuel flexibility</li> <li>Materials development</li> <li>Systems integration</li> </ul>	<ul style="list-style-type: none"> <li>2003: codes and standards in place</li> <li>2005: low-cost materials developed</li> <li>2005: demo multiple hydrogen refueling systems</li> <li>2007: demo multiple hydrogen energy parks</li> <li>2007: fuel flexible reformer</li> </ul>	<ul style="list-style-type: none"> <li>Federal and state government</li> <li>Industry</li> <li>Incentives for high-efficiency and lower polluting technologies</li> </ul>	<ul style="list-style-type: none"> <li>Support FreedomCAR</li> <li>Integrate with stationary power (hydrogen energy park)</li> <li>Flow down customer requirements to subsystem specs</li> <li>Force introduction of high-efficiency, low-pollution systems</li> </ul>





# SECTION 3

## HYDROGEN DELIVERY BREAKOUT SESSION

- **Barriers:** What are the scientific, engineering, environmental, institutional, economic, and market delivery barriers that interfere most with achieving the vision?
- **Needs:** What are the most important needs including research and development, demonstrations, analysis, policy, codes and standards, and outreach to address the barriers?
- **Top needs and entity roles:** What are the top needs, and which entities will address those needs?
- **Next steps:** What are the top priority needs including their descriptions, key milestones and dates, primary funding entities, and next steps?

### Participants:

NAME	ORGANIZATION
Art Katsaros	Air Products
Neil Rossmeissl	U.S. Department of Energy
Rodney Carlisle	History Associates Incorporated
Helena Chum	NREL/HTAP
Ed Danieli	Praxair, Inc.
Bob Dempsey	Chevron Texaco Technology Ventures
Steve Fan	Ford
Rob Friedland	Proton Energy Systems
Bob Hawsey	ORNL
George Kervitsky	SENTECH
Ken Koyama	California Energy Commission
Mike Leister	Marathon Ashland Petroleum
Steve Melancon	Energy Nuclear
Karen Miller	National Hydrogen Association
Marianne Mintz	Argonne National Laboratory
Jim Ohi	National Renewable Energy Laboratory
Venki Raman	Air Products
Paul B. Scott	Stuart Energy USA
Prentiss Searles	American Petroleum Institute
Brad Smith	Shell Hydrogen
Jeff Staser	Denali Commission (Alaska)
Sandy Thomas	H2Gen Innovations, Inc.
Gene Whitney	Office of Science & Technology Policy

**FACILITATOR:** Ed Skolnik, Energetics, Inc. (assisted by Christina TerMaath)

## HYDROGEN DELIVERY BARRIERS

(♦ = Number of Votes) Pertains to (P = pipelines, F = fueling stations, O= other, e.g., barge, rail, truck)

SCIENTIFIC	ENGINEERING	ENVIRONMENTAL	INSTITUTIONAL	ECONOMIC	MARKET
Strategy on carrier media (P, F, O) ♦♦♦♦♦♦♦♦♦♦ ▪ Cost effective means of converting good H <sub>2</sub> carrier (methanol, ammonia) to H <sub>2</sub> ▪ Multiple infrastructures	Technical solutions to H <sub>2</sub> dispensing are not mature (F) ♦♦♦♦♦	Lack of full social costing of alternatives (P, F, O) ♦♦♦♦♦♦♦♦♦♦	Codes and standards don't include H <sub>2</sub> (P, F, O) ♦♦♦♦♦♦♦♦♦♦ ▪ No clear definition of safety criteria ▪ National and international lack of harmonization	Transitional strategy missing (P, F, O) ♦♦♦♦♦♦♦♦♦♦ ♦♦♦♦♦ ▪ Chicken and egg dilemma, economics for fueling depend on volume ▪ Today's dollars, funding for 2020 projects ▪ Lack of investment strategy that matches developing market	Customer expectations (P, O, F) ♦♦♦♦♦♦♦♦♦♦ ▪ Dispensing ▪ Cost performance ▪ Safety
Lack of life cycle environmental impact to all options (P, F, O) ♦♦♦♦♦♦♦♦♦♦	Design criteria (P, F, O) ♦♦♦♦♦ ▪ Materials ▪ Multi-gas usage ▪ Ability to engineer refueling facility to be self-serve ▪ Compatibility	Liquefaction is energy intensive (O) ♦♦♦♦♦ ▪ Greenhouse gases	Community acceptance (P, F, O) ♦♦♦♦♦ ▪ Local interests vs. state/national	Cost of H <sub>2</sub> technologies higher than current technologies (P, F, O) ♦♦♦♦♦♦♦♦♦♦	Match between demand and production (P, F, O) ♦♦♦♦♦
Proprietary aspects (P, F, O) ♦ ▪ Materials data not published	Firm understanding of required purity (P, F, O) ♦♦♦♦♦ ▪ Fuel cells require pure H <sub>2</sub> , current fuels use mercaptans	Environmental concerns with fossil carbon-based feedstock (P, F, O)	Conflicting regulatory jurisdictions (P, F, O) ♦♦♦♦♦	Risk mitigation (P, F, O) ♦♦♦♦♦♦♦♦♦♦ ▪ Investment financial assurance	What are the final delivery points (P) ♦
	CNG not typically at service station (P, F)		Lack of experience and knowledge for operation and maintenance of H <sub>2</sub> technologies (F) ♦♦♦♦♦	Access to affordable capital (P) ♦♦♦♦♦♦♦♦♦♦	Defined value for carbon (P, F, O) ♦
	What is the key H <sub>2</sub> application (P, F, O) ▪ Design requirements		Political resistance to mandates (P, F, O) ♦	Liquid H <sub>2</sub> (F, O) ♦♦♦♦♦ ▪ Cost to liquefy ▪ Transport/storage cost	Lack of knowledge for multi-gas pipelines (P) ♦ ▪ Market/cost?
			Codes/permits (O) ♦ ▪ Access to roads ▪ Safety perception ▪ H <sub>2</sub> venting during transportation	Current weight and capacity of tube trailers (O) ▪ Compressed hydrogen has low energy density ▪ Poor economics for transport over long distance	Storage for local distribution (bulk) (P, F, O)
			Right of way (P) ♦		
			Lack of national management structure (P) ♦		



R&D	DEMONSTRATIONS	ANALYSIS	POLICY	CODES & STANDARDS	OUTREACH
			(P, F, O) ♦		
Study co-mingling hazards with other fuels (F) ♦	Customer expectations (F) <ul style="list-style-type: none"> <li>Need “community outreach” demo (e.g., public transportation, rental cars, etc.)</li> </ul>	Systems analysis of each media for different distances and regions (P, F, O) ♦♦	Expand/upgrade natural gas supply infrastructure (P, F, O)		
Need more efficient and economical transportation containers (F, O) ♦		Need stakes in the ground about what the technology is (P, F, O) <ul style="list-style-type: none"> <li>Technical milestones so that fuel delivery and conversion technologies progress together</li> </ul>			
Develop and install intelligent sensor system for leaks (P, F, O)		Design hydrogen transmission and distribution system (P, F, O) ♦ <ul style="list-style-type: none"> <li>National level</li> </ul>			
		Probabilistic risk assessment of systems (P, F, O)			
		Assess the potential impact of existing infrastructure stranded assets (P, F, O)			
		Realistic analysis of demand and production (P, F, O)			
		Conduct geographic information systems analysis for pipeline planning (P)			
		Complete design evaluation of existing pipelines (P)			

## HYDROGEN DELIVERY TOP NEEDS

(♦ = Number of Votes) Pertains to P = pipelines, F = fueling stations, O= other, e.g., barge, rail, truck  
 I = Industry, G = Government, N = National labs, U = Universities, A = Association  
 (Capital letters: lead, Lower case letters: contributors)

NEED	ROLE	EXPECTED TO OCCUR BY
Analyze current infrastructure suitability for future use (P, F, O) ♦♦♦♦♦♦♦♦	I/G	Prior to 2005
Environmental- establish consensus on total costs of fuel alternatives (F, O) ♦♦♦♦♦♦♦♦♦♦	G, n, u	2005
Better access to existing info (P, F, O) ♦♦♦♦	G, I, u, n	2005
Transition strategy- quantify the vision, need milestones (e.g., economic, performance, efficiency) (P, F, O) ♦♦♦♦♦♦♦♦	I/G, n, u	2010
Improve financial incentives (P, F, O) ♦♦♦♦♦♦♦♦♦♦ Tax, R&D, demos, govt. as a customer	G	2010
Tech validation to address R&D (F) ♦♦♦♦ ▪ High pressure breakaway, sensors, fueling protocol, robotic refueling, compressors, onsite production, establish public/private partnerships on refueling system/components	I, n	2010
Public outreach materials (F) ♦♦♦♦ ▪ Branding/marketing, education, novel benefits	I (A), g, u, n	2010
Support codes and standards development ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ▪ Harmonize codes and standards, technical expertise, data access, test and evaluation, assure cost effective standards, installation standards, assure system compatibility	I (A), g	2010
Develop options that address all potential delivery points (P, F, O) ♦♦♦♦♦♦♦♦	I	2020
Need government sponsored projects in the infrastructure components, e.g., more efficient/economical compressors (P, F, O) ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ▪ Develop demo roll-out plan (start with several states) to establish delivery (P, O) ♦♦♦♦♦♦♦♦ ▪ Include integration of components, government pilot testing of refueling (similar to CNG)	G/I	2005 Develop demo roll-out plan 2010 Design feasibility 2030 Commercialization





TOP VOTE-GETTING NEEDS	NEED DESCRIPTION	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
	<ul style="list-style-type: none"> <li>Govt. funding and tax credits/incentives- federal, state, and local incentives, including R&amp;D</li> <li>Govt. initiate program to purchase hydrogen technologies and implement delivery</li> <li>Implement govt. hydrogen fleet vehicle program to include refueling</li> <li>Govt. issue RFPs on demos for various hydrogen delivery methods (CRADAs, IP concessions, licensing)</li> </ul>			<ul style="list-style-type: none"> <li>Federal govt. implement tax credits</li> </ul>
<p>Transition strategy ♦♦♦♦♦♦♦♦</p> <ul style="list-style-type: none"> <li>Quantify the vision</li> <li>Need milestones (e.g., economic, performance, efficiency)</li> </ul>	Gaining consensus between industry, government, academia on roadmap for transition to hydrogen economy (Delivery of hydrogen)- this should include R&D needs such as identified in this workshop	<ul style="list-style-type: none"> <li>DOE roadmap workshop (2002)</li> <li>Circulate draft widely (2002)</li> <li>Consider existing milestone data (e.g., economic, performance, efficiency) such as NHA Hydrogen Commercialization Plan, NHA Implementation Plan, HTAP reports, multiyear hydrogen R&amp;D plan, etc. synthesized- prior to finalizing roadmap</li> </ul>	<ul style="list-style-type: none"> <li>Federal govt. (DOE) hosts workshop(s)</li> <li>Industry through participation, association consensus, input</li> <li>Federal govt. (DOE) funds facilitators</li> </ul>	<ul style="list-style-type: none"> <li>Collect and synthesize hydrogen roadmaps and plans for quantifying the vision (DOE, NHA, academia, others)</li> <li>Circulate draft roadmap/master plan</li> <li>Collect and incorporate comments</li> <li>Publish final report</li> <li>Education and outreach on vision</li> </ul>
<p>Develop options that address all potential delivery points ♦♦♦♦♦♦♦♦</p>	Identify the option that will supply hydrogen to multiple end users- refueling (comm./retail), industrial parks, retail industry, homes, office buildings	<ul style="list-style-type: none"> <li>Team and budget (2003)</li> <li>Inventory current options and upstream segments (2004)</li> <li>Gap analysis and requirements (2004)</li> <li>Functional analysis of delivery needs (2004)</li> <li>Monitor technology advancement (2004-2020)</li> </ul>	<ul style="list-style-type: none"> <li>Industry</li> </ul>	<ul style="list-style-type: none"> <li>Assemble core group of government and industry</li> <li>Develop information sharing forum/mechanism</li> </ul>
<p>Analyze current infrastructure suitability for future use ♦♦♦♦♦♦♦♦</p>	Better understand existing delivery systems, capacities, potential adaptability to support H <sub>2</sub> - H <sub>2</sub> pipelines, NG pipelines (trans/service), refineries, product terminals/ pipelines, logistics, LNG, LH <sub>2</sub> plants, GH <sub>2</sub> system, gasoline refuel	<ul style="list-style-type: none"> <li>Form team and budget (2002)</li> <li>System inventory (2002)</li> <li>Analyze systems- forecast market, costs, feasibility, opportunities (2003)</li> <li>Report out (2003)</li> </ul>	<ul style="list-style-type: none"> <li>DOE</li> <li>Industry in-kind</li> </ul>	DOE and industry form team

TOP VOTE-GETTING NEEDS	NEED DESCRIPTION	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
Public outreach materials ♦♦♦♦ <ul style="list-style-type: none"> <li>• Branding/marketing, education, novel benefits</li> </ul>	Persuade the public that hydrogen is safe to transport as well as convenient and environmentally friendly	<ul style="list-style-type: none"> <li>• Develop education program for hydrogen targeted for different sectors of population (2003)</li> <li>• Roll out education program (2004)</li> </ul>	<ul style="list-style-type: none"> <li>• Industry</li> <li>• Government</li> </ul>	Assign task to outreach group
Tech validation to address R&D ♦♦♦ <ul style="list-style-type: none"> <li>• High pressure breakaway, sensors, fueling protocol, robotic refueling, compressors, on-site production, establish public/private partnerships on refueling system/components</li> </ul>	Testing and validation of components and subsystems used in providing hydrogen to the consumer with evidence of safe operation satisfactory to permitting authorities	<ul style="list-style-type: none"> <li>• Establish an organization including insurance, government, national labs, and industry to perform testing and certification (end of 2003)</li> <li>• Identify components requiring validation and develop testing protocols (end of 2004)</li> <li>• Conduct testing and validation (ongoing)</li> </ul>	<ul style="list-style-type: none"> <li>• Government</li> <li>• Industry</li> <li>• Insurance providers</li> </ul>	Organize testing and validation workshop including all key players (Nov 2002)
Better access to existing info ♦♦♦	Better access to non proprietary information relating to the delivery of hydrogen to avoid duplication of efforts and get a full understanding of what has already been done and currently ongoing	<ul style="list-style-type: none"> <li>• ID appropriate DOE entity (Oct 2002)</li> <li>• Survey available information from government, industry and associations (June 2003)</li> <li>• Build database (Sept 2003)</li> <li>• Enhance website (Mar 2004)</li> <li>• Routine updates (Annual)</li> <li>• Engage EIA (2003)</li> </ul>	<ul style="list-style-type: none"> <li>• Government</li> </ul>	Steve Chalk to build intra agency team

# SECTION 4

## HYDROGEN STORAGE BREAKOUT SESSION

- **Barriers:** What are the scientific, environmental, engineering, market, institutional, education, and economic barriers for general, physical, and non-physical storage technologies that interfere most with achieving the vision?
- **Needs:** What are the most important needs for storage devices, including codes and standards, crosscutting, education, process, materials, technologies, financing, and others to address the barriers?
- **Next steps:** What are the top priority needs, key milestones, primary funding entities, and primary performing entities for the next steps?

### Participants:

NAME	ORGANIZATION
George Thomas	Sandia National Laboratory
Richard Uchirin	Activated Metals Technologies
Alan Niedzwiecki	Quantum Technologies
Kenichi Sakamachi	JMC USA
Andrew Haaland	Thiokol Propulsion
John Barclay	CryoFuel Systems, Inc.
David DaCosta	Ergenics, Inc.
Katherine McHale	Millennium Cell, Inc.
Randy Schaffer	Structural Composite Inc.
Danesh Chandra	University of Nevada, Reno
Stephen Tang	Millennium Cell, Inc.
William Summers	Savannah River Technology Center
Gregory Schuckman	Florida Solar Energy Center
Andy Abele	Quantum Technologies
Robb Thompson	Dynetek Industries
Jim Ritter	University of South Carolina
Duane Adams	Minnesota Corn Growers Association
Adam Pivovar	National Institute of Standards Technology
Vesna Scepanovic	Natural Resources Canada
Rosa Young	Chevron Texaco Ovonic Hydrogen Systems LLC
Patricia Watson	Dupont
Dale Tiller	Lincoln Composites
Terrence Udovic	National Institute of Standards & Technology
George Fenske	Argonne National Laboratory

**FACILITATOR:** Jennifer Miller, Energetics, Inc. (assisted by Jamie McDonald)



STORAGE TYPE	SCIENTIFIC	ENVIRONMENTAL	ENGINEERING	MARKET	INSTITUTIONAL	EDUCATION	ECONOMIC
				technologies ♦ ▪ Lack of industry leadership in setting high standards for H2 safety and performance			
Physical			▪ Lack of more efficient liquefier technology (FOM >0.5) ♦♦ ▪ Lack of “zero loss” cryogenic tanks that are “smart” ▪ Manufacturing process		▪ No DOT standards for type 3 & 4 tanks for bulk transport and stationary applications ▪ Lack of what pressures will be supported by OEM’s & infrastructure (350 bar, 700 bar?)	▪ Lack of education about “cryogenic” characteristics of gaseous energy systems	▪ Cost reduction in composite materials ♦ ▪ Need for lower cost liquefier technology (1. base load, 2. internal, 3. distributed scales) ♦
Non Physical	▪ Lifetime of existing metal hydride materials ♦♦ ▪ Fast charging of H2 for storage in MH ♦ ▪ Lack of storage media with high density, reversible, low temperature H2 and CH4 ♦♦♦♦♦♦♦♦♦♦ ▪ Inadequate volumetric density in nanotubes ▪ NaAlH4 viable charge/discharge T&P’s for portable applications		▪ safety aspects of “storage material plus H2”		▪ No definition of “fast-charging” ▪ Standards for storage of H2 in MH ♦♦♦		▪ Raw material supply/demand (carbon fiber) ♦

## HYDROGEN STORAGE NEEDS

(♦=Vote for top priority)

(N = near-term < 2010, M = mid-term 2010 < 2020, L = long-term > 2020)

CODES & STANDARDS	CROSSCUTTING	EDUCATION	PROCESS	MATERIALS	TECHNOLOGIES	FINANCING	OTHER
<ul style="list-style-type: none"> <li>▪ Alignment of government and other agencies to develop codes and standards ♦♦♦♦♦♦♦♦♦♦ (N)                             <ul style="list-style-type: none"> <li>- Set up consortium to demonstrate storage technologies</li> </ul> </li> <li>▪ Develop appropriate codes and standards that will allow for new technologies to grow ♦</li> <li>▪ Need to look at process to develop codes and standards ♦</li> </ul>	<ul style="list-style-type: none"> <li>▪ Hydrogen permeation and detection (sensors)</li> <li>▪ Require “wellhead-to-wheels” energy efficiency analysis for all storage technologies ♦♦♦♦ (N)                             <ul style="list-style-type: none"> <li>- Thermodynamic limitations</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ A k-12 and beyond program needs to be developed on H2 storage (gaseous, cyro, and solid state)</li> <li>▪ Education and outreach program for localities</li> </ul>	<ul style="list-style-type: none"> <li>▪ Processes for developing tanks for mass production ♦♦♦♦♦♦ (N)</li> <li>▪ Research support for cost reductions in production process of H2 fuel from chemical hydrides ♦ (N)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Integrated and accessible research network incorporating all government agencies providing funding</li> <li>▪ Coordinated national program to develop alanates (M), carbon storage (L), metal hydrides (N), and chemical (M) ♦♦♦♦♦♦♦♦♦♦ ♦</li> <li>▪ Stability of hydrides under cyclic loading (long term studies) ♦♦♦ (M)                             <ul style="list-style-type: none"> <li>- Mechanism study (alanates, C structure)</li> </ul> </li> <li>▪ Improved fiber and resin performance ♦♦♦♦♦ (N)                             <ul style="list-style-type: none"> <li>- lower cost storage technologies</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Design for “customer acceptance” technology assessment for H2-fuels (especially storage) ♦♦ (N)</li> <li>▪ Need for storage technologies for heavy duty vehicles ♦♦ (M)</li> <li>▪ R&amp;D needs to focus on solid state material systems design and optimization (heat management, etc) ♦♦♦♦ (M)</li> <li>▪ Integrated systems (storage with metering, etc) ♦♦♦ (N &amp; M)                             <ul style="list-style-type: none"> <li>- Heat integration on-board MH system (reversible)</li> </ul> </li> <li>▪ Zero-loss tank (cyro storage)</li> <li>▪ Health monitoring technology (cycle counting, strain monitoring) ♦♦ (N)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Each government agencies needs to have a H2 funding program ♦♦♦♦♦</li> <li>▪ Increase in funding ♦♦♦♦♦♦♦</li> <li>▪ H2 cross-cutting program</li> <li>▪ More cohesive national presence among all interest parties ♦</li> <li>▪ Expand range of storage technologies supported ♦♦♦♦♦♦♦♦♦♦ ♦♦ (L)</li> <li>▪ Encourage industry funding (oil companies) ♦</li> <li>▪ An out of the box call for proposals needs to be offered beyond exploratory ♦♦♦♦♦♦♦ (N)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Large demos to expedite codes and standards ♦♦♦♦ (L)                             <ul style="list-style-type: none"> <li>- large scale for different storage technologies</li> <li>- raise visibility re (safety, codes &amp; standards)</li> </ul> </li> <li>▪ Streamline implementation of H2 (mobile) technology</li> <li>▪ Kinetics of hydrogen uptake and discharge ♦</li> </ul>



CODES & STANDARDS	CROSSCUTTING	EDUCATION	PROCESS	MATERIALS	TECHNOLOGIES	FINANCING	OTHER
				<ul style="list-style-type: none"> <li>▪ Novel/new materials (clays, glass spheres, others) ♦♦♦♦ (L)</li> <li>▪ Hydrogen embrittlement, stress corrosion cracking, permeation ♦ (continuous)</li> <li>▪ Program to develop high risk technologies ♦♦♦ (N)</li> </ul>			

## HYDROGEN STORAGE NEXT STEPS

TOP PRIORITY NEEDS	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	PRIMARY PERFORMING ENTITIES	NEXT STEPS
Large scale demos for storage technologies	<ul style="list-style-type: none"> <li>▪ Demonstrate performance</li> <li>▪ Public acceptance</li> <li>▪ Codes &amp; standards</li> <li>▪ Mobile</li> <li>▪ Stationary</li> </ul>	<ul style="list-style-type: none"> <li>▪ CG, CH<sub>2</sub>, Metal hydrides - ongoing</li> <li>-Performance</li> <li>-Public acceptance</li> <li>-Codes &amp; standards</li> <li>▪ Alanates – 2007</li> <li>▪ Carbon, other - 2010</li> </ul>	<ul style="list-style-type: none"> <li>▪ Cost shared between government and industry</li> </ul>	<ul style="list-style-type: none"> <li>▪ Industry</li> <li>▪ National labs</li> </ul>	<ul style="list-style-type: none"> <li>▪ Demonstrate new technologies as developed</li> </ul>
Develop improved materials for containment	<ul style="list-style-type: none"> <li>▪ Lower cost</li> <li>▪ Higher performance (fibers &amp; resins, etc) tanks</li> <li>▪ Reversible &amp; irreversible hydrides, carbon, etc</li> <li>▪ Chemical</li> </ul>	<ul style="list-style-type: none"> <li>▪ viable storage by 2010</li> <li>▪ visible technology demonstrations by 2005</li> <li>▪ application specific with other hydrogen technologies</li> </ul>	<ul style="list-style-type: none"> <li>▪ Government and industrial base</li> </ul>	<ul style="list-style-type: none"> <li>▪ Technology: Government, academic, and industrial partners</li> <li>▪ Market: Industry – industry partnership</li> </ul>	<ul style="list-style-type: none"> <li>▪ Continued optimization of non traditional materials (composites, high risk, unknown)</li> </ul>
Alignment of government and other agencies to develop codes and standards	<ul style="list-style-type: none"> <li>▪ Alignment of C&amp;S agencies needed to complete in time for need</li> </ul>	<ul style="list-style-type: none"> <li>▪ Establish lead person in government - 2003</li> <li>▪ Establish coordinated U.S. effort - 2005</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOT</li> <li>▪ DOE</li> <li>▪ Industry</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOT</li> <li>▪ National Laboratories</li> <li>▪ Industry (SAE, CGA)</li> </ul>	
Materials performance under unique or extreme conditions	<ul style="list-style-type: none"> <li>▪ Fully understand effects of extreme conditions on new containment systems to ensure safety</li> </ul>	<ul style="list-style-type: none"> <li>▪ Now and ongoing effort</li> <li>▪ Establish database &lt;2010</li> <li>▪ Define test protocol &lt;2010</li> <li>▪ Test new materials – on going</li> </ul>	<ul style="list-style-type: none"> <li>▪ Government agencies (DOT, DOE)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Established by: national labs and universities</li> <li>▪ Ongoing validation by independent testing organizations</li> </ul>	<ul style="list-style-type: none"> <li>▪ Establish database on existing materials</li> <li>▪ Define performance and test criteria</li> </ul>
Process for developing mass production H <sub>2</sub> storage	<ul style="list-style-type: none"> <li>▪ Need for process with interim steps to go from lab scale to full mass production</li> <li>▪ Transition from R&amp;D to high-speed, high volume manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>▪ Compressed - &lt;2010</li> <li>-System development progress</li> <li>-Inspection techniques</li> <li>▪ Metal &lt; 2010</li> <li>▪ Chemical &lt;2020</li> <li>-Market pull to drive production efficiency</li> </ul>	<ul style="list-style-type: none"> <li>▪ Industry</li> <li>▪ DOD</li> <li>▪ DOE</li> <li>▪ Cost shard effort between government and industry partnership</li> </ul>	<ul style="list-style-type: none"> <li>▪ Industry</li> <li>▪ Universities</li> <li>▪ National labs</li> </ul>	<ul style="list-style-type: none"> <li>▪ Define actual programs</li> <li>▪ Solicit funding</li> <li>▪ Consider government incentives to create markets</li> <li>▪ Broad area announcement to industry, national labs, and universities</li> </ul>
Develop novel/new material	<ul style="list-style-type: none"> <li>▪ Need better performing, lower cost storage</li> </ul>	<ul style="list-style-type: none"> <li>▪ Demonstrate new materials – 2010</li> <li>▪ Establish program,</li> </ul>	<ul style="list-style-type: none"> <li>▪ Government</li> <li>▪ Some industry (in kind, tax credit)</li> </ul>	<ul style="list-style-type: none"> <li>▪ National labs</li> <li>▪ Universities</li> <li>▪ Industry</li> </ul>	<ul style="list-style-type: none"> <li>▪ Call for proposals</li> </ul>

TOP PRIORITY NEEDS	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	PRIMARY PERFORMING ENTITIES	NEXT STEPS
		<ul style="list-style-type: none"> <li>make awards – 2004</li> <li>Identify new candidate – 2007</li> </ul>			
Program for high risk technologies	<ul style="list-style-type: none"> <li>Freedom to pursue non-obvious technology solutions independent of traditional performance metrics</li> </ul>	<ul style="list-style-type: none"> <li>Specific accessible funding routes in place by 2004</li> <li>Develop high risk technology roadmap &amp; funding profile ASAP (2003)</li> </ul>	<ul style="list-style-type: none"> <li>Government</li> </ul>	<ul style="list-style-type: none"> <li>Government labs</li> <li>Academia</li> <li>Industry</li> </ul>	<ul style="list-style-type: none"> <li>Establish a steering committee to develop long-term technology roadmap and funding profile</li> </ul>
Achieve a funding level commensurate with importance of storage	<ul style="list-style-type: none"> <li>Lack of funding to investigate all material possibilities (development and discovery)</li> </ul>	<ul style="list-style-type: none"> <li>Rapid jump in near term</li> <li>&gt;\$100M by 2005 (minimum)</li> </ul>	<ul style="list-style-type: none"> <li>DOE</li> <li>DOT</li> <li>US Armed services</li> <li>Industry (proprietary)</li> </ul>	<ul style="list-style-type: none"> <li>Near term – Gov approximately 80% and decrease level of involvement as time progresses</li> <li>Near term – Industry approximately 20% and increases as time progresses</li> <li>Unsure as to whether energy companies should play a role</li> </ul>	<ul style="list-style-type: none"> <li>Maintain a reasonable level that is commensurate with demands and needs over time</li> </ul>
Have a coordinated national program to develop H2 storage materials	<ul style="list-style-type: none"> <li>Need for funded national program for advanced materials research to improve performance and reduce cost</li> <li>Alanes</li> <li>Carbon structures</li> <li>Metal hydrides</li> <li>Chemical</li> </ul>	<ul style="list-style-type: none"> <li>ID areas of research - &lt;2010</li> <li>Set up funding - &lt;2010</li> <li>Manage program</li> <li>-Existing technologies 2010&lt;2020</li> <li>-New materials &gt;2020</li> </ul>	<ul style="list-style-type: none"> <li>Government</li> <li>Industry</li> </ul>	<ul style="list-style-type: none"> <li>Industry</li> <li>Universities</li> <li>National labs</li> </ul>	<ul style="list-style-type: none"> <li>ID level of funding needed</li> <li>Secure funding</li> </ul>

## HYDROGEN ENERGY CONVERSION BREAKOUT SESSION

- **Barriers:** What are the scientific, engineering, market, financial, and institutional barriers that interfere most with achieving the vision?
- **Needs:** What are the most important needs for fuel cells and combustion devices, including research, technology development, demonstration, codes and standards, analysis, institution building, market development, legislation, and education and training?
- **Paths forward:** What are the top priority needs including, their scopes, key milestones, next steps, and partnerships?

### Participants:

NAME	ORGANIZATION
Tim Armstrong	Oak Ridge National Laboratory
Gordon Gillerman	Underwriters Laboratories
Shiro Matsuo	Honda R&D America
Tad Wyser	U.S. Environmental Protection Agency
Faruq Marikar	Consultant
David Lax	American Petroleum Institute
Dan Smith	GE Research
Jim Miller	Argonne National Laboratory
Don Hardesty	Sandia National Laboratory
Bill Ernst	Plug Power
Wison Luangdilok	Fauske & Associates
Brent Gerdes	Lincoln Composites
Krishna Sapru	Energy Conversion Devices
Bill Smith	Proton Energy Systems
John Donohue	DCH Technology
George King	Houston Advanced Research Center
Rich Carlin	Office of Naval Research
John Celentano	Startech Environmental Corporation
Dexter Sutterfield	National Energy Technology Laboratory
John Baker	JMC (USA), Inc.
Nancy Garland	U.S. Department of Energy
Mike Davis	Avista Labs
Francis Lau	Gas Technology Institute
Stacy Klein	Hart Downstream Energy Services
Richard Sassoon	SAIC

**FACILITATOR:** Rich Scheer, Energetics, Inc. (assisted by Tara Nielson)

## HYDROGEN ENERGY CONVERSION BARRIERS

(◆=Vote for top priority)

SCIENTIFIC	ENGINEERING	MARKET <i>(Both Fuel Cells and Combustion)</i>	FINANCIAL	INSTITUTIONAL <i>(Both Fuel Cells and Combustion)</i>
<p><b>FUEL CELLS</b></p> <ul style="list-style-type: none"> <li>• Lack of fundamental understanding prevents “marriage” of electrochemistry with materials science ◆◆◆◆◆◆◆◆◆◆</li> <li>• Insufficient focus and coordination of current R&amp;D programs ◆◆◆</li> <li>• Unsolved sealing, joining, and interconnect materials issues in SOFC ◆◆◆</li> <li>• Lack of fundamental understanding prevents progress in making fuel cells more durable and affordable</li> </ul> <p><b>COMBUSTION</b></p> <ul style="list-style-type: none"> <li>• Lack of understanding about safety implications of H<sub>2</sub> combustion properties ◆◆</li> <li>• Lack of low cost materials in combustion systems for using H<sub>2</sub> ◆</li> </ul>	<p><b>FUEL CELLS</b></p> <ul style="list-style-type: none"> <li>• High costs of materials and manufacturing for all fuel cell types ◆◆◆◆◆◆◆◆◆◆</li> <li>– Membranes and catalysts for PEMs</li> <li>• Unproven durability and reliability of performance ◆◆◆◆◆◆◆◆◆◆</li> <li>– Lack of demonstrated service life and performance</li> <li>• Start-up time less than needed (depends on fuel cell type and application) ◆◆◆</li> <li>• Safety issues have not been adequately addressed (for both fuel and fuel cell) ◆</li> <li>• Unsolved corrosion issues in MCFC</li> <li>• Questions about performance under differing environmental conditions and geographic locations</li> </ul> <p><b>COMBUSTION</b></p> <ul style="list-style-type: none"> <li>• Lack of proven engine and turbine performance using H<sub>2</sub> ◆◆◆◆◆◆◆◆◆◆</li> <li>– Emissions</li> <li>– Efficiency</li> <li>– Safety</li> <li>– Vehicle range, power versus load, use in heavy duty vehicles</li> <li>• Lack of understanding about flame requirements and impacts on engine designs ◆◆◆◆</li> <li>– Flame management in turbines</li> <li>• Combined cycle combustion turbines using natural gas are relatively clean and very efficient, why use H<sub>2</sub>?</li> </ul>	<ul style="list-style-type: none"> <li>• Market (Both Fuel Cells and Combustion)</li> <li>• No market pull for clean power ◆◆◆◆◆◆◆◆◆◆</li> <li>• Oil is cheap (public has short memory) ◆◆◆◆◆</li> <li>• No value proposition for using H<sub>2</sub> rather than fossil fuels ◆◆◆◆◆</li> <li>• No clear business model for profitable widespread distributed energy market ◆◆◆◆◆</li> <li>• No H<sub>2</sub> fueling infrastructure◆</li> <li>• Public has no idea of H<sub>2</sub> advantages ◆</li> </ul>	<p><b>FUEL CELLS</b></p> <ul style="list-style-type: none"> <li>• Overly optimistic projections of fuel cell business growth</li> <li>• Lack of incentives to address high capital costs ◆</li> </ul> <p><b>COMBUSTION</b></p> <ul style="list-style-type: none"> <li>• Turbines will outperform reciprocating engines for locomotive/marine applications but will be much more expensive</li> </ul> <p><b>BOTH FUEL CELLS AND COMBUSTION</b></p> <ul style="list-style-type: none"> <li>• Financial markets have no confidence in the predictability/stability of this sector ◆◆◆◆◆◆◆◆◆◆</li> <li>– Lack of commercial drivers</li> <li>• Large risks of being overcome by competing technologies ◆◆◆</li> <li>• No source of “patient” capital ◆</li> <li>• No clear early market leader for development or adoption</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of coordinated development of technical requirements and conformity assessment methods to deliver necessary confidence in safety and reliability ◆◆◆◆◆◆◆◆◆◆</li> <li>– Lack of product safety standards</li> <li>– Lack of building and utility codes</li> <li>• Lack of clear national policies for H<sub>2</sub> and conversion devices ◆◆◆◆◆◆◆◆◆◆</li> <li>– Lack of sufficient and sustained R&amp;D funding</li> <li>– No value for carbon reduction/sequestration</li> <li>• Lack of national support for enforcement of higher efficiency/cleaner air regulations (e.g. CAFÉ) ◆</li> <li>– No legislation that compels action</li> <li>– Not enough tax credits</li> </ul>

## HYDROGEN ENERGY CONVERSION NEEDS

(♦=Vote for top priority)

[I=Industry; G=Government; U=Universities; L=National labs; SD=Standards developing organizations]

[N\*= by 2005; N= by 2010; M= by 2020;L= by 2030]

FUNDAMENTAL RESEARCH FOR FUEL CELLS	TECHNOLOGY DEVELOPMENT FOR FUEL CELLS	FUNDAMENTAL RESEARCH FOR COMBUSTION	TECHNOLOGY DEVELOPMENT FOR COMBUSTION	DEMONSTRATIONS OF FUEL CELLS AND COMBUSTION DEVICES	CODES AND STANDARDS FOR BOTH FUEL CELLS AND COMBUSTION
<ul style="list-style-type: none"> <li>• Electrochemistry ♦♦♦ I&amp;G; N-M-L</li> <li>• Interface ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ I&amp;G; N-M-L                             <ul style="list-style-type: none"> <li>– Ceramics</li> <li>– Characterization methods</li> <li>– Degradation mechanisms</li> <li>– High temperature PEMs</li> <li>– Low temperature SOFCs</li> </ul> </li> <li>• Materials Science ♦♦♦♦ I&amp;G; N-M-L                             <ul style="list-style-type: none"> <li>– Stack materials</li> <li>– Oxygen cathodes</li> <li>– Membranes</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Enhanced manufacturing capabilities ♦♦♦♦♦ I; N-M-L                             <ul style="list-style-type: none"> <li>– Large volumes</li> <li>– Better consistency and quality control</li> <li>– Better fabrication techniques</li> </ul> </li> <li>• Expanded consideration of all types of fuel cells ♦♦♦♦ G; N</li> <li>• Component cost reductions through a more reliable supply chain ♦♦♦ I; N*                             <ul style="list-style-type: none"> <li>– E.g., Lower cost power electronics</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Higher efficiency H<sub>2</sub> engines and turbines ♦♦♦♦♦♦♦♦♦♦ I&amp;G;N-M-L                             <ul style="list-style-type: none"> <li>– Higher temperature materials</li> <li>– Better sensors and instrumentation</li> <li>– H<sub>2</sub>-fossil fuel blending</li> </ul> </li> <li>• Better techniques for H<sub>2</sub> combustion management and control ♦♦ I&amp;G;N-M-L</li> </ul>	<ul style="list-style-type: none"> <li>• Engine designs and after treatment controls for low NO<sub>x</sub> ♦♦♦♦♦♦♦ I; N                             <ul style="list-style-type: none"> <li>– Engines</li> <li>– SCR for turbines</li> </ul> </li> <li>• In-situ use of H<sub>2</sub> as a NO<sub>x</sub> reducing agent ♦♦ I; N</li> <li>• Integrated H<sub>2</sub> storage release and engine/turbine controls ♦♦♦ I; N</li> <li>• Recip engine designs and controls for H<sub>2</sub> blends ♦♦ I; N*</li> <li>• Turbine designs and controls for H<sub>2</sub> blends ♦ I; N</li> <li>• H<sub>2</sub> catalytic combustors and controls for large turbines ♦ I; N</li> <li>• Better H<sub>2</sub> sensors for leak controls ♦ I; N*</li> <li>• Lower cost components, e.g., fuel injectors, sensors</li> </ul>	<ul style="list-style-type: none"> <li>• Expand existing demonstrations of fuel cells, IC engines, and turbines in both stationary, mobile, and portable applications ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ G; N*                             <ul style="list-style-type: none"> <li>– Power parks and fueling stations</li> <li>– Test for reliability of advanced materials</li> <li>– Test for durability of performance</li> </ul> </li> <li>• Validate product attributes by in-service field testing to establish durability, cost effectiveness, and life cycle efficiency ♦ I; N</li> </ul>	<ul style="list-style-type: none"> <li>• Product safety standards for mobile and stationary applications ♦♦♦♦♦♦♦♦ SD;N</li> <li>• Amend/extend existing building, vehicle, utility codes to enable day-to-day business ♦♦♦ SD;N                             <ul style="list-style-type: none"> <li>– Utility interconnection</li> <li>– Power quality</li> <li>– Plumbing and connections</li> </ul> </li> <li>• Safety standards for H<sub>2</sub> fuels and fuel quality ♦♦♦ SD;N</li> </ul>



## HYDROGEN ENERGY CONVERSION NEEDS (CONTINUED)

(♦=Vote for top priority)

[I=Industry; G=Government; U=Universities; L=National labs; SD=Standards developing organizations]

[N\*= by 2005; N= by 2010; M= by 2020;L= by 2030]

ANALYSIS FOR BOTH FUEL CELLS AND COMBUSTION	INSTITUTION BUILDING FOR BOTH FUEL CELLS AND COMBUSTION	MARKET DEVELOPMENT FOR FUEL CELLS AND COMBUSTION	LEGISLATION	EDUCATION AND TRAINING
<ul style="list-style-type: none"> <li>• Market analysis with product requirements and timing ♦♦♦♦ I; N</li> <li>• Catalogue (electronic database) of existing research findings ♦♦♦♦ G; N*</li> <li>• Software tools to simulate vehicle collisions for H<sub>2</sub> fuels ♦♦ I; N</li> <li>• Benefits/impacts of reduced carbon emissions on the environment ♦ G; N*</li> <li>• “Killer applications” for fuel cells</li> <li>• Architecture of H<sub>2</sub> fuel distribution system</li> <li>• Accelerated testing</li> </ul>	<ul style="list-style-type: none"> <li>• Enhance, expand, and integrate fuel cell and H<sub>2</sub> combustion research and form “National Center” for pre-competitive efforts ♦♦♦♦ I&amp;G; N*</li> <li>– Inform industry of national lab resources</li> <li>• Public-private partnerships for bridging technologies</li> <li>• Industry collation building to promote H<sub>2</sub> in IC engines for vehicles</li> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>• Understand and communicate value propositions ♦♦♦♦ I; N*</li> <li>• Attract more investment to finance small fuel cell businesses ♦♦♦♦ I; N*</li> <li>• Guaranteed market will justify H<sub>2</sub> engine development</li> <li>• Large markets will drive cost reductions</li> </ul>	<ul style="list-style-type: none"> <li>• EPA vehicle emissions regulation flexibility for H<sub>2</sub> fueled engines ♦ G; N*</li> <li>• More financial incentives for H<sub>2</sub> conversion technologies</li> <li>• Government mandates to facilitate market development</li> <li>• Net metering</li> </ul>	<ul style="list-style-type: none"> <li>• Installers and technicians</li> <li>• Emergency responders</li> </ul>

## HYDROGEN ENERGY CONVERSION PATHS FORWARD

TOP PRIORITY NEED	SCOPE	KEY MILESTONES	NEXT STEPS	PARTNERS
Fuel Cell Research	<ul style="list-style-type: none"> <li>Broad materials science</li> <li>Improved reliability</li> <li>Improved durability</li> <li>Lower Cost</li> </ul>	<ul style="list-style-type: none"> <li>Catalysts with 50% better performance and 50% cost reduction</li> <li>120-120 degree C PEM</li> <li>500 degree C ionic conductors (400 degree C in ten years)</li> </ul>	<ul style="list-style-type: none"> <li>Evaluate on-going research</li> <li>Re-focus on roadmap priorities</li> </ul>	<ul style="list-style-type: none"> <li>Industry-government partnerships</li> <li>Cost-shared R&amp;D</li> <li>With universities and national labs</li> </ul>
Fuel Cell Technology Development	<ul style="list-style-type: none"> <li>Stacks</li> <li>Components</li> <li>Systems</li> <li>Manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>Evaluate existing program targets</li> <li>Modify as needed</li> <li>Set priorities for cost reduction strategies</li> </ul>		
Fuel Cell Demonstrations	<ul style="list-style-type: none"> <li>Customer involvement</li> <li>Evaluation and dissemination</li> <li>Products not technologies</li> <li>Fleets not individuals</li> </ul>	<ul style="list-style-type: none"> <li>Commercial sale of products</li> <li>Natural outflow of successful technology development</li> <li>Strategy to collect results and disseminate</li> <li>Will happen, challenge is to make valuable</li> </ul>		
Combustion Research	<ul style="list-style-type: none"> <li>Covers all devices and applications</li> <li>Improve power density</li> <li>Optimize “knock management</li> <li>Integrate on-board storage with fuel injection</li> <li>HCCI research</li> <li>Turbine systems fuel injection mixing, dilution, and controls</li> <li>Materials</li> <li>Modeling and analysis of vehicle collisions</li> </ul>	<ul style="list-style-type: none"> <li>Systems analysis of H2 fuel cycle for all devices and applications</li> </ul>	-Expand DOE combustion research activities	<ul style="list-style-type: none"> <li>Industry-government partnerships</li> <li>-Cost-shared R&amp;D</li> <li>-With universities and national labs</li> </ul>
Combustion Technology Development				
Combustion Demonstrations				
Product Safety Standards	<ul style="list-style-type: none"> <li>All fuel cell types</li> <li>Turbines</li> <li>IC engines</li> <li>Stationary and mobile</li> </ul>	<ul style="list-style-type: none"> <li>Select standards developers by 2003</li> <li>Propose standards by 20034</li> <li>Begin development by 2003</li> <li>Publish 2005</li> </ul>		<ul style="list-style-type: none"> <li>UL, IEEE, CGA, ISO, DOT, CSPC, Trade Associations, AHJs, DoD, DOE</li> </ul>
	<ul style="list-style-type: none"> <li>H<sub>2</sub> vehicles</li> </ul>	<ul style="list-style-type: none"> <li>Select standards developers by 2003</li> <li>Propose standards by 20034</li> <li>Begin development by 2003</li> <li>Publish 2005</li> </ul>		<ul style="list-style-type: none"> <li>SAE, DOT, DOE, Insurers, CGA, Auto Associations</li> </ul>

TOP PRIORITY NEED	SCOPE	KEY MILESTONES	NEXT STEPS	PARTNERS
Amend Existing Codes and Regs	<ul style="list-style-type: none"> <li>FCs, turbines, and engines in buildings</li> <li>H<sub>2</sub> plumbing and storage</li> </ul>	<ul style="list-style-type: none"> <li>Select standards developers by 2003</li> <li>Propose standards by 2003/4</li> <li>Begin development by 2003</li> <li>Publish 2005</li> </ul>		<ul style="list-style-type: none"> <li>NFPA, ICC, ASME, DOT, DOE, CSA, CSPC, Insurers</li> </ul>
	<ul style="list-style-type: none"> <li>Utility interconnection</li> </ul>	<ul style="list-style-type: none"> <li>Existing IEEE process</li> </ul>		<ul style="list-style-type: none"> <li>IEEE, DOE, FERC, Trade associations</li> </ul>
National H <sub>2</sub> Energy Conversion Center(s)	<ul style="list-style-type: none"> <li>Semitech model</li> <li>Virtual entity</li> <li>Pre-competitive R&amp;D</li> <li>Fuel cells, engines, reciprocating</li> <li>Stationary and mobile</li> <li>H<sub>2</sub> fuel blends/mixing</li> </ul>	<ul style="list-style-type: none"> <li>Evaluate existing R&amp;D entities in 2002</li> <li>Develop charter for new integrated organization by 2003</li> <li>Establish new organization 2003</li> <li>Develop R&amp;D plan 2--3</li> </ul>		<ul style="list-style-type: none"> <li>Government – DOE, DOD, NASA, DOT, EPA, DOC</li> <li>Industry – Auto, Energy, Equip Manufacturers</li> <li>Labs</li> <li>Universities</li> </ul>
Research Compendium & Database	<ul style="list-style-type: none"> <li>Public domain documents</li> <li>Covers all devices and applications</li> <li>Widespread dissemination</li> </ul>	<ul style="list-style-type: none"> <li>Develop scope and issue competitive solicitation 2002</li> <li>Begin development 2003</li> <li>Working product 2005</li> </ul>		<ul style="list-style-type: none"> <li>DOE and selected contractor</li> </ul>

# SECTION 6

## HYDROGEN APPLICATIONS BREAKOUT SESSION

- **Barriers:** What are the barriers that interfere most with achieving the vision?
- **Needs:** What are the most important needs to undertake between now and 2030 to address the barriers and achieve the vision?
- **Top needs and next steps:** What are the top needs, including their key milestones and dates, primary funding entities, and next steps to addressing them?

### Participants:

NAME	ORGANIZATION
Frank Balog	Ford Motor Company
Ed Bless	H2 Solutions
Andrew Browning	Methanex, Inc.
David Bruderly	Clean Power Engineering
Ken Cameron	General Motors
Rodney Carlisle	History Associates
Kipp Coddington	Covington and Burling
William Craven	DaimlerChrysler
Erin Cready	Sentech, Inc.
James Daley	U.S. Department of Energy
Jason Francque	Deere & Co.
Michael Gan	Hamilton Sundstrand
Norma Glover	South Coast AQMD
Mark Grist	QuestAir Technologies
Michael Hainsselin	Praxair
Jim Hempstead	
Raphael Herz	Massachusetts Renewable Energy Trust

### Participants:

NAME	ORGANIZATION
Peter Johnston	Pinnacle West Capital Corp.
Ferris Kawar	ATTIK
Jay Keller	Sandia National Laboratory
Ben Knight	Honda R&D
Jaimie Levin	Alameda Contra Costa Transit
James Lide	History Associates, Inc.
Maggie Mann	National Renewable Energy Laboratory
Robert Mauro	U.S. TAG ISO TC 197
James Miller	Argonne National Laboratory
Terry Penney	National Renewable Energy Laboratory
Richard Rashilla	Lincoln Composites
Jerry Rogers	GM R&D Center
Michael Romanco	Gas Technology Institute
Andrew Searcy	So. Hydrogen Fuel Cell Research Partnership
Kenneth Stroh	Los Alamos National Laboratory
Bruce Wood	John Deere

**FACILITATORS:** Jack Eisenhauer, Keith Jamison, Energetics, Inc. (assisted by Charlie Smith)

**BARRIERS - APPLICATIONS (MOBILE) (1 of 2)**  
 ☉ = Most Critical Barrier

COMPONENT TECHNOLOGY	SAFETY	CONSUMER AND MARKET ACCEPTANCE	TECHNOLOGY DEVELOPMENT STRATEGY	SUPPORTING INFRASTRUCTURE	COMPETING TECHNOLOGIES, FUELS AND INFRASTRUCTURES	PUBLIC POLICY
<ul style="list-style-type: none"> <li>▪ Lack of on-board storage technology ☉☉☉☉☉☉</li> <li>▪ Demand for hydrogen vehicles is limited by performance/cost ☉☉☉☉</li> <li>▪ Lack of on-board reforming technology ☉☉☉☉</li> <li>▪ Materials limitations ☉                             <ul style="list-style-type: none"> <li>- science</li> <li>- applications</li> </ul> </li> <li>▪ Components:                             <ul style="list-style-type: none"> <li>- radiators</li> <li>- compressors</li> <li>- storage</li> </ul> </li> <li>▪ Cost and functionality of end-use technology</li> </ul>	<ul style="list-style-type: none"> <li>▪ Perceived safety issues ☉☉☉☉☉</li> <li>▪ Developing a safe fueling interface/procedure ☉☉☉</li> <li>▪ Electrical safety issues</li> </ul>	<ul style="list-style-type: none"> <li>▪ Customer perception of cost/benefit ☉☉☉☉☉☉☉☉☉☉</li> <li>▪ Customer acceptance and retraining regarding vehicle range and refueling time ☉☉</li> <li>▪ Perceived lack of public acceptance of hydrogen</li> </ul>	<ul style="list-style-type: none"> <li>▪ Lack of national leadership for long-term strategy ☉☉☉☉☉☉☉☉☉☉☉☉</li> <li>▪ Lack of obvious infrastructure pathway ☉☉</li> <li>▪ Burden of technology development costs for core and enabling technologies ☉☉</li> <li>▪ Planned, incremental technology migration</li> <li>▪ No coordinated plan</li> <li>▪ Lack of innovative technology integration</li> </ul>	<p><b>Fueling</b></p> <ul style="list-style-type: none"> <li>▪ Chicken vs. egg, infrastructure vs. vehicles ☉☉☉☉☉☉☉☉☉☉</li> <li>▪ Limited hydrogen availability ☉☉☉                             <ul style="list-style-type: none"> <li>- lack of hydrogen fueling infrastructure</li> </ul> </li> <li>▪ Hydrogen production technology must draw upon a diverse energy feedstock, must be impact sensitive</li> </ul> <p><b>Other</b></p> <ul style="list-style-type: none"> <li>▪ Parts of the mobile infrastructure ☉☉                             <ul style="list-style-type: none"> <li>- parking garages</li> <li>- service stations</li> </ul> </li> <li>▪ Lack of practical codes and standards ☉☉</li> <li>▪ Lack of mechanics training standards</li> </ul>	<ul style="list-style-type: none"> <li>▪ Low-risk, old technologies inhibit development of new, risky technologies ☉☉☉☉☉☉☉☉☉☉</li> <li>▪ Institutional ☉☉☉☉☉                             <ul style="list-style-type: none"> <li>- stranded cost</li> <li>- regulations</li> </ul> </li> <li>▪ Cost of existing fuels too cheap ☉☉</li> <li>▪ Lack of insurance for risk mitigation (safety and economics) ☉</li> <li>▪ Alternative choices ☉                             <ul style="list-style-type: none"> <li>- fuel cells</li> <li>- ICE's</li> <li>- turbines</li> <li>- stirling</li> </ul> </li> <li>▪ Sunk costs of existing manufacturing technologies, labor structure sales and service network</li> <li>▪ Low consumer cost of existing mobile technologies is hard to overcome</li> </ul>	<ul style="list-style-type: none"> <li>▪ Uncertain long-term program and political commitment (&gt; 20 years) ☉☉☉☉☉☉☉☉☉☉☉☉</li> <li>▪ Lack of a sustained financial commitment from the government ☉☉☉☉☉</li> <li>▪ Conflicting perceptions of "social good" provided by energy ☉☉☉☉</li> <li>▪ Political partnership over energy resource, energy development choice ☉</li> <li>▪ Social benefits not clearly articulated</li> <li>▪ Uninformed decisionmakers</li> <li>▪ Economics of carbon-free generation of hydrogen, reliance on hydrocarbon feedstocks</li> <li>▪ Public perception of problem                             <ul style="list-style-type: none"> <li>- available gas</li> <li>- smog</li> </ul> </li> </ul>

## BARRIERS - APPLICATIONS (STATIONARY) (2 of 2)

⊗ = Most Critical Barrier

INSTITUTIONAL/REGULATORY	MARKET (Mis)PERCEPTIONS	SCIENTIFIC/ENGINEERING	MARKET DEVELOPMENT	EDUCATIONS
<ul style="list-style-type: none"> <li>▪ No premium received for “clean fuel” ⊗⊗⊗⊗⊗⊗                             <ul style="list-style-type: none"> <li>- need environmental driver for conversion</li> </ul> </li> <li>▪ Too much policy emphasis on fuel cells, not enough on ICEs ⊗⊗⊗⊗⊗⊗</li> <li>▪ No national, uniform interconnect standards ⊗</li> <li>▪ Not enough policy emphasis on fuel benefits, public/social costs ⊗</li> <li>▪ Safety codes and standards not generally known (or available) ⊗</li> <li>▪ End-users lack of clarity on siting process</li> <li>▪ Regulatory-hydrogen plants A.Q. permits?</li> <li>▪ Uncertainty with electric power restructuring/ deregulation</li> <li>▪ Central power orientation in institutions and policies</li> <li>▪ Portable, no standard to allow shipping hydrochloride storage containers</li> <li>▪ If zero net CO<sub>2</sub> is a goal, distributed fossil fuel systems are problematic</li> <li>▪ Lack of a supportive consortium for innovative industries</li> <li>▪ Lack of air pollution control integration with industry</li> <li>▪ Pollution costs are external to fuel cost</li> </ul>	<ul style="list-style-type: none"> <li>▪ Perception of hydrogen safety and accident risks ⊗</li> <li>▪ Lack of perceived solutions for hydrogen ⊗</li> <li>▪ Customers may be risk-averse</li> <li>▪ Traditional energy sources viewed as cheap, available, and acceptable</li> <li>▪ Customers’ perception that there is a limited choice of stationary products</li> <li>▪ Unrealistic expectations about opportunity for residential-type applications of PEM ⇒ potentially misdirects funding</li> </ul>	<ul style="list-style-type: none"> <li>▪ <u>Portable</u>: Lack of cheap, efficient, long-lived fuel cell ⊗⊗⊗⊗⊗</li> <li>▪ Fuel cell life is inadequate ⊗⊗⊗⊗</li> <li>▪ <u>Stationary</u>: Cost of hydrogen storage, particularly at locations of low power cost ⊗⊗⊗</li> <li>▪ Cost of hydrogen storage (especially for renewable hydrogen) ⊗⊗⊗</li> <li>▪ Investment communities have short-term payback horizon ⊗⊗⊗</li> <li>▪ Hydrogen systems are too complex ⊗⊗</li> <li>▪ Immature technologies ⊗                             <ul style="list-style-type: none"> <li>- fuel cells</li> <li>- reformers</li> <li>- system integration</li> </ul> </li> <li>▪ Systems not optimized for hydrogen</li> <li>▪ Distributed carbon sequestration with small hydrogen production</li> <li>▪ Limited features of small-scale reformers</li> <li>▪ How to convert natural gas pipeline to hydrogen pipeline?</li> <li>▪ Cost of small-scale reformers</li> <li>▪ Demand changes</li> <li>▪ Fuel cell price per kW too high</li> <li>▪ Cost and storage of renewable energy</li> <li>▪ Limited incentives for utility industry deployment</li> <li>▪ From the utility perspective, cost-compared to natural gas                             <ul style="list-style-type: none"> <li>- wholesale vs. retail</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Lack of support and funding for hydrogen business newcomers ⊗⊗⊗⊗⊗</li> <li>▪ Lack of fuel delivery infrastructure ⊗⊗⊗⊗⊗</li> <li>▪ Little incentive for early adopters ⊗⊗⊗</li> <li>▪ Availability of hydrogen, specialty chemical, not a fuel ⊗⊗⊗</li> <li>▪ Lack of “killer applications” ⊗⊗                             <ul style="list-style-type: none"> <li>- length-of-use issue</li> </ul> </li> <li>▪ Need success on mobile side for stationary adoption ⊗⊗</li> <li>▪ Lack of talent in hydrogen-related industries (human capital) ⊗</li> <li>▪ Lack of coordinated effort for different application areas</li> <li>▪ Applications are small</li> <li>▪ Geographic issues with fuel infrastructure                             <ul style="list-style-type: none"> <li>- need to join with rest of the distributed generation market</li> </ul> </li> <li>▪ No mass production, no product available for hydrogen turbines (MW scale), and hydrogen ICEs (piston)</li> <li>▪ Combined heat and power is not a way of operating in the United States</li> <li>▪ Who will service?                             <ul style="list-style-type: none"> <li>- how often?</li> <li>- disruption?</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Lack of public education (what is driver?), why go to hydrogen? ⊗</li> <li>▪ Lack of knowledge among code officials</li> <li>▪ Need more familiarity with equipments, safety, codes, insurance issues</li> <li>▪ Limited awareness and understanding of potential efficiency and environmental benefits</li> </ul>



**APPLICATIONS NEEDS TO ADDRESS THE BARRIERS AND ACHIEVE THE VISION BY 2030**

(☛ = Most Critical Barrier)

Time Frame: (N = Now-2010; M = 2010-2020; L = 2020-2030+)

Lead (capital letters) and Supporting (lower-case letters) Roles: (I = Industry; G = Government; U = Universities; NL = National Labs; TA = Technical Associations)

REGULATIONS, CODES, STANDARDS	DEMONSTRATIONS AND TEST BEDS	PUBLIC POLICY	APPLICATION TECHNOLOGIES	HYDROGEN PRODUCTION	TECHNOLOGY DEVELOPMENT AND PARTNERSHIP	MARKET CONDITIONING
	<ul style="list-style-type: none"> <li>- test bed environment</li> <li>▪ “Broad Based Deployments” of hydrogen and fuel cell technologies (G) Dykema Gossett, PLLC</li> </ul>	<p>carrier ☛</p> <ul style="list-style-type: none"> <li>▪ Making fleet demonstrations effective: DOT and DOE/DOD, EPA must coordinate programs/activities</li> <li>▪ Public Policy Steps                             <ul style="list-style-type: none"> <li>- bipartisan</li> <li>- demos (Fuel Cell, ICE)</li> <li>- tax incentives</li> <li>- education</li> <li>- branding</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>- advance comp</li> <li>- H<sub>2</sub> sensor</li> <li>- manufacturable membrane</li> <li>▪ Reliability and durability of operating systems (N-L) ☛☛☛☛☛</li> <li>▪ Fuel infrastructure-chicken/egg ☛☛                             <ul style="list-style-type: none"> <li>- need for small-scale, user-friendly, low-cost fueling device</li> </ul> </li> <li>▪ Redesign auto for early adoption ☛☛</li> <li>▪ Alleviate strain on stationary fuel cells by subsidizing distributed PVs and wind ☛</li> <li>▪ Increase hydrogen in topping cycle turbines for power generator ☛</li> </ul>		<p>competitive” R&amp;D ☛</p> <ul style="list-style-type: none"> <li>▪ Super coordination of hydrogen efforts (international)</li> <li>▪ Support cost/benefit analysis for CHP and vehicle fuel deployment in residential/small office</li> </ul>	



### TEN MOST WANTED – APPLICATIONS (1 of 3)

TOP VOTE GETTING IDEAS	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<b>Agree on Intelligent, Technically-Based Standards</b>	<ul style="list-style-type: none"> <li>▪ Consensus among states</li> <li>▪ Harmonization with international standards</li> <li>▪ Increase level of attention in United States</li> </ul>			<ul style="list-style-type: none"> <li>▪ Build consortium of agencies (e.g., DOT, EPA, California Air Resources Board [CARB]) to set codes, '02-'03 precede early applications</li> <li>▪ Intensive process, feedback from lessons learned and new technologies 2 years later</li> </ul>
<b>Create Federal-State-Local-Private Partnership Program to Demonstrate Systems</b>	<ul style="list-style-type: none"> <li>▪ Government (less risk adverse) regulating change gives industry direction and assurance on where private investment should go</li> <li>▪ Government is more sensitive to public policy issues and the global impacts and externalities of existing consumer demand</li> </ul>	<ul style="list-style-type: none"> <li>▪ Alternative fuel mandate in 2001 requiring bus fleets in southern California to use fuels other than diesel</li> <li>▪ CARB ZEV mandate for bus fleets                             <ul style="list-style-type: none"> <li>- 2003 demo</li> <li>- 2008 15% of all vehicles</li> </ul> </li> <li>▪ CaFCP bus fleet demonstration begins 2004</li> <li>▪ Establish similar Federal mandate</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOE and DOT</li> <li>▪ Car registration fees</li> <li>▪ Public and private partnerships</li> <li>▪ Local and state funding</li> </ul>	<ul style="list-style-type: none"> <li>▪ Federal plan backed up by federal money</li> <li>▪ Benchmark California</li> </ul>
<b>Establish Government as Early Adopter Customer</b>	<ul style="list-style-type: none"> <li>▪ Implement as many demonstration programs to introduce and evaluate emerging technologies</li> </ul>	<ul style="list-style-type: none"> <li>▪ Federal government needs to mandate hydrogen programs for all government agencies today</li> <li>▪ Enforce present law (Energy Policy Act of 1992)</li> <li>▪ Fully funded, well-designed demonstration programs beginning with FY 04</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOE and DOT (T21 reauthorization) are primary funding sources</li> </ul>	<ul style="list-style-type: none"> <li>▪ Substantially fund Hydrogen Futures Act in FY 04</li> <li>▪ Fund successful demonstration programs on a sustained basis</li> <li>▪ Adopt "Freedom Fuel" Action Plan along with Freedom Car Program</li> </ul>
<b>Provide Government Leadership and Financial Support for Infrastructure Development</b>	<ul style="list-style-type: none"> <li>▪ Develop limited number of demonstration sites for infrastructure using California Fuel Cell Partnership model</li> <li>▪ Private industry financial criteria only supports term projects</li> </ul>	<p>Milestones:</p> <ul style="list-style-type: none"> <li>▪ Fleet demos (&lt; 100) – immediate</li> <li>▪ Fleets (5,000+ in United States) – 2008-2012</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOE</li> <li>▪ DOD</li> <li>▪ DOT</li> <li>▪ State and local</li> </ul>	
<b>Develop Very Short-Term Hydrogen End-Use Technologies to Stimulate Infrastructure and Market Readiness</b>	<ul style="list-style-type: none"> <li>▪ Promote and develop near-term products and technologies to stimulate and accelerate the implementation of hydrogen infrastructure</li> <li>▪ Have regulatory agencies adopt philosophy of encouraging this approach (i.e., in lieu of ZEV mandate)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Stationary power generation 500 stationary units</li> <li>▪ Generate the market by FY 03 and FY 04 with the purchase of fleets that use these technologies</li> </ul>	<ul style="list-style-type: none"> <li>▪ Continued DOE support</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel cell report to Congress</li> <li>• Hydrogen Futures Act</li> <li>• Let's not wait for the Holy Grail!</li> </ul>

**TEN MOST WANTED – APPLICATIONS (2 of 3)**

TOP VOTE GETTING NEEDS	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<p><b>Research and Develop On-Board H<sub>2</sub> Storage Systems</b></p>	<ul style="list-style-type: none"> <li>▪ Duplicate range of equivalent gasoline vehicles</li> <li>▪ Hi pressure gas                             <ul style="list-style-type: none"> <li>- low weight/high strength</li> <li>- permeation standards</li> </ul> </li> <li><u>Requires:</u> <ul style="list-style-type: none"> <li>▪ R&amp;D engineering                                     <ul style="list-style-type: none"> <li>- high pressure</li> <li>- hydrides</li> <li>- nanotechnology</li> </ul> </li> <li>▪ Codes and standards</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ 6% by weight</li> <li>▪ Ultimate goal 7-8%</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOE                             <ul style="list-style-type: none"> <li>- national laboratories</li> </ul> </li> <li>▪ Industry</li> </ul>	<ul style="list-style-type: none"> <li>▪ Build demo's for 6, 7, 8% systems</li> <li>▪ Qualify</li> <li><u>Suggestions:</u> <ul style="list-style-type: none"> <li>▪ Study Sematec example for application to hydrogen and fuel cells (Bob Walker)</li> </ul> </li> </ul>
<p><b>Develop Low-Cost Stack and Systems</b></p>	<ul style="list-style-type: none"> <li>▪ Increase life (reliable/durable)</li> <li>▪ Reversible</li> <li>▪ Decreased cost (comparable to ice)</li> <li><u>Requires:</u> <ul style="list-style-type: none"> <li>▪ research/engineering                                     <ul style="list-style-type: none"> <li>- high volume manufacturing</li> <li>- high temperature membrane</li> <li>- sensors/controls</li> <li>- advanced components (compressors . . .)</li> <li>- catalyst loading</li> <li>- hybrids (ultra cap/battery)</li> <li>- basic material science</li> </ul> </li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Fuel cell report to congress dates</li> </ul>	<ul style="list-style-type: none"> <li>▪ DOE/DOD</li> <li>▪ Industry</li> <li>▪ States</li> <li>▪ DOT</li> </ul>	<ul style="list-style-type: none"> <li>▪ Build demo's (fleets/off-road)</li> <li>▪ Qualify</li> <li>▪ Codes, standards</li> </ul>
<p><b>Assist Development of Community-Based Clustered Applications and Installations</b></p>	<ul style="list-style-type: none"> <li>▪ Seed the creation of mini hydrogen economies</li> </ul>	<ul style="list-style-type: none"> <li>▪ Issue RFP                             <ul style="list-style-type: none"> <li>- FY 03</li> </ul> </li> <li>▪ Select winners                             <ul style="list-style-type: none"> <li>- FY 04</li> </ul> </li> <li>▪ Commence building                             <ul style="list-style-type: none"> <li>- FY 05</li> </ul> </li> <li>▪ Complete installations by 2010</li> </ul>	<ul style="list-style-type: none"> <li>▪ Federal Grants (DOE) 70%</li> <li>▪ State/local cost share 20%</li> <li>▪ Industry cost share 10%</li> </ul>	<ul style="list-style-type: none"> <li>▪ Develop the RFP solicitation</li> </ul>

**TEN MOST WANTED – APPLICATIONS (2 of 3)**

TOP VOTE GETTING NEEDS	BRIEF DESCRIPTION OF THE NEED	KEY MILESTONES AND DATES	PRIMARY FUNDING ENTITIES	NEXT STEPS
<p><b>Improve Reliability and Durability of Operating Systems</b></p>	<ul style="list-style-type: none"> <li>▪ To warranty hydrogen infrastructure and products to the same level as conventional systems</li> </ul>	<ul style="list-style-type: none"> <li>▪ Develop performance-predictive analysis tools</li> <li>▪ Field trial validation (ongoing)</li> </ul>	<ul style="list-style-type: none"> <li>▪ National labs establish generic models, procedures, and criteria</li> <li>▪ Industry applies results to products</li> </ul>	<ul style="list-style-type: none"> <li>▪ Establish certification facility at a national lab</li> </ul>
<p><b>Promote/Publicize Local Demonstration Products Nationally through News Events, Town Hall Meetings, etc.</b></p>	<ul style="list-style-type: none"> <li>▪ Public image of hydrogen as a fuel is absent</li> <li>▪ Need to educate public, state and local officials, schools, corporations, government, decision-makers, media, industry organizations</li> </ul>	<ul style="list-style-type: none"> <li>▪ Documentaries (now)</li> <li>▪ News events</li> <li>▪ Safety videos</li> <li>▪ Training</li> <li>▪ Ride and drive</li> </ul>	<ul style="list-style-type: none"> <li>▪ Joint DOE/Industry</li> <li>▪ SAE, NHA</li> <li>▪ API</li> <li>▪ Other industry associations</li> <li>▪ State and local government</li> </ul>	



## HYDROGEN OUTREACH AND EDUCATION BREAKOUT SESSION

- What are the key hydrogen messages to communicate for education and outreach?
- Who are the target audiences?
- What are the barriers that most interfere with achieving the vision?
- What actions must be taken to address the barriers and achieve the hydrogen vision?
- What are the top priority action plans for education and outreach?

### Participants:

NAME	ORGANIZATION
Shannon Baxter	California Air Resources Board
EJ Belliveau	H <sub>2</sub> Solutions
Maria Bellos	Fuel Cells 2000
Christine Messina-Boyer	Millennium Cell
Ken Cameron	General Motors
Bill Clapper	Sunline Transit
Mary-Rose de Valladares	DCH Technology, Inc.
Marshall Gilmore	Florida H2 Business Council
Art Hartstein	U.S. DOE, Fossil Energy
Katie Hoffner	Hydrogen Now!
Peter Holran	Wexler & Walker Public Policy Assoc.
Jonathan Hurwitch	SENTECH, Inc.
Susan Leach	Hydrogen 2000, Inc.
Jennifer Schaeffer	Plug Power Inc.
Greg Schuckman	University of Central Florida/ Florida Solar Energy Center
Jeff Serfass	National Hydrogen Association
Lauren Segal	BP
Charles Veley	US Hydrogen
Greg Vesey	Chevron Texaco
Suzanne Watson	Northeast-Midwest Institute
Steve Zimmer	Daimler Chrysler

**FACILITATOR:** Jan Brinch, Energetics (assisted by Lauren Giles)

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## MESSAGES

- ◆ Need to “brand” hydrogen
- ◆ This is a long-term proposition
- ◆ Cleaner, more dependable, secure fuel
- ◆ Domestic = independent
- ◆ Source of hydrogen gives flexibility/diversity
- ◆ “A” hydrogen economy—integrated with other fuels (as opposed to “the” hydrogen economy)
- ◆ Hydrogen is another—not the only—energy source
- ◆ “Safe”
- ◆ Economics, environment, security
- ◆ Hydrogen is “cool,” culturally “hip”
- ◆ “Pop” culture
- ◆ Bring down to “the peoples’ level”
- ◆ Hydrogen is affordable—is it?
- ◆ Consumer convenience
- ◆ For stationary as well as vehicles
- ◆ Cost-effective in rural areas
- ◆ Environmental interests of the young
- ◆ Predictability
- ◆ Know the audience
- ◆ Hydrogen age must be inclusive—build on existing efforts
- ◆ Hydrogen must be affordable
- ◆ Need to tie in climate change and dependency on foreign oil
- ◆ Market to global economy
- ◆ Hydrogen and fossil fuel industry nexus

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## TARGET AUDIENCES

- ◆ John Q. Public
- ◆ K-12 school age children
- ◆ College students
- ◆ Policy makers (decision makers and legislators)
- ◆ State PUCs
- ◆ Local and state code officials
- ◆ Allied industries—secondary
- ◆ Science teachers
- ◆ Industry executives
- ◆ Professional/trade associations
- ◆ Media and press (trade and mainstream)
- ◆ Early adopters
- ◆ Service station operators and owners
- ◆ Transit agencies
- ◆ Foundations
- ◆ R&D community
- ◆ Government agencies
- ◆ Vehicle fleet owners/operators
- ◆ Regional planning organizations
- ◆ Environmental groups
- ◆ Multilateral institutions (World Bank, etc.)
- ◆ Commercial electric consumers (with high demand)
- ◆ FIRE: (Financial—lenders, investors, Inurance, Real Estate industries)

**Hydrogen Education and Outreach**  
**WHAT ARE THE BARRIERS THAT MOST INTERFERE WITH ACHIEVING THE VISION?**

PUBLIC AWARENESS	EXAMPLE/SUCCESS STORIES	EDUCATION (Students)	BUSINESS INVESTMENT	CULTURAL BARRIERS
<ul style="list-style-type: none"> <li>• Lack of consensus about severity of environmental problems ◆◆◆◆◆◆◆◆</li> <li>– Insufficient understanding of relationship to global warming</li> <li>– Lack of publicity of consistent quantification of GHG emission reductions</li> <li>– Little understanding of social costs of hydrocarbons</li> <li>• Lack of general knowledge of H<sub>2</sub> as a fuel ◆◆◆◆◆◆◆◆</li> <li>• Need to personalize the hydrogen economy (for the consumer) ◆◆◆◆</li> <li>– No clear/simple explanation, i.e., how does it work?</li> <li>• Lack of \$ dedicated to educating public ◆◆◆</li> <li>• Too much focus on vehicles ◆</li> <li>• Too many parochial interests ◆</li> <li>– Lack of single focus application to present to public</li> <li>• Too few well-known and knowledgeable champions, i.e., Jay Leno</li> <li>• Lack of news coverage, too few reporters covering hydrogen</li> <li>• Inconsistent nomenclature for H<sub>2</sub> <ul style="list-style-type: none"> <li>– Calling H<sub>2</sub> an “energy carrier” rather than just another energy source</li> </ul> </li> <li>• Almost no understanding of where energy comes from?</li> <li>• No constituency</li> </ul>	<ul style="list-style-type: none"> <li>• Not enough demo \$ ◆◆◆◆◆◆◆◆</li> <li>– Too few opportunities to see fuel cells in operation</li> <li>• Need ongoing public experiment (model communities)</li> </ul>	<ul style="list-style-type: none"> <li>• Limited educator/teacher training ◆◆◆◆◆◆◆◆</li> <li>– Too few structured education programs</li> <li>• Limited distribution channels for existing educational materials K-12</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of consumer pull ◆◆◆◆◆◆◆◆</li> <li>• Over emphasizing need to meet business profitability immediately</li> <li>• Too few early adopters with deep pockets</li> <li>• Not enough certainty of long term commitment/funding for H<sub>2</sub> investors</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of patience to keep vision “alive” ◆◆</li> <li>• Too many other innovative technologies</li> <li>• Consumer inconvenience</li> <li>• Lack of sufficient compulsion to change</li> <li>• Perception of numbers</li> </ul>

**Hydrogen Education and Outreach**  
**WHAT ARE THE BARRIERS THAT MOST INTERFERE WITH ACHIEVING THE VISION? (CONTINUED)**

IMPLEMENTATION	POLICY AND IMPLEMENTATION	POLICY	SAFETY
<ul style="list-style-type: none"> <li>• Too little urgency placed on commercialization ◆◆◆◆</li> <li>• Lack of standards ◆◆◆</li> <li>• Too many unproven technologies with potential (OEMs and energy companies not ready to make big investments) ◆ – Too many technologies, not enough \$</li> <li>• Need a critical mass! (Effort can get diluted in the short/mid run)</li> <li>• Slow movement on infrastructure</li> <li>• Timeframe uncertainty</li> <li>• Cost of entry for the public/industry</li> </ul>	<ul style="list-style-type: none"> <li>• Too few sustainable supporting policies ◆◆</li> <li>• Weak public-private partnership and policy ◆</li> <li>• Lack of a viable pathway to buy into ◆</li> <li>• Lack of nearer term vision-tangibles – 10 year focus</li> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>• Inconsistent regulations ◆◆◆◆◆◆</li> <li>– Lack of understanding among legislative policymakers and regulators</li> <li>– Lack of equitable “rules of the road”</li> <li>– Over-regulation</li> <li>• Lack of monetization of cost/environmental impact of choices ◆◆◆◆</li> <li>• Too much entrenched energy interest (traditional means of power) and promotion thereof ◆</li> <li>• Misdirected incentive funding</li> <li>• Energy choices—impact on foreign policy</li> <li>• Not enough support for taxes to support H<sub>2</sub> development. Gasoline too cheap vs. “real” cost</li> <li>• Lack of long-range planning by government</li> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>• Too much fear of hydrogen safety problems or risks ◆◆◆◆◆◆◆◆◆◆◆◆</li> <li>• Lack of understanding danger/safety of current fuels ◆◆◆◆</li> <li>• Too little effort on business and regulatory communities in FIRE (Financial, Insurance, Real Estate) trades ◆◆</li> <li>•</li> </ul>

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## Hydrogen Education and Outreach

### WHAT ACTIONS MUST BE TAKEN TO ADDRESS THE BARRIERS AND ACHIEVE THE VISION OF H<sub>2</sub>?

BUSINESS INFRASTRUCTURE	EDUCATION	FUNDING ADVOCACY	MARKETING	
<ul style="list-style-type: none"> <li>– Integrate codes and standards (national level) ◆◆◆◆◆◆</li> <li>– Communicate codes and standards ◆◆◆</li> <li>– To insurance companies</li> <li>– To operators, e.g., service stations</li> <li>– To builders/contractors/architects</li> <li>– To regulators</li> <li>• Communicate a reasonable timeframe (with exit gates) for commercialization</li> <li>• Require accounting (FASB, etc.) of environmental costs/benefits</li> </ul>	<ul style="list-style-type: none"> <li>• Commit long-term resources to educate K-12 and beyond about H<sub>2</sub> energy.                             <ul style="list-style-type: none"> <li>– Develop curriculum for K-12, vocational, 4-year engineers, and advanced degree</li> <li>– Include H<sub>2</sub> lesson plan packages with video, demo hardware, and experiments to help educate science teachers and their students</li> <li>– Program for educator training (K-12, vocational)</li> <li>– Have summer workshops for high school teachers (similar to economic group)</li> <li>– Increase number of trained K-12 science teachers</li> <li>– Inventory existing resources</li> </ul> </li> <li>• Formulate the path of continuous education                             <ul style="list-style-type: none"> <li>– Hydrogen fellowship program</li> <li>– Offer \$ for college engineering theses/projects for hydrogen: e.g., vehicle systems, stationary applications, storage, catalysis</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>– Legislate tax and other incentives to invest in H<sub>2</sub> and fuel cells by 2005 ◆◆◆◆◆◆◆◆</li> <li>– Incentivize state-to-state hydrogen partnerships</li> <li>– Create public acceptance for sustained and increasing government funding for the hydrogen economy ◆</li> <li>– Fund R&amp;D now</li> <li>– Fund the federal government to purchase H<sub>2</sub> equipment (vehicles, power generation, etc.)</li> <li>• Take results from current partnerships and publicize them</li> </ul>	<ul style="list-style-type: none"> <li>• Create consumer demand through all media ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆</li> <li>– Create cartoons</li> <li>– Product placement in various mediums, i.e., films</li> <li>– Develop community model that identifies stakeholders, products, and infrastructure to transition to a H<sub>2</sub> economy. The model would be transportable, repeatable, nonpartisan, non-parochial</li> <li>– Determine how to incentivize the population to move to a hydrogen economy</li> <li>• Create compelling message or value proposition                             <ul style="list-style-type: none"> <li>– Definable goals</li> <li>– Environmental understanding</li> <li>– Gear public toward solution</li> <li>– For the grandchildren</li> <li>– Personalize message</li> <li>– Safety</li> <li>– “Brand” H<sub>2</sub> as clean fuel, freedom fuel</li> <li>– Tie need for H<sub>2</sub> to environmental, economic, and foreign policy</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Develop P&amp;R plan ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆</li> <li>– Could be similar EPA/DOE-driven EnergyStar<sup>®</sup></li> <li>– Implement a “What is H<sub>2</sub>?” campaign</li> <li>– Create H<sub>2</sub> traveling education exhibit</li> <li>– Develop PR strategy, briefing package media kit, Op-ed pieces</li> <li>– Identify public spokespersons, e.g., Jay Leno</li> <li>– Develop trade show and association presentation/booth</li> <li>– Organize coordinated policymaker outreach and education</li> <li>– Invite consumer groups to participate in hydrogen meeting</li> <li>– Create hydrogen education and information center to disseminate H<sub>2</sub> information</li> <li>– Create safety/regulatory information clearinghouse</li> <li>– Educational H<sub>2</sub> programs</li> <li>– Educational video</li> </ul>

## Hydrogen Education and Outreach

### WHAT ACTIONS MUST BE TAKEN TO ADDRESS THE BARRIERS AND ACHIEVE THE VISION OF H<sub>2</sub>? (CONTINUED)

GOVERNMENT ADVOCACY	DEMOS
<ul style="list-style-type: none"> <li>• Federal advocacy – build broad business, political, environmental, and higher education coalition to influence U.S. energy policy toward H<sub>2</sub> ◆◆◆◆◆◆◆◆◆◆</li> <li>– To earmark public awareness \$</li> <li>– Form Congressional H<sub>2</sub> fellows program</li> <li>– Deliver message that illustrates the consequences of inconsistent regulations</li> <li>– Increase number of Congressional hydrogen advocates</li> <li>– Advocate acceptance and passage externalities</li> <li>– Support appropriations in Congress</li> <li>– Advocate subsidy incentives and policies to bring hydrogen “up to par” with other fuel/power options</li> <li>– Deliver message that promotes continuous path of technology improvement</li> <li>– Analyze/build case for monetizing environmental externalities</li> <li>– Draft externality legislation to impact energy policy</li> <li>• Coordinate all Federal H<sub>2</sub> funding under, for example, OSTP/NSTC for R&amp;D crosscut program ◆◆◆</li> <li>• Influence regulatory groups for positive outcome on hydrogen initiative</li> <li>• Encourage regional H<sub>2</sub> initiatives/partnerships               <ul style="list-style-type: none"> <li>– League of Cities, Conference of Mayors, National Governors’ Association, etc.</li> <li>– Town Hall meetings for legislators</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Create a public demo H<sub>2</sub> village ◆◆◆◆◆◆◆◆◆◆</li> <li>– Fund the creation of a H<sub>2</sub> “micro-economy village” for public education—web cast, reality TV, etc.</li> <li>• Launch phased model community projected to showcase H<sub>2</sub> and fuel cell technologies and solutions by 2005               <ul style="list-style-type: none"> <li>– Get Disney to create “hydrogen world” with hydrogen characters</li> <li>– Get portable fuel cells to market to familiarize public with H<sub>2</sub> fuel</li> <li>– Create PR campaign to support the demo</li> </ul> </li> <li>• Advocate the development of a cost-shared program leading to demonstration of H<sub>2</sub> products and services ◆◆◆◆◆◆</li> <li>– Not enough demos. Develop a “clean H<sub>2</sub>” demo program similar to clean coal demo program (to policy makers).</li> <li>– Develop (and fund) cost-shared demos -- stationary fuel cells; vehicular fuel cells; H<sub>2</sub> production, infrastructure, and storage</li> <li>• Sponsor “challenge prizes” for H<sub>2</sub> applications or vehicle achievements</li> </ul>

## Hydrogen Education and Outreach ACTION PLANS

TOP VOTE GETTING ACTIONS	BRIEF DESCRIPTION OF THE ACTION	TARGET AUDIENCE(S)	PRIMARY PERFORMING ENTITIES	PRIMARY FUNDING ENTITIES	NEXT STEPS	TIMEFRAME
<b><i>Build broad coalition to influence U.S. energy policy on Hydrogen</i></b>	<ul style="list-style-type: none"> <li>• Support appropriations</li> <li>• Explain consequences of inconsistent regulations</li> <li>• Support continuous path of technological improvement</li> <li>• Support tax incentives</li> </ul>	<ul style="list-style-type: none"> <li>• Colleagues</li> <li>• Congress/Administration</li> <li>• Stakeholders</li> <li>• State governments</li> </ul>	<ul style="list-style-type: none"> <li>• NHA-Advocacy role and interest</li> <li>• DOE</li> <li>• Industry support and leadership</li> <li>• High-profile sponsorship               <ul style="list-style-type: none"> <li>– Challenge to all to launch a coalition ask for DOE support</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Initial seed \$ from DOE               <ul style="list-style-type: none"> <li>– Advocate for demo and authorize \$, tax status.</li> </ul> </li> <li>• Estimated cost: \$2.5-3 million</li> <li>• Grass roots funding</li> </ul>	<ul style="list-style-type: none"> <li>• Identify coalition members</li> <li>• Bring all groups together</li> <li>• Figure out broad message and common policy agenda</li> <li>• Fund organization</li> <li>• Congressional caucus</li> </ul>	<ul style="list-style-type: none"> <li>• Immediately</li> </ul>
<b><i>Develop public relations plan</i></b>	<ul style="list-style-type: none"> <li>• Similar to EnergyStar®</li> <li>• Hydrogen “on the map”</li> <li>• Hydrogen campaign</li> <li>• Exhibits</li> <li>• Briefing packets</li> <li>• Public spokespersons</li> <li>• Hydrogen “in your life”</li> </ul>	<ul style="list-style-type: none"> <li>• Everyone</li> </ul>	<ul style="list-style-type: none"> <li>• Coordinated effort</li> <li>• DOE</li> <li>• NHA</li> <li>• New coalition</li> <li>• Fortune 100</li> <li>• Hydrogen success stories</li> <li>• Hydrogen associations</li> </ul>	<ul style="list-style-type: none"> <li>• New coalition</li> <li>• DOE and EPA</li> <li>• Foundations</li> <li>• States</li> <li>• Grass roots organization (PIRG)</li> <li>• Industry support</li> </ul>	<ul style="list-style-type: none"> <li>• Organize!</li> <li>• Coalition needs to develop PR plan</li> <li>• NHA can begin process</li> <li>• Focus on NEP agenda—hydrogen outreach</li> <li>• Find 3 messages</li> <li>• Reach out to NASEO,NGA, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Immediately</li> </ul>
<b><i>Create consumer demand interest through all media</i></b>	<ul style="list-style-type: none"> <li>• Product placement in films</li> <li>• Community models</li> <li>• Incentives for consumer action</li> </ul>	<ul style="list-style-type: none"> <li>• Everyone</li> </ul>	<ul style="list-style-type: none"> <li>• Coordinated effort</li> <li>• DOE</li> <li>• NHA</li> <li>• New coalition</li> <li>• Fortune 100</li> <li>• Hydrogen success stories</li> <li>• Hydrogen associations</li> </ul>	<ul style="list-style-type: none"> <li>• New coalition</li> <li>• DOE and EPA</li> <li>• Foundations</li> <li>• States</li> <li>• Grass roots organization (PIRG)</li> <li>• Industry support</li> </ul>	<ul style="list-style-type: none"> <li>• Create awareness through PR</li> </ul>	<ul style="list-style-type: none"> <li>• Immediately</li> </ul>

**Hydrogen Education and Outreach**  
**ACTION PLANS (CONTINUED)**

TOP VOTE GETTING ACTIONS	BRIEF DESCRIPTION OF THE ACTION	TARGET AUDIENCE(S)	PRIMARY PERFORMING ENTITIES	PRIMARY FUNDING ENTITIES	NEXT STEPS	TIMEFRAME
<b>Create a public demonstration hydrogen village (10 years out)</b>	<ul style="list-style-type: none"> <li>• Launch phased model community project</li> <li>• Fund creation of “micro-economy village” for public education</li> <li>• Demos</li> <li>• HO tech development</li> </ul>	<ul style="list-style-type: none"> <li>• Working models</li> <li>• Around country</li> <li>• General public: 1) HO, 2) Technology development</li> <li>• Customers</li> <li>• NAHB</li> <li>• A/E’s</li> <li>• Implementers</li> <li>• HO</li> <li>• Tech development</li> </ul>	<ul style="list-style-type: none"> <li>• HUD</li> <li>• Home builders and contractors</li> <li>• Fannie Mae</li> <li>• NAHB</li> <li>• National Association of Realtors</li> </ul>	<ul style="list-style-type: none"> <li>• HUD</li> <li>• DOE</li> <li>• EPA</li> <li>• Industry</li> <li>• DOT</li> <li>• Foundations</li> <li>• Habitat for Humanity</li> </ul>	<ul style="list-style-type: none"> <li>• DOE Lead</li> <li>• Hawaii project-base</li> <li>• Subcommittee of coalition</li> <li>• DOE solicitation-Buildings of the Future</li> <li>• Support basic R&amp;D               <ul style="list-style-type: none"> <li>– Support for R&amp;D activities</li> <li>– Then, educate and outreach</li> <li>– Raise awareness—temper expectations</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Near- to mid-term (in about 10 years)</li> </ul>
<b>Commit long-term resources to K-12→ graduate level education</b>	<ul style="list-style-type: none"> <li>• Target curriculum—all levels</li> <li>• Educate teachers</li> <li>• Hold summer teacher workshops</li> <li>• Inventory existing resources</li> </ul>	<ul style="list-style-type: none"> <li>• Entire education community</li> <li>• K-12 students</li> <li>• Teacher: NSTA, Dept. of Education</li> <li>• State and local reg.</li> <li>• School districts</li> <li>• Publishing companies</li> </ul>	<ul style="list-style-type: none"> <li>• Coalition</li> <li>• School board associations</li> <li>• Teachers’ associations</li> <li>• Publishers</li> </ul>	<ul style="list-style-type: none"> <li>• Legislatures</li> <li>• Foundations</li> <li>• Private sector support</li> <li>• DOE</li> <li>• NSF</li> </ul>	<ul style="list-style-type: none"> <li>• Inventory resources</li> <li>• Peer review existing resources</li> <li>• Set up teacher training</li> <li>• Try to integrate into existing curriculums</li> </ul>	<ul style="list-style-type: none"> <li>• Immediately</li> </ul>

## HYDROGEN SYSTEMS INTEGRATION BREAKOUT SESSION

- **Key messages from breakout sessions:** What are the key barriers and needs you identified from the production, delivery, storage, energy conversion, applications, and education and outreach breakout sessions?
- **Systems integration issues:** What are the crosscutting, missing, and conflicting pieces of information from the breakout sessions that need to be considered by the systems integration group?

### Participants:

NAME	ORGANIZATION
Dave Nahmias	HTAP
Bill Smith	Proton Energy Systems
Francis Lau	Gas Technology Institute
Lauren Segal	BP
Chung Liu	South Coast AQMD
Shannon Baxter	California ARB
Matthew Fairlie	Stuart Energy
Douglas Wheeler	UTC Fuel Cells
Seth Dunn	World Watch Institute
Steve Tang	Millennium Cell
Bob Miller	Air Products and Chemicals, Inc.
Revis James	Electric Power Research Institution
Joan Ogden	Princeton University
Catherine Gregoire-Padro	National Renewable Energy Laboratory
Richard Bradshaw	Dykema Gossett, PLLC
Brendan Doohar	National Academy of Engineering

**FACILITATOR:** Tara Nielson, Energetics, Inc.

## KEY MESSAGES FROM BREAKOUT SESSIONS

	BARRIERS	NEEDS
<b>PRODUCTION</b>	<ul style="list-style-type: none"> <li>• Policy—dealing with (accounting for) fossil fuel externalities</li> <li>• Funding</li> <li>• Codes and standards</li> <li>• Crosscutting R&amp;D on:               <ul style="list-style-type: none"> <li>○ Catalysts</li> <li>○ Materials</li> <li>○ Manufacturability</li> <li>○ Mass production</li> </ul> </li> <li>• Technology—carbon sequestration               <ul style="list-style-type: none"> <li>○ How?</li> <li>○ How much?</li> </ul> </li> <li>• “Carbon free energy sources” – Linking renewables / nuclear power and public opinion</li> </ul>	<ul style="list-style-type: none"> <li>• Demonstrations, demonstrations, demonstrations</li> <li>• Policy – have a vision, need a mission – near-term goals!</li> <li>• Market pull               <ul style="list-style-type: none"> <li>○ Product definition—what are the hydrogen solutions?</li> <li>○ What people think of / know about hydrogen</li> </ul> </li> </ul>
<b>DELIVERY</b>	<ul style="list-style-type: none"> <li>• Lack of consensus on total costs – both for hydrogen and alternatives</li> <li>• Codes and standards</li> <li>• Technical maturity of refueling stations</li> <li>• Lack of safety criteria (connects to public expectations)</li> <li>• Chicken or egg—what will be the initial key driving application?               <ul style="list-style-type: none"> <li>○ Ability to match investment to market</li> </ul> </li> <li>• Imbalances between hydrogen supply and demand</li> <li>• Cost of hydrogen technologies</li> <li>• Externality costing</li> <li>• Customer expectations for refueling</li> <li>• Lack of major technology advances</li> </ul>	<ul style="list-style-type: none"> <li>• Demonstrations: initial government funding and government-industry partnerships</li> <li>• Codes and standards development, harmonization</li> <li>• Public outreach, education, access to existing information</li> <li>• Policy, financial incentives</li> <li>• Analyses on lifecycle cost, transition strategies</li> </ul>

	<b>BARRIERS</b>	<b>NEEDS</b>
<b>STORAGE</b>	<ul style="list-style-type: none"> <li>• Insufficient funding</li> <li>• Lack of codes and standards</li> <li>• Energy density too low</li> <li>• Lack of education</li> <li>• Customer acceptance at risk</li> <li>• Lack of major technology advances</li> </ul>	<ul style="list-style-type: none"> <li>• Breakthrough solutions to energy density issues</li> <li>• “Agony neutral” solutions</li> <li>• Education on storage safety</li> <li>• Materials RD&amp;D <ul style="list-style-type: none"> <li>○ Pressurized storage</li> <li>○ Metal hydrides</li> <li>○ Chemicals (hydrides, carbon, allenenes)</li> </ul> </li> <li>• Technology RD&amp;D <ul style="list-style-type: none"> <li>○ Manufacturing</li> <li>○ Systems integration</li> </ul> </li> <li>• Major increase in funding for R&amp;D</li> <li>• Raise visibility, expedite, and align interagency activities on codes and standards</li> </ul>
<b>CONVERSION</b>	<ul style="list-style-type: none"> <li>• Lack of coordinated technology development</li> <li>• Oil and gas are too cheap</li> <li>• Lack of a clear, consistent, long-term policy. High degree of uncertainty makes financial markets unwilling to invest</li> </ul>	<ul style="list-style-type: none"> <li>• Clear, realistic understanding of achievable near-term product value propositions</li> <li>• Fuel cell research in materials, interface</li> <li>• New IC engines R&amp;D on electrochemistry, low NOx, efficiency</li> <li>• Expansion and continuation of demonstration projects</li> <li>• Successful incentive mechanism (e.g. California ZEV mandate, wind production)</li> </ul>
<b>APPLICATIONS</b>	<ul style="list-style-type: none"> <li>• No premium for clean technologies. Hydrogen as a fuel does not give financial benefit to user.</li> <li>• Limited incentive for “early adopters” of applications</li> <li>• Cost of hydrogen is high compared to natural gas (where hydrogen cost is low, power cost is low)</li> <li>• Lack of “level playing field” for distributed generation technologies (efficiency, environmental, relative benefits are not fully captured in the market)</li> <li>• Too much reliance on fuel cells while ignoring current technologies</li> <li>• Reliability</li> <li>• Lack of long-term leadership</li> <li>• Chicken and egg issues</li> </ul>	<ul style="list-style-type: none"> <li>• Materials science and basic research</li> <li>• Demonstrations</li> <li>• Bipartisan outreach</li> <li>• National outreach</li> <li>• Local outreach</li> <li>• Government as an “early adopter” (procurement, infrastructure support, demonstrations)</li> <li>• Price parity <ul style="list-style-type: none"> <li>○ Tax credits for oil but no tax credits for hydrogen</li> </ul> </li> <li>• Distributed generation policy supports (interconnection standards, codes, etc.)</li> <li>• Optimization in current hydrogen product technologies</li> <li>• Stranded industries “buggy whip”</li> <li>• Uniform tests and evaluation standards</li> <li>• Uniform codes and standards</li> </ul>

	<b>BARRIERS</b>	<b>NEEDS</b>
<b>EDUCATION</b>	<ul style="list-style-type: none"> <li>• Inconsistent regulations, codes and standards, permitting processes</li> <li>• Not enough demonstrations (and funding) to educate the public</li> <li>• Lack of trained educators</li> <li>• Too many technologies—dilutes short-term efforts</li> <li>• Fear of hydrogen safety</li> <li>• Lack of consensus regarding green house gas impact on environment</li> <li>• Lack of consumer pull               <ul style="list-style-type: none"> <li>○ Sexiness</li> <li>○ Cost externalities</li> <li>○ Knowledge</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Need a religion for hydrogen culture—long term and personalized</li> </ul>



## INTEGRATION ISSUES

CROSS-CUTTING		MISSING	CONFLICTS	
<ul style="list-style-type: none"> <li>• Policy on external costs of energy (environmental, energy security)</li> <li>• Basic R&amp;D               <ul style="list-style-type: none"> <li>○ Coordination across multiple organizations – gaps and overlaps</li> <li>○ Use R&amp;D resources wisely – so as not to dilute</li> <li>○ Materials</li> <li>○ Catalysts</li> <li>○ Manufacturability</li> <li>○ Testing</li> <li>○ Certification</li> <li>○ Technology storage</li> <li>○ Durability and reliability</li> </ul> </li> <li>• Timing of subsystem development uneven</li> <li>• Consumer confidence               <ul style="list-style-type: none"> <li>○ Technology</li> <li>○ Dread</li> <li>○ Acceptance</li> <li>○ “Why hydrogen?” drivers</li> </ul> </li> <li>• develop method to both integrate this work with previous work and parallel programs</li> <li>• Development of transition strategies               <ul style="list-style-type: none"> <li>○ Realigning existing program concentration to match the vision and roadmap</li> </ul> </li> <li>• Regulatory consistency – over time and among agencies</li> <li>• Technology uncertainties v. sub-technology system alignment</li> <li>• Applications drive attributes or targets for hydrogen supply chains and infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated hydrogen system demonstration funded by government</li> <li>• Global perspective and international markets (benchmark with other government strategies, e.g., EU, Japan, Iceland)</li> <li>• Leadership               <ul style="list-style-type: none"> <li>○ Setting goals</li> <li>○ Policy – societal values</li> <li>○ Market – products</li> </ul> </li> <li>• Investment to upgrade / advance existing technologies, and to launch new technologies</li> <li>• More cooperative efforts (e.g., PNGV)               <ul style="list-style-type: none"> <li>○ Universities (NSF grants)</li> <li>○ National Labs (Fed)</li> <li>○ Industry partnerships</li> </ul> </li> <li>• Systems analysis work</li> <li>• Valuation of hydrogen benefits               <ul style="list-style-type: none"> <li>○ Energy security</li> <li>○ Environmental</li> <li>○ What is it worth to consumers, government, society</li> </ul> </li> <li>• Build on “lessons learned” from other industry roadmaps: nuclear power, biotechnology</li> <li>• Limited recognition of mutually reinforcing nature of hydrogen ICE and hydrogen fuel cell technologies</li> <li>• Time frames for roadmap process (2010, 2020, 2030) not appropriate—desire for better near-term definition</li> </ul>	<ul style="list-style-type: none"> <li>• Chicken or egg</li> <li>• Demonstrations (technology and education) best way to educate and reduce anxiety (LA hydrogen ICE project)</li> <li>• Demonstrate integrated systems – not only technology, also value propositions</li> <li>• Codes and standards               <ul style="list-style-type: none"> <li>○ Cross-cut everything</li> <li>○ Critically important</li> <li>○ Single permitting process</li> <li>○ Coordinated level</li> <li>○ Stationary interconnect</li> <li>○ Mobile storage/handling</li> </ul> </li> <li>• Safety/value</li> <li>• Public outreach</li> <li>• Price/financial drivers absent</li> <li>• Systems approach – need to</li> <li>• Advancement of storage technology for production, transport, and mobile, stationary, and portable applications</li> <li>• \$7,000,000,000,000 in 30 years (Greene, ORNL)</li> <li>• Breakthrough technologies and thinking needed</li> <li>• Timing – need a short term technology to bridge to longer term (e.g., ICE—fuel cells, DG—pipeline)</li> <li>• Balancing and optimizing supply and demand</li> <li>• Hydrogen is a problem and an opportunity</li> <li>• Government as an early adopter (behaving as a consumer)</li> </ul>	<ul style="list-style-type: none"> <li>• Need to define value in terms of dollars, environment, electricity system, economic productivity</li> <li>• Need to define focus of first application in terms of where greatest value delivered</li> <li>• Life cycle / full system benefit-cost analysis: need more, need to reconcile</li> </ul>	<ul style="list-style-type: none"> <li>• Optimizing production, delivery, storage technologies separately may sub-optimize system or lead to false conclusions</li> <li>• Role of and proper balance of leadership from government, industry</li> <li>• Does industry focus on a few technologies – prioritize R&amp;D?</li> <li>•</li> </ul>

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## SUMMARY OF KEY CROSSCUTTING ISSUES

Codes and standards
Putting and keeping passion behind the vision
Systems analysis
Safety
Chicken and egg—matching supply and demand
R&D component
Development of integration and optimization of systems
Demonstration projects that are integrated
Industry-government demonstration projects and outreach
Government leadership of demonstration projects
Customer acceptance
Policy reflecting external costs and energy security

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# SECTION 9

## CLOSING PLENARY SESSION

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### Breakout Session Reports

#### Production

*Gene Nemanich, Chevron Texaco Technology Ventures*

The top needs identified in the hydrogen production breakout group include:

- Capture and sequester of carbon dioxide in the production process that makes hydrogen and electricity
- Separation of purified hydrogen on a small and large scale
- Cheap small scale reformers
- Codes and standards
- Better large scale gas fires that can use various feedstocks
- Better electrolyzers
- Demonstrations of new technologies, with public and private entities working together because of the risk and expense (e.g., nuclear via Thermochemical)
- Advances in technology (e.g., biological, photolytic, and high temperature separation)
- Funding for programs (e.g., incentives, rewards and penalties relating to long term goals)

Comment from the audience: Clarification regarding the costs of using nuclear power to produce hydrogen – costs should not be misrepresented, as the technology already exists and future efforts can build on this.



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## Delivery

*Art Katsaros, Air Products and Chemicals, Inc.*

The methods for delivering hydrogen already exist, however, these methods need to be more cost-effective and better developed. Delivery needs include:

- Codes and standards, and compatibility requirements
- Comprehensive demonstration programs, as there are a lot of new technologies that will be developed
- Solid understanding of various options, especially regarding carbon
- Improved financial incentives (e.g., tax credits)
- Better understanding of the transition to a hydrogen economy
- Current infrastructure—how much is convertible for dual-use or how much will be built out for a new hydrogen system?
- Better understanding of delivery system options
- Getting better access to existing information



## Storage

*Alan Niedzwiecki, Quantum Technologies*

Hydrogen storage technologies are a critical component to the success of achieving a hydrogen economy. Storage crosses many boundaries and is part of the big pictures. There are early adopters of the technology, but they are not as developed as they need to be. The top needs identified in the hydrogen storage breakout group include:

- Allow new technologies to improve and move forward
- Codes and standards—champions, developers, and harmonizers
- Finding a way to get from research and development to mass commercialization—the education component is a big challenge
- Long term strategies for recycling storage devices



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## Energy Conversion

*Mike Davis, Avista Labs*

The energy conversion group found that roles will need to be addressed as everyone moves forward. There is tension between the private sector's need to move quickly, and the long-term transition for the nation – this caused debate. Regarding timeframes for the identified next steps, activities have to be accelerated in order to get products into the marketplace.

The top needs identified in the energy conversion breakout session include:

- Codes and standards (e.g., product safety and performance standards, jurisdictional issues)
- Research and development for fuel cells and internal combustion engines—there needs to be a broad effort on materials, electrochemical, and interface R&D, which feeds into product development and demonstrations
- Cost reduction, reliability, productivity, durability
- Demonstrations – the challenge is making them valuable. They need to involve customers, have evaluations and feedback, and have realistic expectations.
- Institution-building
- Existing work needs to be shared before moving forward and reinventing the future.



## Applications

*Frank Balog, Ford Motor Company*

This breakout session focused on the components and systems requirements for mobile and stationary end-use applications for hydrogen. Most of the time was spent discussing mobile applications.

Key barriers the group identified include:

- Infrastructure (e.g., fuel, affordability, widespread use)
- Customer acceptance (e.g., need a reason to switch from current system)
- Lack of technology development strategies
- Leadership void (e.g., public policy)
- Technological shortfalls (e.g., onboard storage)



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Key needs the group identified include:

- Hydrogen storage technologies
- Conversion (e.g., low cost fuel cell stack with improved reliability and durability)
- Technology-based codes and standards
- Government leadership (e.g., government as customer and infrastructure developer) with industry support
- Demonstrations
- Community-based clustered applications (e.g., hydrogen centers for mobile and stationary applications)
- Short-term end use technologies (fuel cells and combustion engines) to stimulate the infrastructure development
- Promotion of local demonstration pockets and their application on a national scale (e.g., California Fuel Cell Partnership)
- Increased sense of urgency
- Adequate funding, coordinated with the market and government
- Outreach and education

### **Public Education and Outreach**

*Jeff Serfass, National Hydrogen Association*

For the purposes of this breakout session, the public included all audiences – 22 different audiences were identified, along with the messages and actions that need to be targeted to the various populations.

The top barriers identified in this breakout session include:

- Safety fears
- Lack of good examples to latch onto
- Lack of consensus in terms of environmental problems and hydrogen as a fuel
- Lack of training
- Lack of consumer pull
- Lack of monetization of environmental risks

Actions that the participants identified to address these barriers:

- Build a broad coalition to advocate energy policy—this would include participation at the state and local levels, and would involve advocacy on appropriations, regulations, continued paths of technology improvements, legislation, and incentives. There is a sign on sheet for volunteers.
- Organize public relations and education campaigns, which include briefings, identifying spokespersons, creating an Energy Star®-type program, identifying a convener for the various efforts, and having the Department of Energy seed the efforts
- Improve consumer awareness to create demand and facilitate understanding





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- Initiate product placements in films
  - Create a compelling message that stresses safety
  - Brand hydrogen, with an environmental spin
  - Create a long-term education plan that trains teachers at all educational levels

Messages that were identified:

- Freedom Fuel
- Tie hydrogen to fast-moving train
- Hydrogen is clean and adds new options
- Hydrogen is everywhere—it's right in your back yard
- Hydrogen "economy" is not a great term for resonating with the public
- Safety needs messaging—cool, hip, use pop culture
- Hydrogen provides independence, is cost-effective, and is the environmental choice
- Hydrogen works – it's big business today

### **Systems Integration**

*Joan Ogden, Princeton University*

The top crosscutting themes identified during the systems integration breakout session include:

- Government leadership is needed to put the passion in the vision
- Policies are needed that reflect the external costs of energy and that are consistent with energy security
- Codes and standards development needs to continue
- Safety
- Consumer acceptance
- Research and development in technical areas needs to continue—industry will select out and put successful technologies into integrated systems. Looking at the system as a whole is important.
- Transition strategies need to be put into place, with consideration for the full costs to society—analysis needs to be used to think through all of this.
- There is a chicken and egg issue and supply and demand need to be matched
- There is a need for public-private partnerships to maximize demonstrations and what is learned from them
- This is a long-term vision, but we need to take steps now to achieve it



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## Audience Comments

Regarding integration, life cycle analysis across industry segments needs to be conducted—please consider this for the integration chapter.

What if the unthinkable happens – an oil crisis – please consider including a contingency plan for producing hydrogen.

It is important to keep in mind the importance of international markets – they are a big aspect. Perhaps the vision and roadmap could be applied globally.

Powerful integration could occur between stationary and mobile markets – an analysis is needed.

Enabling markets are needed – they can happen through government-industry partnerships.

Regarding leadership issues, the superconductivity effort can be an example of how to advance the hydrogen goal.

Regarding integration – leadership will come from industrial and entrepreneurial entities. Industry cannot look just to government for leadership. A “do-able” pathway needs to be established and then follow-through is needed. The roadmap should include what is “do-able” and then improvements should be made in those areas.

## Next Steps

*Rich Scheer, Energetics, Inc.*

- Thanks to everyone for sharing his or her good ideas and for your hard work – but we have just begun.
- After the workshop ends the notes and ideas will be documented and will be posted on the web for comment. These notes will be used to write the chapters for the roadmap document.
- I urge you to comment on the materials and provide your input.



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## Closing Remarks from Department of Energy Officials

### *Robert Dixon, Office of Energy Efficiency and Renewable Energy*

- There seems to be a lot of enthusiasm here, I'm pleased that that is the case. Thanks to the industry leaders and Department of Energy colleagues for heading up this effort.
- It is one of my personal dreams to see the hydrogen technology portfolio flourish.
- During the presentations there were several references to leadership, and the Department of Energy leadership is here today. Please welcome David Garman, Assistant Secretary for Energy Efficiency and Renewable Energy.

### *David Garman, Assistant Secretary, Energy Efficiency and Renewable Energy*

- One of my purposes here today is to thank Secretary Abraham. He challenged us to leap frog the technological status quo for environmental benefits. He has created a collegial Department of Energy and a team that is working together and with the private sector to develop new ideas.
- Government leadership needs to go hand in hand with public, Congressional, and boardroom plans. Leadership needs to take place inside and outside of government.
- Thanks also to Robert Card. Mr. Card has taught us that passion is important but not enough, and has asked us tough, uncomfortable questions as we make plans about the nation's energy future. He has reminded us of the link between taxpayer dollars and America's future.
- Thanks also to Kyle McSlarrow for his work behind the scenes in support of hydrogen energy development. He helped give hydrogen its role in transitioning markets and the nation's energy future. He made an impression on the President, and has since been nominated to be the Deputy Secretary of the Department of Energy. Please welcome Kyle McSlarrow.



### *Kyle McSlarrow, Chief of Staff for the Secretary of Energy*

- I would like to compliment everyone here on work well done. This effort will take time, and will not end after these two days.
- Last year during the planning process for the National Energy Policy, there was a traditional debate over energy production versus conservation. We realize that this is not a zero sum game – America can do both with the entrepreneurial spirit and genius we have in this country. We have been asked to leap frog this old, tired, stale debate and start thinking outside the box.



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- Hydrogen is just one focus in the National Energy Policy, but the Secretary has spoken about hydrogen more than any other subject mentioned in the Plan. The greatest opportunity and the biggest legacy he can leave would be to focus on incremental changes that will end up being large changes to society and our economy in the long-term future.
  - I view this like a revolution—the scale of this effort is staggering, and everyone will need to be prepared before it can be fully launched. We have not seen change on this scale for several generations. I'll turn the microphone back over to Mr. Garman for closing remarks.

*David Garman, Assistant Secretary, Energy Efficiency and Renewable Energy*

- There are two paths we need to follow: research and development, and public outreach to capture the imagination of the American people. This will be a long journey and process, and the Department of Energy will work with you as we move forward.
- Thanks to all of you.

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# SECTION 10

## LIST OF PARTICIPANTS

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Andris Abele, Quantum Technologies  
Mark Ackiewicz, Technology and Management Services, Inc.  
Duane Adams, Minnesota Corn Growers Association  
Tim Armstrong, Oak Ridge National Laboratory  
Arvind Atreya, University of Michigan  
Rita Bajura, National Energy Technology Laboratory  
John Baker, JMC, Inc.  
Balu Balachandran, Argonne National Laboratory  
Frank Balog, Ford Motor Company  
John Barclay, CryoFuel Systems, Inc.  
David Bartine, NASA Kennedy Space Center  
Shannon Baxter, California Air Resources Board  
E.J. Belliveau, H2 Solutions, Inc.  
Maria Bellos, Fuel Cells 2000  
Gottfried Besenbruch, General Atomics  
Ed Bless, H2 Solutions, Inc.  
Christopher Bordeaux, U.S. Department of Energy  
Richard Bradshaw, Dykema Gossett, PLLC  
Jeannette Brinch, Energetics, Inc.  
Ross Brindle, Energetics, Inc.  
David Bruderly, Clean Power Engineering Company  
Melvin Buckner, Westinghouse Savannah River Company  
Kenneth Cameron, General Motors Corporation  
Robert Card, U.S. Department of Energy  
Richard Carlin, Office of Naval Research  
Rodney Carlisle, History Associates, Inc.  
Tracy Carole, Energetics, Inc.

Lucito Cataquiz, U.S. Department of Energy  
John Celentano, Startech Environmental Corp.  
Steven Chalk, U.S. Department of Energy  
Dhanesh Chandra, University of Nevada, Reno  
Ron Chittim, American Petroleum Institute  
Wilson Chu, Johnson Matthey Fuel Cells  
Helena Chum, National Renewable Energy Laboratory  
William Clapper, SunLine Transit Agency  
Kipp Coddington, Covington and Burling  
Adam Cohn, IET  
Daniel Cohn, Massachusetts Institute of Technology  
William Craven, DaimlerChrysler  
Erin Cready, Sentechn, Inc.  
Anthony Cugini, National Energy Technology Laboratory  
David DaCosta, Ergenics, Inc.  
James Daley, U.S. Department of Energy  
Ed Danieli, Praxair  
J. Michael Davis, Avista Labs, Inc.  
Robert Dempsey, ChevronTexaco Technology Venture  
Robert Dixon, U.S. Department of Energy  
Richard Doctor, Argonne National Laboratory  
Greg Dolan, Methanol Institute  
John Donohue, DCH Technology, Inc.  
Brendan Dooher, National Academy of Engineering  
Louise Dunlap, Dunlap & Browder, Inc.  
Seth Dunn, Worldwatch Institute  
Jack Eisenhauer, Energetics, Inc.

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Kathi Epping, U.S. Department of Energy  
William Ernst, Plug Power  
Kellye Eversole, Eversole Associates  
Kay Fabian, Pacific Carbon International  
Matthew Fairlie, Stuart Energy Systems  
Stephen Fan, Ford Motor Company  
George Fenske, Argonne National Laboratory  
Patrick Findle, Gas Technology Institute  
Jason Francque, Deere & Company  
Alexander Fridman, University of Illinois  
Robert Friedland, Proton Energy Systems, Inc.  
Michael Gan, Hamilton Sundstrand  
Nancy Garland, U.S. Department of Energy  
David Garman, U.S. Department of Energy  
David Gelman, Antares Group, Inc.  
Brent Gerdes, Lincoln Composites  
Lauren Giles, Energetics, Inc.  
Gordon Gillerman, Underwriters Laboratories  
Marshall Gilmore, Florida Hydrogen Business Council  
Norma Glover, South Coast Air Quality Management District  
Thomas Grahame, U.S. Department of Energy  
Leo Grassilli, Office of Assistant Secretary of the Navy (I&E)  
Mark Grist, QuestAir Technologies, Inc.  
Sigmund Gronich, U.S. Department of Energy  
Thomas Gross, U.S. Department of Energy  
Andrew Haaland, ATK Thiokol Propulsion  
F. Henry Habicht, Global Environment & Technology Foundation  
Michael Hainsselin, Praxair  
Donald Hardesty, Sandia National Laboratories  
Art Hartstein, U.S. Department of Energy  
Robert Hawsey, Oak Ridge National Laboratory  
James Hempstead  
David Henderson, U.S. Department of Energy

Raphael Herz, Massachusetts Renewable Energy Trust  
Donna Ho, U.S. Department of Energy  
Susan Hock, National Renewable Energy Laboratory  
Peter Hoffmann, The Hydrogen and Fuel Cell Letter  
Katie Hoffner, Hydrogen Now!  
Peter Holran, Wexler & Walker Public Policy Associates  
Neville Holt, Electric Power Research Institute  
Jonathan Hurwitch, Sentech, Inc.  
Revis James, Electric Power Research Institute  
Arun Jhaveri, U.S. Department of Energy-Seattle Regional Office  
Alan Johnson, ZECA Corporation  
Peter Johnston, Pinnacle West Capital Corporation  
Arthur Katsaros, Air Products and Chemicals, Inc.  
Matthew Kauffman, U.S. Department of Energy  
Ferris Kawar, ATTIK  
Jay Keller, Sandia National Laboratories  
George Kervitsky, Sentech, Inc.  
Danny Keuter, Energy Nuclear, Inc.  
Karen Kimball, U.S. Department of Energy  
George King, Houston Advanced Research Center  
Stacy Klein, Hart Downstream Energy Services  
Joseph Klimek, Startech Environmental Corporation  
Ben Knight, Honda R&D Americas, Inc.  
Kenneth Koyama, California Energy Commission  
Stephen Kukucha, Ballard Power Systems  
Ravi Kumar, GE  
Jay Laskin, Teledyne Energy Systems, Inc.  
Francis Lau, Gas Technology Institute  
David Lax, American Petroleum Institute  
Susan Leach, Hydrogen 2000, Inc.  
Michael Leister, Marathon Ashland Petroleum, L.L.C.  
Jaimie Levin, Alameda Contra Costa Transit  
William Lewis, ExxonMobil Refining & Supply Company

---

James Lide, History Associates, Inc.  
Tedd Lima, Hamilton Sundstrand  
Chung Liu, South Coast Air Quality Management District  
Wisou Luangdilok, Fauske and Associates, Inc.  
Margaret Mann, National Renewable Energy Laboratory  
Faruq Marikar  
Shiro Matsuo, Honda R&D Americas, Inc.  
Robert Mauro, U.S. TAG ISO TC 197  
Jamie McDonald, Energetics, Inc.  
Gary McDow, Air Liquide America  
Katherine McHale, Millennium Cell  
Kyle McSarrow, U.S. Department of Energy  
Stephen Melancon, Entergy Nuclear, Inc.  
Christine Messina-Boyer, Millennium Cell  
C. Lowell Miller, U.S. Department of Energy  
James Miller, Argonne National Laboratory  
Jennifer Miller, Energetics, Inc.  
Karen Miller, National Hydrogen Association  
Robert Miller, Air Products and Chemicals, Inc.  
JoAnn Milliken, U.S. Department of Energy  
Marianne Mintz, Argonne National Laboratory  
David Nahmias, Hydrogen Technical Advisory Panel  
Gene Nemanich, ChevronTexaco  
Edson Ng, QuestAir Technologies, Inc.  
Michael Nicklas, Innovative Design, Inc.  
Alan Niedzwiecki, Quantum Technologies  
Tara Nielson, Energetics, Inc.  
Zdenek Nikodem, U.S. Department of Energy  
Richard Noceti, U.S. Department of Energy/NETL  
Joan Ogden, Princeton University  
Jim Ohi, National Renewable Energy Laboratory  
Robert Olson, Institute for Alternative Fuels  
Manuel Pacheco, PDVSA-Citgo

Catherine Gregoire Padro, National Renewable Energy Laboratory  
Terry Penney, National Renewable Energy Laboratory  
Adam Pivovar, National Institute of Standards and Technology (NIST)  
Venki Raman, Air Products and Chemicals, Inc.  
Richard Rashilla, Lincoln Composites  
James Ritter, University of South Carolina  
Jerry Rogers, General Motors R&D  
Peter Rohde, Inside Washington Publishers  
Michael Romanco, Gas Technology Institute  
Samuel Rosenbloom, U.S. Department of Energy  
Neil Rossmeyssl, U.S. Department of Energy  
Kenichi Sakamachi, JMC, Inc.  
Jodi Salup, Wexler & Walker Public Policy Associates  
Krishna Sapru, ECD, Inc.  
Richard Sassoon, SAIC  
Vesna Scepanovic, Natural Resources Canada  
Jennifer Schafer, Plug Power, Inc.  
Randolph Schaffer, Structural Composites Industries  
Rich Scheer, Energetics, Inc.  
Edward Schmetz, U.S. Department of Energy  
Gregory Schuckman, University of Central Florida  
Ken Schultz, General Atomics  
Paul Scott, Stuart Energy USA  
Andrew Searcy, Southern Hydrogen Fuel Cell Research Partnership  
Prentiss Searles, American Petroleum Institute  
Lauren Segal, BP  
Rajat Sen, Sentech, Inc.  
Jeffrey Serfass, National Hydrogen Association  
Martin Shimko, Gas Equipment Engineering Company  
Surindar Singh, Alberta Energy Research Institute  
Edward Skolnik, Energetics, Inc.  
Brad Smith, Shell Hydrogen

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Charles Smith, Energetics, Inc.  
Daniel Smith, G.E. Corporate Research & Development  
William Smith, Proton Energy Systems, Inc.  
Jeffrey Staser, Denali Commission  
Glenn Strait, World & I Magazine  
Kenneth Stroh, Los Alamos National Laboratory  
Andrew Stuart, Stuart Energy Systems  
William Summers, Savannah River Technology Center  
F. Dexter Sutterfield, National Energy Technology Laboratory/NPTO  
Chris Sutton, Air Products and Chemicals, Inc.  
Satish Tamhankar, The BOC Group  
Stephen Tang, Millennium Cell  
Christina TerMaath, Energetics, Inc.  
C.E. Thomas, H2Gen Innovations, Inc.  
George Thomas, Sandia National Laboratories  
Robb Thompson, Dynetek Industries Ltd.  
Dale Tiller, Lincoln Composites  
David Tsay, Ztek Corporation  
John Turner, National Renewable Energy Laboratory

Richard Uchrin, Activated Metals Technologies  
Terrence Udovic, National Institute of Standards and Technology  
Charles Veley, U.S. Hydrogen  
Greg Vesey, ChevronTexaco Technology Venture  
Robert Walker, Wexler & Walker Public Policy Associates  
Patricia Watson, DuPont Company  
Suzanne Watson, Northeast Midwest Institute  
Kyle Wetzel, K. Wetzel & Company, Inc.  
Doug Wheeler, UTC Fuel Cells  
Gene Whitney, Office of Science and Technology Policy  
Frank Wilkins, U.S. Department of Energy  
James Williams, American Petroleum Institute  
Kathleen Winn, K. Winn & Associates, Inc.  
Bruce Wood, Deere & Company  
Adriene Wright, E2I  
John Wysor, U.S. Environmental Protection Agency  
Rosa Young, Chevron Texaco Ovonic Hydrogen Systems, L.L.C.  
Stephen Zimmer, DaimlerChrysler Corporation  
Mary Rose de Valladares, DCH Technology, Inc.