Proceedings

NATIONAL HYDROGEN VISION MEETING

Washington, DC

November 15-16, 2001

"The President's Plan directs us to explore the possibility of a hydrogen economy…"

Spencer Abraham, Secretary of Energy

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INTRODUCTION

On November 15-16, 2001, more than forty senior executives representing the energy industries, environmental organizations, and federal and state government agencies met for a "Hydrogen Vision Meeting," during which they discussed the potential role of hydrogen energy systems in America's energy future. (A list of the participants can be found at the end of this document.) The intent was to identify a common vision of a "hydrogen economy," the time frame in which such a vision could be expected to occur, and the key milestones that would need to be accomplished to get there.

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 meeting. There will be a forthcoming national vision document released shortly.

SECTION **1.0**

HYDROGEN INDUSTRY DRIVERS

Sense of the Group: *Which factors are most likely to **support/inhibit** the development of a "hydrogen economy" in the United States?*

Key Supporting Drivers
National security
Global warming/carbon
Promising technology advances
Long-term energy to support world population

Key Inhibiting Drivers
Lack of infrastructure
Cost issues/competing technologies
Storage technologies
Lack of coherent /sustained public policy
Perception of safety issues and fear of accidents

Drivers that both Support and Inhibit
Customer acceptance/market inertia
Availability of oil and gas resources

Supporting Drivers
(♦ = Number of Votes)

MARKET	POLICY	TECHNOLOGY	ENVIRONMENTAL	OTHER
• Increasing world population and their need for energy long term ♦♦♦♦♦ • Limited amount of oil/gas and preservation of natural resources for the future ♦♦♦♦ • Customer choice ♦♦♦ • Increasing public recognition of the need and advantages of energy system change ♦♦ • Better, exciting cars ♦♦ • Broad commercial availability of hydrogen production capacity (fuel cells – portable, stationary, other) ♦ • Mechanism and innovation for gradual introduction to market (e.g. subsidized high quality power) ♦ • Possibility of crude oil production peaking between 2010 and 2020 ♦ • Continuing global population will demand power diversity at decreasing cost ♦ • Multiple successful market-driven hydrogen energy solutions in which government has taken appropriate steps to facilitate this due to multiple benefits *(continued)*	• National security – alternate to oil/gas ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ • National energy security and carbon-free technology ♦♦♦♦♦♦♦♦♦♦♦♦♦ • Government policy and funding priority for non-emitting technologies ♦♦♦♦ • Government support through incentives, tax credits, etc. in transition ♦♦♦ • Need for the U.S. to be less dependent on foreign energy sources ♦♦ • Generating public awareness and support through well-managed, carefully-evaluated demonstrations ♦♦ • Large part of world sees global climate change – push U.S. to do something (carbon tax, etc.) ♦ • Worldwide efforts to develop hydrogen economies ♦ • Fair access to electric grid ♦ • No tax on hydrogen as a fuel for 30 years • Government must commit to transitioning from fossil fuel to renewable sources *(continued)*	• Expected advancements in hydrogen storage and production ♦♦♦♦♦♦♦♦♦♦ • Achievement of low-cost commercial electro chemical fuel cells and hydrogen generators ♦♦♦♦ • Utilization of new advanced nuclear plants to produce emission free hydrogen ♦♦ • Development of clean coal technology to generate electricity for water electrolysis • Coordinated focus on technology development on a worldwide basis • Efficiency …energy multiplier • Only incremental technology necessary	• Global warming – carbon ♦♦♦♦♦♦♦♦♦♦♦♦♦♦ • Climate change – carbon sequestration, local pollution, carbon tax/renewable (carbon free) credit ♦♦ • Limits on CO_2 emissions from power plants • In the future, count efficiency/renewables in environmental regulations • Planned environmental agenda aligned with economical technology development	• Multiple benefits ♦♦♦♦ • Being able to offer innovative products and services ♦♦♦♦ • Abundance of hydrogen ♦♦♦ • Disconnecting the production and use (consumption) of energy from the environment and geography and calamity ♦♦ • Multi-use utility ♦ • Innovative idea that will grab consumers (e.g. very small electronic device – hydrogen power supply) ♦ • Good public relations for companies pursuing these hydrogen products ♦ • Need to replace current aging infrastructure and insecure fuels ♦ • Unexpected oil interruptions to industrial countries or price hikes • Cost-effective, publicly acceptable technologies for non-fossil derived hydrogen (very large scale) • Viable road map to use hydrogen in current power plants • Consumer need *(continued)*

Market	Policy	Technology	Environmental	Other
• Managing consumer expectations – speed of products to market, cost, capabilities	• Energy security – broader application of domestic sources • Energy in the U.S. is a critical asset for economic growth • U.S. seen as big “waster” of the world – global pressure • Window of opportunity with public demanding domestic energy			• Unrest in the Middle East • Unforeseen global circumstances (environmental/political) • Technical talent, ability to focus and deliver • Distributed power is eagerly anticipated in the Third World, in the U.S. (in wake of rolling blackouts)

Inhibiting Drivers

(♦ = Number of Votes)

Market	Policy	Technology	Other
• Cost of hydrogen production, utilization, infrastructure ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ • Customer acceptance of new technology ♦♦♦♦♦♦♦♦ • SULEV gasoline vehicles ♦♦♦ • What goes first? Cars or infrastructure? Interdependency of investment ♦♦♦ • How to get the money – utilities? ♦♦ • Mass/size of existing infrastructure and cost effectiveness of existing systems ♦♦ • Hydrogen supply (natural gas supply and carbon sequestering) ♦♦ • Evolution of competing technologies (lower cost, lower emissions, higher efficiency) “Moving baseline” ♦♦ • Low energy prices (oil) discourage alternatives to petroleum ♦ *(continued)*	• Political indecision and lack of political support ♦♦♦♦♦♦♦♦♦ • New alliances needed (government and industry) ♦♦♦ • Building codes for storage of hydrogen ♦♦♦ • We are up against two commodities: fuel and electricity – partially priced; the use of the environment – unpriced ♦♦ • CAVE – Citizens Against Virtually Everything, people’s resistance to change ♦♦ • Lack of environmental credits for low emitting sources ♦♦ • Sustained, high-level government support to keep industry involved ♦ *(continued)* • Public policy: U.S. and	• Lack of technology to store hydrogen with sufficient energy density ♦♦♦♦♦♦♦♦♦♦♦ • Need to standardize technologies ♦♦ • Slowdown in the rate of technology advances for fuel cells, hydrogen storage, hydrogen production ♦ • Taking our “sweet time” refining technology and reaching commercialization	• Lack of infrastructure clarity going forward – how to get hydrogen to consumers, number of required transactions ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ • Perception of safety, especially storage in living areas ♦♦♦♦♦♦♦ • U.S. strategy: 10-20 years too long, business/industry payback, U.S. election cycles – no instant gratification ♦♦♦♦ • Very visible safety accident involving hydrogen ♦♦♦ • Refueling infrastructure ♦♦ • “Surprise”: environmental, resource, technical, geopolitical • Brakes in hydrogen programs ♦ • Incoherent/inconsistent voice from industry

MARKET	POLICY	TECHNOLOGY	OTHER
• No profits ♦ • Failure of early adopter (fuel cells, infrastructure, independent applications, portable, UPS, intermittent fuel cell power) ♦ • Mindset cost to produce hydrogen is a barrier – Amory Lovins – What is the true value of earth's resources we use? • Clean<u>er</u>, cheaper, plentiful domestic coal • Public acceptance of large distribution networks – safety issue • Economic vulnerability from energy insecurity	internationally – U.S. being a follower rather than a leader and not maintaining a sustained effort ♦ • Regulatory/economic barriers to distributed generation – e.g. interconnection standards, exit fees, standby charges ♦ • Insufficient level of government funding, partnering, due to earmarked programs – synergies of funded programs not realized e.g. IGCC/hydrogen • Lack of <u>early</u> government support to kick-start hydrogen application • Carbon as a religion • Political or economic inertia (large hesitancy to start something new, such as infrastructure) • Present level of political support • Regulatory codes and standards development • Hydrogen is versatile but complex – means many things to many people – political challenges		

SECTION 2.0

BREAKOUT GROUP #1

- **Vision of a Hydrogen Economy**
- **Characteristics of a Hydrogen Economy in 2030**
- **Transition to a Hydrogen Economy**
- **Transition Milestones**
- **Next Steps for Industry and Government**

Participants:
Breakout Group #1

NAME	ORGANIZATION
Frank Balog	Ford Motor Company
Dave Bartine	Kennedy Space Center
Susan Brown/Louise Dunlap	California Energy Commission/ Dunlap & Browder, Inc.
Mike Davis	Avista Labs, Inc.
John Donohue	DCH Technology, Inc.
Jae Edmonds	Battelle-Pacific Northwest Laboratory
Arthur Katsaros	Air Products and Chemicals, Inc.
Dan Keuter	Entergy Nuclear, Inc.
Daniel Lashof	Natural Resources Defense Council
Lauren Segal	BP
Andrew Stuart	Stuart Energy Systems
Robert Walker	The Wexler Group

FACILITATOR: Jack Eisenhauer, Energetics, Incorporated

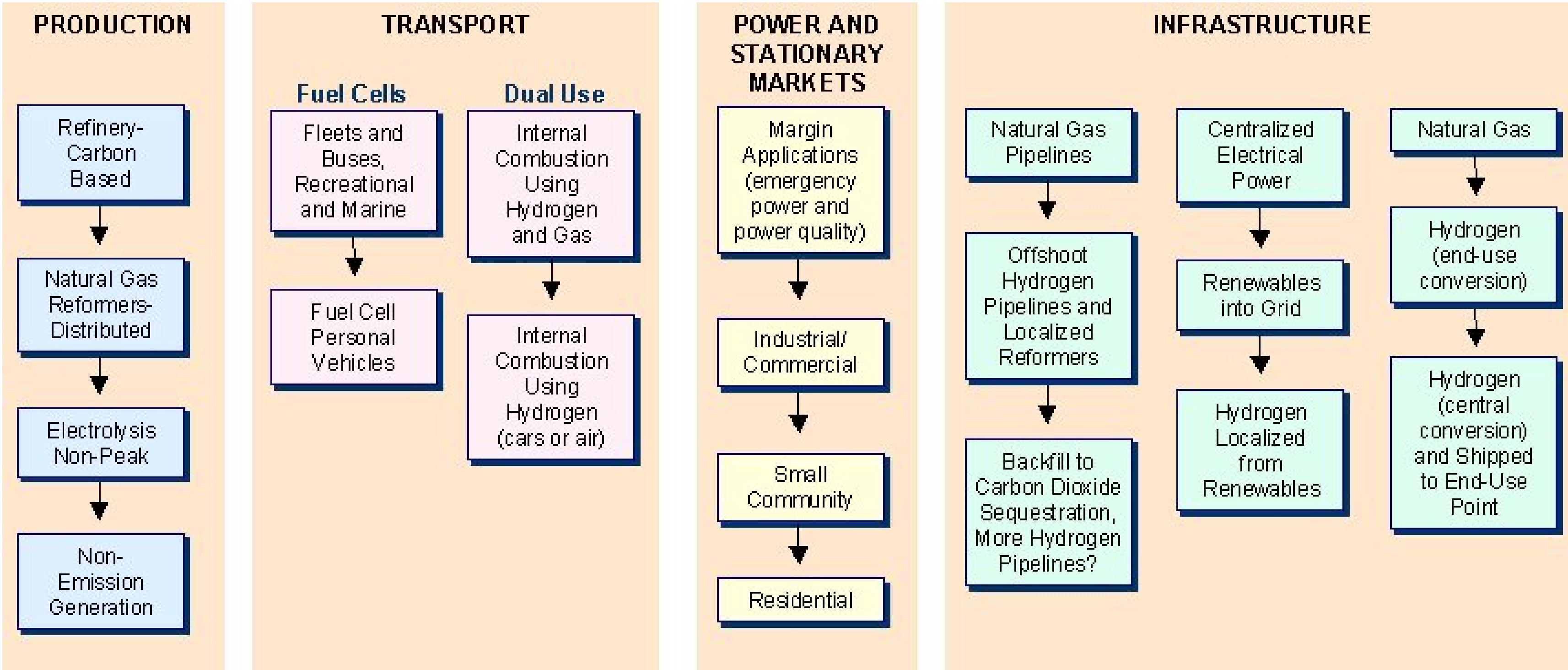
Vision of a Hydrogen Economy

DESCRIPTION	EXPECTED TO OCCUR BY
• Hydrogen is economically produced from a variety of renewable energy sources (i.e. carbon-free sources); for transportation and distributed generation uses	2050
• Production and consumption of energy with no environmental impact • Production and consumption with no geographic limits • Production and consumption is secure and robust • Unlimited access to unlimited supply of clean, affordable energy	2050
• Quieter, cleaner, and prosperous world • Similar world- cars, buses, planes; homes a bit more modern • Electrons and hydrogen interchangeable and distributive • Nuclear, hydrocarbon-carbon as building material, solar/wind, hydrogen fusion starting	2025-first parts in place 2050-all new systems will be hydrogen-based 2100-total capital and infrastructure turnover
• Globalization of technology for transportation and power • Variation of production with local resources • Stable, safe storage (long-term, self-maintaining) • Air quality improvement, overall environmental quality	2025-big parts in place 2050-dominant form of energy
Additional descriptive words for the visions: ▪ Automated systems ▪ Ubiquitous access to electricity ▪ Everyone in the energy business	

Characteristics of a Hydrogen Economy in 2030

PRODUCTION	INFRASTRUCTURE	END-USE MARKETS	SHARE OF U.S. ENERGY PORTFOLIO
• Hydrogen production is centralized and uses carbon capture technology • Electricity/hydrogen cogeneration • Energy efficiency of the system will be a critical factor • Energy primarily from hydrocarbons; some renewables used • Distributed power application developed and in use • Hydrogen production in a transition period	• New hydrogen pipelines being built • Hydrogen/natural gas dual use pipelines • Some conversion of existing natural gas pipelines • Storage technology challenges largely solved • Hydrogen fueling in existing service stations for vehicles • Over road transportation by tanker trucks • Distributed power technologies developed • Integration of centralized and decentralized power production	• Hydrogen is the dominant fuel for buses and fleets • Hydrogen captures about 25% of auto and light truck market • Dual gasoline/hydrogen fueling stations • Fuel cells fully developed • Industrial/large commercial fuel cells lead the market • Peaking fuel cell units used • Residential use of hydrogen about 10% if economical fuel cells are developed and supporting policies are present	• Key transition period for hydrogen • 1/3 of end use will involve hydrogen if costs are at \$50/kW • 10%-20% of end-use will involve hydrogen if costs are over \$50/kW

Transition to a Hydrogen Economy



Transition Milestones and Next Steps for Government and Industry

TECHNOLOGY DEVELOPMENT	POLICIES	NEXT STEPS FOR GOVERNMENT AND INDUSTRY
• Non-emission generation; carbon capture • Meeting cost goals for generation • Mass storage • Safety features • Conversion to electricity-cost goals	• Standardization of technologies • Codes and standards; certification • Corporate and government environmental policies and incentives • National security • Insurability	• Create programs to use & highlight existing hydrogen infrastructure • Develop technology roadmap • Begin to address institutional barriers- coordinate codes, standardization, regulations • Create government-industry partnership to build the first advanced reactor to produce hydrogen • Initiate collaboration/ technology investments on roadmap priorities • Describe & analyze current technology & infrastructure • Begin strong outreach & communication; appropriate messages - educate consumers and the public!

SECTION **3.0**

BREAKOUT GROUP #2

- **Vision of a Hydrogen Economy**
- **Characteristics of a Hydrogen Economy in 2030**
- **Transition to a Hydrogen Economy**
- **Transition Milestones**
- **Next Steps for Industry and Government**

Participants:
Breakout Group #2

NAME	ORGANIZATION
Ethan Brown	National Governors Association
Rich Carlin	ONR, Navy
Sanjay Correa	GE Corporate R&D
Leo Grassilli	Navy
Steve Kukucha	Ballard Power Systems
Jaime Levin	AC Transit
Buford Lewis	Exxon-Mobil
Jim MacKenzie	World Resources Institute
Byron McCormick	General Motors
Joan Ogden	Princeton University
Don Terry	Praxair, Inc.

FACILITATOR: Rich Scheer, Energetics, Incorporated

Vision of a Hydrogen Economy

SUBGROUP #1	SUBGROUP #2	SUBGROUP #3
Buildings in 2030 • Combined heat and power • Fuel cells and microturbines with hydrogen site-generated and delivered • Microprocessors optimizing cost Transportation in 2030 • Vehicles integrated into home systems and external • Fuel cells, microturbines and battery • Refueled at home and at service stations Personal use in 2030 • Small, integrated fuel cell batteries	• Hydrogen economy = large scale use of hydrogen for energy • Policy drivers needed o Carbon dioxide o Air pollution o Energy security • Hydrogen economy will be regionally diverse (more like electricity) • Distributed fuel production and centralized • Hydrogen economy will enable new industries • It will take decades to complete the transition (1020% hydrogen by 2030)	• Hydrogen will be a significant carrier in a distributed and integrated system In 2030 • Hydrogen will provide energy and environmental solutions to a broad range of applications in a broad range of markets. In 2030 • Hydrogen will open up access to currently underserved/new markets.

Characteristics of a Hydrogen Economy in 2030

SECTOR	VISION
PRODUCTION	Mix of sources based on local resource endowments/policies
	Mostly natural gas
	Methanol
	Use of domestic coal and nuclear achieves energy independence
	Carbon dioxide sequestering
	Public acceptance of nuclear
	Biomass and waste make contributions; also wind and solar until costs come down
	Existing hydrogen waste streams captured and used
	Mix of both on-site and centralized
INFRASTRUCTURE	Existing infrastructure leveraged – both electricity and natural gas
	Transportation and electricity grids merged
	Filling stations – 30% penetrations required
	Can it be regional, or must it be national?
	Widespread distributed generation for "perfect power"
	Pipelines used where demand is "dense" e.g. urban areas
	Onsite production and trucks deliver hydrogen where demand is less dense
	Evolving infrastructure
	Beyond 2030
	Tanker fleets
	Oil refineries
END-USE MARKETS	People want energy on demand
	People want unfettered mobility
	All fleets use hydrogen
	DC-based appliances and equipment (low voltage)
	Opportunistic use of buildings CHP
	Opportunistic use of hydrogen personal power devices ultimately ubiquitous
	Opportunistic use of small hydrogen power generators
	Large-scale generators – coal gasifiers, shift/carbon dioxide sequestration, hydrogen fuel cell, 500 MW / 70%
HYDROGEN CONTRIBUTION TO NORTH AMERICAN ENERGY MIX	Use of electricity or hydrogen, whichever makes sense
	2030 is soonest end state likely to be reached
	Policy alignment will have to have occurred
	Liquid fuels in use for a long time to come

Transition to a Hydrogen Economy

SECTOR	CHARACTERISTICS
PRODUCTION	**Premium power** **Distributed generation** **Large co-production with capture power, hydrogen, and thermal** Stationary markets Merger of transportation and stationary applications Mixture of hydrogen and other fuels
INFRASTRUCTURE	**Fleets for transit, corporate, and government users** **Vehicles for early adopters and the mass market** Transportation markets All hydrogen eventually
TRANSPORTATION MARKETS	**Fueling for fleets** **Trucks serving as stationary power** **Hydrogen at 30% of fueling stations** Centralized production with pipes Infrastructure development Simplification of standardized storage
STATIONARY MARKETS	**Continued improvements in small-scale (10-100 kW—mostly reformers, purification, renewables)** Carbon dioxide capture for large-scale applications Continued improvements in large-scale (efficiency, other fuels) Production and the use of nuclear during off-peak times

Transition Milestones and Pitfalls

TRANSITION METHOD	MILESTONES AND PITFALLS
TECHNOLOGY DEVELOPMENTS	< 500 kW hydrogen equivalent – reformer, storage
	Improved hydrogen storage by 2010
	Standardized designs and package systems
	Durable, low-cost fuel cells and fuel cell systems
	Safety concerns
PUBLIC POLICIES	"System" approach
	Stability
	Continuity and sustainability
	Certainty around carbon dioxide policy/tax
	Leadership role backed up by comprehensive action plan and funding
	Government is first customer
	Direct government funding for leadership role
	Endorsement by President and Congress for programs similar to man on moon program
	Communicate vision to public
	Include externalities in energy costs
	No mandates on CAFÉ solutions – market-based solutions needed
	Grid interconnect and exit protocols
	Incentivization through tax policies – fuels choice, infrastructure investment, fleet vehicle owners
	Establish uniform codes and standards

Next Steps for Industry and Government

- Government is customer
- Government district power stations
- Department of Defense first customer
- Government provides fleet incentive
- Urban transport
- Government – enable the market
- Support and fund effective, measurable demonstration programs
- Develop joint government/industry education program
- Articulate vision to the public
- Establish a change in the process – create the "need"
- Promote industry solutions
- Industry: continued commitment to technology development
- Anticipate and neutralize negative court actions
- Develop codes and standards

SECTION 4.0

BREAKOUT GROUP #3

- **Vision of a Hydrogen Economy**
- **Characteristics of a Hydrogen Economy**
- **Transition to a Hydrogen Economy**
- **Transition Milestones**
- **Next Steps for Industry and Government**

Participants:
Breakout Group #3

NAME	ORGANIZATION
Graham Batcheler	Texaco Energy Systems
Thomas Bean	Verizon
William Craven	DaimlerChrysler
Richard Cromwell	Sunline Transit Agency
William Miller	International Fuel Cells
Richard Rocheleau	Hawaii Natural Energy Institute
Arthur Smith	NiSource, Inc.
William Smith	Proton Energy Systems, Inc.
Stephen Tang	Millennium Cell
Richard Truly	National Renewable Energy Laboratory
James Zucchetto	National Academy of Sciences

FACILITATOR: Ross Brindle, Energetics, Incorporated

Vision of a Hydrogen Economy

SUB-GROUP VISION STATEMENTS
▪ An all-electricity economy, enabled by a "self-regulated," secure network with hydrogen as the energy medium made with renewable, sustainable energy sources ▪ A world where hydrogen is the primary fuel for cars, buses, and trucks, and where hydrogen is readily available in the community and is attractive to the customer ▪ Energy transformation toward non-carbon fuels, and ensure secure supply ▪ Environmental change through improved air quality and public health ▪ Commitment in a timeframe that ensures success ▪ Abundant domestic supply of cheap hydrogen ▪ U.S. is world leader in a thriving hydrogen economy ▪ Established infrastructure for all end uses ▪ Environmentally friendly with virtually no emissions ▪ Enhances the conservation of fossil resources
COMMON VISION ELEMENTS
▪ Hydrogen is recognized as a fuel by the general public ▪ Abundant hydrogen supply produced in a sustainable, environmentally responsible manner ▪ Transition in energy portfolio over long period of time to a hydrogen and electricity economy ▪ Widespread applications for hydrogen ▪ It works the same or better: is safer, cleaner, cheaper ▪ Hydrogen as an energy carrier ▪ End-state: completely renewable, sustainable source that is economics driven ▪ Hydrogen economy does not mean that fossil goes away ▪ Similar to natural gas—we use natural gas today but don't say "We are in a natural gas economy"

Characteristics of a Hydrogen Economy in 2030

PRODUCTION	INFRASTRUCTURE	END-USE MARKETS	POLICY
• Technology exists for small- to large-scale conversion • Low-cost, easy to use generation appliances are widely available • National standard for production is in place • Hydrogen is based on all sources of energy, defined by end-use and economics • Principally fossil generation at first (selective production from coal, natural gas), large and growing renewable production over time, nuclear is uncertain • Ultimately, largely produced by sustainable supplies—e.g., electrolysis of renewables	• Vastly improved security in infrastructure • Storage technology exists, including novel liquid and solid storage • Customer convenience—homes and businesses will be able to make electricity from a variety of sources • Infrastructure will be defined by end-use needs • Combination of distributed and centralized delivery with many points of distribution • Localized or at select locations/service stations; nodes of development • Modest infrastructure with some dedicated fleets • Public will see a combination of central and distributed infrastructure as safe	• Autos, home, buildings, business, industry, portable: across the board • Autos: more will be in fleet/public transportation (as opposed to private) • Residential: remote, off-grid applications first • Consumer products, vehicles, stationary power will be real penetration—growing consumer satisfaction • Personal applications led by the military—portable power • Backup and auxiliary power—luxury power services • UPS—instant startup	• Consistent and stable policy—government commitment with establishment of goals in a set time frame • Federal and state alignment • Recognition of energy security as economic driver • Fuel cells and hydrogen are recognized in state and local building codes • More stringent emissions standards, especially for vehicles—carbon emissions standards • Investment capital incentives • Tax incentives

Transition to a Hydrogen Economy

Technology			Markets		
Production	**Infrastructure**	**Storage**	**Portable**	**Stationary**	**Transport**
• Small electrolysis units • Smaller fuel processors become more efficient (on-site reformers)—wider range of fuel • Catalyst improvements • Large, multi-MW reformer and distribution of hydrogen • Chemical hydrides • Utilities may decide to buy fuel and supply kWh—end-users won't be buying large boxes • Transportation: methanol may be dispensed instead of hydrogen • Where value proposition exists will be first, drive development • Mass production is key to drive cost down in all markets	• Trucking hydrogen is useful for some applications in maybe the next 10 years • Certain size metro areas will support centralized production and distribution via pipeline—otherwise: distributed • Fleets use stations, but open to public transportation also • Small-scale production and distribution • Large-scale production and distribution • Individual fuel processors for small power plants • On-site hydrogen production from natural gas, liquids • Infrastructure in 2030 will be mix of distributed and locally centralized—not like power plants	• Compressed hydrogen in early years • May be liquid storage in some applications • Hydrides and cylinders and some applications • Electrochemical compression early on • 2030s: nanotubes, chemical hydrides may be answer • Customer prefers liquid to gas—must keep this in mind when transitioning to hydrogen economy to avoid technology conundrum	• 2002: products being sold moving toward commercial—backup power • Refueling cylinders • Few kWh, high value proposition • Displacement of batteries; batteries powered by hydrogen	• 2003- $1500/kWh • 2004-1 million cells/year sold • 2004: small UPS units, other stationary products • Supply natural gas to power unit and complete development of suitable fueling • Evolution drives volume, generates profits to sustain development	• Small fuel cells in specialty vehicles (forklifts, mowers) • Fleet-fueling facilities—fuel will be location-specific • 2007-08: Transportation is visible • Bus market: 5000 buses per year equals 1million cells/year • 1 million cars equals 300 million cells/year

Major Milestones

TECHNOLOGY DEVELOPMENT	ENERGY AND ENVIRONMENTAL POLICIES	NEXT STEPS FOR GOVERNMENT AND INDUSTRY
• Decrease total cost to own fuel cells (e.g., Moore's law-type rate of improvement for fuel cells) • Short-term improvements to fuel cells (e.g., quick start, temperature range, durability) • Different approach to warranties • Carbon sequestration • Decrease total cost to produce and deliver hydrogen • Storage: on-board storage for transportation must be cheap, light, small, with increased energy density • Hydrogen production systems that are sustainable (long-term milestone)—i.e., production from renewables • Storage must be low-cost and convenient • Multi-fuel fuel processors available "off-the-shelf" • Membrane technology improve hydrogen production • Manufacturing techniques to reduce cost (mass production)	• Designate energy security as primary concern over the long-term • Elimination of carbon dioxide emissions • Put effective commercial and technical codes and standards in place • Alignment of all energy sources toward hydrogen manufacturing • Increase support of public/private, state/Federal partnerships • For stationary growth, exit fees and standby charges must be removed—create national standard since all states now differ • Hydrogen should have an increased role as time goes on—hydrogen should be the "common denominator" • Government should have more involvement with utilities up front • Government role: sustained R&D effort over long-term • Commit to/realize value of education of workers—establish training programs • Environmental regulations have to recognize energy efficiency in use of renewables • Flexible carbon policy and criteria of pollutants—e.g., carbon trading • Financial support for demonstrations—current grid and telecommunication are outdated	• Write a vision that can be supported by all meeting attendees • Finish roadmapping exercise to define appropriate roles for government, industry, etc. • Education on joint industry/government basis • Increase funding for core technology development: fuel cells, carbon sequestration, etc. • Identify and coordinate work related to hydrogen economy across Federal agencies—e.g., military, DoD, EPA, DOE • Focus some efforts on integrating hydrogen with some of its other efforts (e.g., clarity, holistic) • Look for more remote power opportunities at national parks, Indian reservations • Coordinate with states • Industry has to continue to educate Capitol Hill • Perhaps create an Assistant Secretary position for Hydrogen within the U.S. DOE? (similar to Fossil) • Get industries to accept the concept of distributed generation • Get products to market as soon as possible—commercial release of early products • Government should become first customers where appropriate—e.g., military applications • Government/industry partnerships such as Partnership for a New Generation of Vehicles—research, demonstration common goals in all markets
• Smooth operation of electric grid; bringing grid up to speed—support distributed markets		• Create tax incentives for initial purchase of products • Include national security theme in hydrogen economy

SECTION **5.0**

WRAP-UP SESSION

- "We should be both visionary and practical."
- "This meeting has been educational and rewarding. I am happy to see that the U.S. Department of Energy is listening."
- "The future is always more important than the past. The opportunity of a lifetime is here—we must push ahead toward the Hydrogen Economy."
- "Energy security is a major issue. The transition will be a long one."
- "We need to work on determining how to communicate the value of demonstrations. Demonstrations are very valuable for benchmarking."
- "This is the first time that I've attended a meeting like this: the Administration was in attendance and listened."
- "It is important that we all take part in the Roadmap development process to follow."
- "I have been very encouraged by this meeting. Next steps will have to be a collective effort."
- "Utilities, oil companies, etc. are going to have to work together to reach the Hydrogen Economy."
- "Many good discussions took place at this meeting. We must remember no to be too parochial and not to over-promise. We must think internationally."

- "This meeting was certainly 'something new'. It was interesting to see how much confluence exists among participants. We now must articulate the vision and implement it."

- "Since the U.S. is a world leader, everyone will be looking to us to get the Hydrogen Economy right."

- "It is good to see a consensus among participants because the U.S. 'works on consensus'. The Hydrogen Economy is a system, and we've dealt with portions of the system at this meeting."

- "We need to come up with a forward-thinking vision that would get members of the coal industry to sign on. I am encouraged by the coherent leadership that has been exhibited at this meeting—it is very important. I commend the U.S. Department of Energy for putting this meeting together."

- "The Hydrogen Economy transition problem is really a policy problem…the pricing of fuels today is 'out of whack'. We need to get the price right and then regulate."

- "Technology exchange between Federal agencies is always good. We need to continue to develop a 'forcing function'. We need to think in terms of 'systems'."

- "One potential solution to obtaining a large supply of low-cost hydrogen with very low emissions is the use of advanced nuclear plants that make hydrogen."

- "We must continue to work in bringing down the cost of key hydrogen technologies like storage devices and fuel cells."

- "There are six key issues that we need focused on, including systems reliability, durability, and cost reduction within the private sector, and safety, liability, and permitting within the public sector."

SECTION **6.0**

PRESENTATIONS: THE HYDROGEN ENERGY INDUSTRY TODAY

6.1 Production, *Graham Batcheler, Texaco Energy Systems*

6.2 Transport/Infrastructure, *Arthur Katsaros, Air Products and Chemicals*

6.3 Storage, *Alan Niedzwiecki, Quantum Technologies, Inc.*

6.4 Fuel Cells, *William Miller, UTC (International) Fuel Cells*

6.5 End-Use, *Byron McCormick, General Motors;*
and Arthur Smith, NiSource, Inc. (speakers used talking points)

Section **7.0**

Presentations: The Future of Hydrogen Energy Development

7.1 The Honorable Robert Walker, *The Wexler Group (presenter used talking points)*

7.2 <u>Dr. Jae Edmonds, *Battelle, Pacific Northwest Laboratory*</u>

SECTION **8.0**

LIST OF PARTICIPANTS

Rita Bajura, National Energy Technology Laboratory
Frank Balog, Ford Motor Company
David Bartine, Kennedy Space Center
Congressman Roscoe Bartlett, U.S. House of Representatives
Graham Batcheler, Texaco Energy Systems
Thomas Bean, Verizon
Peter Blair, National Academy of Sciences
Ethan Brown, National Governors Association
Susan Brown, California Energy Commission
Robert Card, U.S. Department of Energy
Richard Carlin, Office of Naval Research
Sanjay Correa, GE Corporate Research & Development
William Craven, DaimlerChrysler
Richard Cromwell, SunLine Transit Agency
John Darnell, House Committee on Science
J. Michael Davis, Avista Labs, Inc.
Robert Dixon, U.S. Department of Energy
John Donohue, DCH Technology, Inc.
Louise Dunlap, Dunlap & Browder, Inc.
Jae Edmonds, Battelle-Pacific Northwest National Laboratory
David Garman, U.S. Department of Energy
Leo Grassilli, Office of Assistant Secretary of the Navy (I&E)
Tom Gross, U.S. Department of Energy
R. Shane Johnson, U.S. Department of Energy
Arthur Katsaros, Air Products and Chemicals, Inc.
Dan Keuter, Entergy Nuclear, Inc.
Karen Kimball, U.S. Department of Energy
Robert Kripowicz, U.S. Department of Energy
Stephen Kukucha, Ballard Power Systems
Daniel Lashof, Natural Resources Defense Council
Jaimie Levin, Alameda Contra Costa Transit
William Lewis, ExxonMobil Refining & Supply Company
James MacKenzie, World Resources Institute
Byron McCormick, General Motors
William Miller, UTC (International) Fuel Cells
Jaffer Mohiuddin, Office of Senator Akaka
Richard Moorer, U.S. Department of Energy
Alan Niedzwiecki, Quantum Technologies
Joan Ogden, Princeton University
William Parks, U.S. Department of Energy
Richard Rocheleau, Hawaii Natural Energy Institute
Rich Scheer and Energetics, Inc. Facilitation Team
Lauren Segal, BP
Arthur Smith, NiSource Inc.
William Smith, Proton Energy Systems, Inc.
Andrew T.B. Stuart, Stuart Energy Systems
Stephen Tang, Millennium Cell
Donald Terry, Praxair, Inc.
Richard Truly, National Renewable Energy Laboratory
Robert Walker, The Wexler Group
Frank Wilkins, U.S. Department of Energy
James Zucchetto, National Academy of Science