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Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen

Workshop Proceedings

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Sacramento, California
April 3, 2008

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NREL/BK-560-43669
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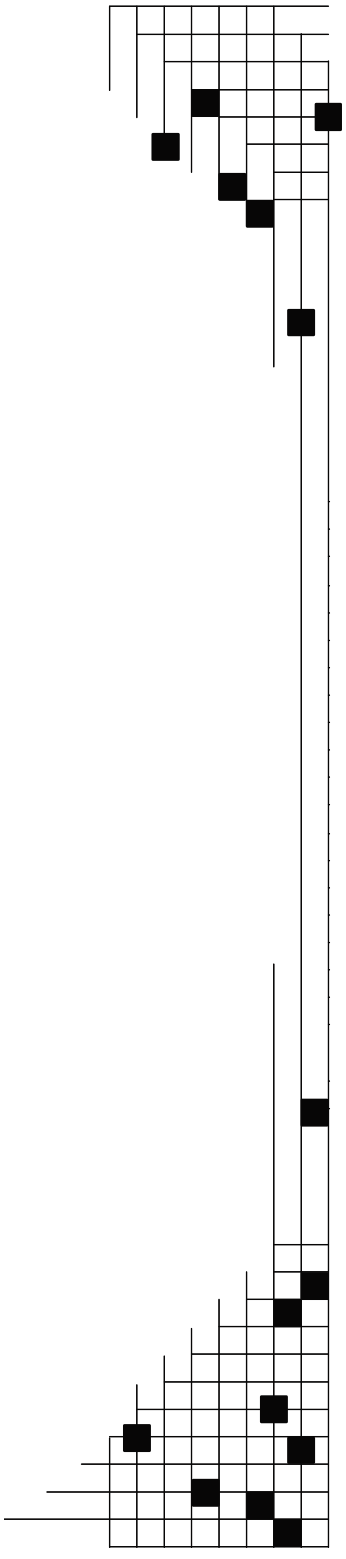

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Office of Energy Efficiency and Renewable Energy
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Contract No. DE-AC36-99-GO10337

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Acknowledgements

This workshop was planned under the guidance of Marc Melaina of the National Renewable Energy Laboratory (NREL), with input from Fred Joseck and John Garbak of the Department of Energy's Hydrogen, Fuel Cells & Infrastructure Technologies Program. Workshop organization and facilitation was provided by Energetics, Incorporated in Columbia, Maryland. Breakout group facilitators included Jeannette Brinch, Sabine Brueske, and Mauricio Justiniano. The proceedings were prepared by Marc Melaina (NREL), Jeannette Brinch (Energetics), and Shawna McQueen (Energetics). Special thanks are extended to the workshop speakers and participants for contributing their time and knowledge.

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1 Introduction

The U.S. Department of Energy (DOE) sponsored the *Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen* workshop to gather input on the role of refueling infrastructure in introducing alternative fuel vehicles (AFVs) and how lessons from past experiences can inform ongoing and future efforts to commercialize hydrogen vehicles. Infrastructure-related challenges include consumer convenience and refueling availability, fueling station siting and installation, permitting, liability, capital and operating costs, technological compatibility, and consumer acceptance. This document captures the highlights of the workshop's presentations and the major themes that emerged during discussion sessions.

Over sixty stakeholders from automotive, hydrogen, and alternative fuel industries, government agencies, universities, federal laboratories, and non-governmental organizations participated in the workshop (see Appendix B). Most of the invited participants provided feedback based upon significant experience with hydrogen and other alternative fuels; others were relatively new to alternative fuels but brought expertise from related fields. While the workshop was intended to build upon past lessons learned, the orientation was forward-looking, with presentations and discussions focused on new information and data from modeling, research, and demonstration projects. The resulting dialogue among this diverse group of knowledgeable stakeholders provides valuable input to ongoing and future opportunities to create a refueling infrastructure to support the early commercialization of hydrogen fuel cell vehicles.

As shown in Appendix A, the agenda included panel sessions followed by facilitated breakout group discussions. Panel presenters reviewed past experiences with AFVs, hydrogen station demonstration projects, and efforts to facilitate innovation and stakeholder coordination in AFV programs. Panel discussion sessions offered an opportunity for participants to comment and share their perspectives. The facilitated breakout groups provided a framework for expanding on the many AFV lessons learned and identifying priority action items required to address near-term challenges to developing a hydrogen refueling infrastructure.

2 Summary of Panel Sessions

Three panel sessions addressed a variety of past and ongoing AFV efforts and the role of technology innovation and stakeholder coordination:

- Panel Session I: Lessons from the AFV Experience
- Panel Session II: Lessons from Hydrogen Demonstration Projects
- Panel Session III: Innovation and Coordination

The sessions featured presentations from hydrogen vehicle and refueling infrastructure experts, as well as key natural gas and ethanol stakeholders. Speakers represented a variety of organizations, including federal and state agencies, fuel providers, automotive companies, academia, and non-governmental organizations. The presentations, which are available on the workshop Web site,[1] were followed by panel discussions and set the stage for the issues addressed during the breakout groups. Sections 2.1, 2.2 and 2.3 below summarize the highlights of each panel session.

[1] http://www1.eere.energy.gov/hydrogenandfuelcells/refueling_infrastructure_workshop.html

2.1 Panel Session I: Lessons from the AFV Experience

Presenters in this panel session reviewed infrastructure lessons from past experiences with AFVs, historical trends and recent developments with compressed natural gas (CNG) vehicles and infrastructure, and hydrogen infrastructure transition issues. Panelists noted changes over the past several years that influenced market conditions and outlook for AFVs:

- Technology has improved
- The high price of oil – above $100 a barrel – provides an economic driver for AFVs[2]
- Peak oil and climate change drivers have overshadowed air quality concerns
- Regulatory agencies are beginning to focus on more concrete and ambitious climate change regulations.

A wide variety of lessons have been learned from past experiences with ethanol, natural gas, and electric vehicles. Panel presenters reviewed recommended lessons for hydrogen from a previous NREL/DOE workshop, including the following: 1) set realistic deployment goals and do not let deployment get out ahead of research and development, 2) educate policy makers, automakers, vehicle dealers, fleets, and consumers, 3) address both vehicle and infrastructure costs, 4) create and maintain a cohesive, consistent national policy, 5) use local efforts for deployment, and 6) use fleets for initial deployment, but create a strategy to leap to the individual consumer market.[3] References discussing these and other lessons learned are provided in Appendix D.

"There has to be some real coordination between the stations, the fuel providers, and the vehicle providers."

The CNG vehicle industry has gone through many phases over the past several decades, resulting in a recent consolidation of refueling infrastructure to focus on heavy duty vehicles. An infrastructure boom occurred between 1990 and 1997 in response to anticipated government mandates and the introduction of the first factory-built CNG vehicles. The main purchasers of these vehicles were municipal governments, utilities, and transit agencies. A period of decline and market correction then occurred when mandates failed to materialize and deregulation negatively impacted utility CNG vehicle programs. Since 2005, with the introduction of Federal Tax Credits, increased diesel vehicle ownership costs, and continued improvement in vehicle technology, the CNG vehicle industry has seen a revival in heavy-duty vehicle (HDV) applications. These HDV successes stand out against a generally lackluster background of light-duty CNG activity, partly due to the limited number of light-duty vehicle models provided by automakers.

The strategy of introducing AFVs by focusing on centrally fueled vehicle fleets has been criticized as being ineffective at bringing light-duty vehicle technologies into the mass market and expanding public refueling infrastructure. The most recent phase within the CNG vehicle industry suggests that stations supporting HDVs have been more successful than other stations.

[2] The price of crude oil averaged $112.58 per barrel in April 2008 and $133.88 in June 2008 (source: Energy Information Administration. Petroleum Navigator. "Cushing, OK WTI Spot Price FOB (Dollars per Barrel)." Accessed July 9, 2008. <http://tonto.eia.doe.gov/dnav/pet/hist/rwtcM.htm>.

[3] M. Melendez, K. Theis, and C. Johnson. August 2007. Lessons Learned from the Alternative Fuels Experience and How They Apply to the Development of a Hydrogen-Fueled Transportation System. NREL/TP-560-40753. Available online: http://www.nrel.gov/docs/fy07osti/40753.pdf

However, only a subset of stations capable of serving HDV fleets can also be prime stations for broader household light-duty vehicle fleets.

Panel presenters reviewed issues concerning future hydrogen infrastructure rollout, including the number of stations required to support early vehicle markets, the phased city-by-city and regional rollout approach articulated in a recent Oak Ridge National Laboratory (ORNL) Scenario Transitions report,[4] and the sequence of vehicle and infrastructure investments over time in relation to future fuel savings and greenhouse gas emission reductions. These analyses suggest that the total transition costs during the first decade or two of development would require tens of billions of dollars in investment, with about 80% of the investment dollars being used to buy down the cost of vehicles and the other 20% going to delivery and refueling infrastructure.[5] [6]

The general lessons from past AFV experiences discussed in this panel were echoed at various times by speakers and participants throughout the workshop, with a focus on infrastructure challenges. Speakers agreed that the availability of refueling infrastructure is critical to the successful roll-out of hydrogen vehicles. They acknowledged the need for a geographically focused approach to infrastructure rollout, the need for solid partnerships across public and private sectors, and the need to engage fuel providers effectively. Panelists generally supported a "lighthouse" approach in which hydrogen fuel cell vehicles and infrastructure are rolled out in a phased manner, beginning with one or two pilot cities. By concentrating efforts geographically, this strategy provides benefits from economies of scale and may help to accelerate stakeholder learning. Panel presentations and discussions underscored the value of past AFV lessons for both the research and planning phase and the infrastructure and vehicle rollout phase.

2.2 Panel Session II: Lessons from Hydrogen Station Demonstration Projects

Panel presenters focused on lessons learned from recent hydrogen fueling station demonstration projects.[7] The presentations covered a broad range of hydrogen station issues including: identifying station locations, permitting processes, legal contracts, reducing costs to be more competitive, hydrogen purity, public outreach and education, equipment acquisition, and station design, construction, and operation. The major lessons learned proposed by the speakers included the following:

- Significant technical and design advances are required to reduce station footprint size
- Station demonstration partners should have complementary objectives and capabilities
- Aligned or complementary business cases help build solid partnerships

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[4] Greene, D. L.; P. N. Leiby; B. D. James; J. Perez; M. Melendez; A. Milbrandt; S. Unnasch; M. Hooks (2008). Analysis of the Transition to Hydrogen Fuel Cell Vehicles & the Potential Hydrogen Energy Infrastructure Requirements. ORNL/TM-2008/30, Oak Ridge National Laboratory. Available online: http://www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf

[5] For a discussion of learning and buy-down costs for energy technologies, see Wene, C.-O. (2000). Experience Curves for Energy Technology Policy. Paris: OECD, IEA. Available online: http://www.iea.org/textbase/nppdf/free/2000/curve2000.pdf

[6] For a discussion of vehicle and infrastructure costs, see National Research Council (2008). Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies. National Academies Press. Available online: http://www.nap.edu/catalog/12222.html.

[7] For more information on DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project, see: http://www.nrel.gov/hydrogen/proj_learning_demo.html

- Station safety cannot be compromised
- Public outreach and education is essential
- Supply and demand must be coordinated (i.e., vehicles must accompany stations)
- Convenient locations and accessibility tend to increase utilization
- Legal contracts and permitting can be significant obstacles, resulting in delays
- Educating authorities and standardization can improve permitting process
- Hydrogen purity specification and testing issues need to be resolved.

Solid and effective public-private partnerships are fundamental for successful hydrogen station demonstrations. Demonstration projects should not be confused with commercial investments, as demonstrations are primarily intended to provide field trials for technologies and to accumulate experience. As demonstration station developments transition into commercial station developments, an important technical and commercial goal is to make the price of dispensed hydrogen competitive with gasoline, which will ultimately increase demand and ensure that station investments receive an acceptable rate of return. However, increasing hydrogen demand to the level that makes this possible will take some time. Until this happens, station owners would have to operate at a loss in the absence of mitigating factors such as policy support, cross subsidies, or investment incentives. In addition, several technical and design challenges remain, with reductions in station footprint being one of the most critical.

Permitting requirements at the state and local level can be onerous, but increased awareness and experience should improve the permitting process over time.[8] Another issue raised by the panel was the limited capacity of the existing vendor base for station equipment, making it difficult to install more than one station at a time. Additional challenges include developing legal contracts, reaching agreement on hydrogen purity specifications, coordinating supply and demand, and producing consistent messaging and public outreach. Experiences with past demonstration projects have shown that resolving these types of issues effectively will require collaboration and coordination among involved partners.

During the panel discussion, speakers made it clear that fuel providers have learned valuable lessons from station demonstration projects, but they do not necessarily see the installation of a large number of additional hydrogen refueling stations as the next near-term step. This position was at odds with automotive and other stakeholders who expressed a critical need for additional stations in key urban areas.

2.3 Panel Session III: Innovation and Coordination

Presenters in this panel addressed opportunities for both technical and institutional innovation and the coordination of stakeholder efforts to develop and deploy hydrogen refueling stations and related infrastructure. Innovation was discussed in terms of both technological and institutional efforts, including vehicle technology, fuel production, delivery and storage technology, marketing, codes and standards, and education and outreach. The panel was opened with the recognition that efforts to support innovation, which tends to happen quickly and

[8] "Workshop on Facilitating Permitting of Hydrogen Fueling Stations," DOE/NREL workshop proceedings (draft), March 2007, Available online: http://www.hydrogenandfuelcellsafety.info/resources/workshops/07feb

sometimes unpredictably, must be balanced with efforts to support coordination, which tends to happen slowly and deliberately.

Presenters reviewed and discussed the success of promoting ethanol (E85) stations in Minnesota in reference to challenges facing hydrogen station installations. Persistent and long-term support from the American Lung Association of the Upper-Midwest has contributed to this success. Their efforts included providing grant assistance for retailers, offering technical and marketing troubleshooting, providing outreach to raise consumer and industry awareness, matching supply and demand on an individual station basis, and leveraging the efforts of local champions. There are currently about 355 E85 stations in Minnesota, up from seven stations in 1997, and E85 sales have increased approximately ten-fold over the past several years. E85 refueling station costs are modest compared to hydrogen; with supporting grants ranging in size from $10,000 to $40,000 (some stations have simply converted existing premium or midgrade pumps to supply E85). Moreover, E85 has had a significant retail cost advantage over gasoline on a per gallon basis and the state has sold E10 year-round since 1997. The higher capital costs and technological complexity of hydrogen stations and vehicles provide a stark contrast to E85 station requirements; it is estimated that approximately $30 million would be required to complete the E85 fueling network in Minnesota.

"Outreach is absolutely essential – it cannot be overlooked."

Several presenters and participants emphasized the need for additional hydrogen refueling stations in promising early markets, such as Los Angeles and New York. As a point of reference, the recent ORNL Scenario Transitions report[9] suggested that 40 stations may be needed in the near term in Los Angeles. Identifying stakeholders willing to take on the technical and financial risks associated with installing these stations will prove challenging. Large energy companies or fuel providers do not necessarily own, operate, or design stations as a core business strength; additionally, they do not necessarily own the primary energy resources these systems would draw upon and they may not see an advantage in shifting expertise and capital into retail hydrogen stations. Industrial gas companies or other hydrogen equipment suppliers have less access to capital than energy companies and lack expertise with retail stations. Companies with renewable technology expertise are even further removed from the retail outlet industry. Given these stakeholder positions, the potential role of entrepreneurial agents should not be underestimated. One workshop participant noted that the hydrogen transition will involve a major technology change, and incumbent companies are almost never the agents of major change. It would therefore be prudent to engage the entrepreneurial community, including venture investors, rather than relying exclusively on existing energy companies and equipment suppliers to act as first movers.

Of the existing hydrogen stations in operation, few are highly accessible in terms of limited fueling agreements, credit card access, and 24/7/365 operation. This suggests that a large number of highly accessible hydrogen stations will require a significant departure from today's mindset regarding hydrogen stations. Suggestions for addressing this challenge include focusing on the consumer experience, building grassroots support, and ensuring the installation of a limited

[9] Greene et al., op. cit.

number of appealing, "retail-like" stations that are supported by a number of more modest stations that extend coverage across a given urban area (e.g., mobile refuelers). In addition, various "expectation management" tools may be employed to help match supply with future demand, including the use of surveys that capture fuel provider and automaker deployment expectations, providing real-time information on station availability and planned installations, analyzing gaps where additional stations or supply may be needed, developing effective approaches to improve legal and project management issues, and constructing realistic projections of future local and regional infrastructure developments. As grassroots efforts emerge at regional, state, and local levels, it is important that they remain engaged with industry stakeholders so that realistic expectations and practical plans are developed.

Other key messages from this panel include the following: excellent customer experience is necessary to build consumer demand, a new generation of hydrogen stations is needed to inspire consumer confidence, consistent codes and standards are required, local "champions" among fire and safety code officials must be identified, and training, education, and outreach are imperative.

3 Summary of Breakout Group Results

Workshop participants were divided into three parallel breakout groups that convened during two sessions. During the first breakout session, groups clarified and expanded upon lessons learned from past AFV refueling infrastructure developments and discussed how to apply these lessons going forward with hydrogen. Each group was asked to discuss critical lessons learned and pitfalls to avoid, and to recommend detailed action items for overcoming those pitfalls when developing a near-term hydrogen refueling infrastructure. At the end of the first breakout session, participants voted to prioritize the action items proposed within their respective groups. During the second breakout session, each group discussed their five "top priority" action items in greater detail.

Breakout group participants, from left: Catherine Dunwoody (CaFCP), Nicole Barber (Chevron), and Jonathan Weinert (Chevron). (Used with permission.)

Each breakout group included representatives from a range of stakeholder groups, including fuel providers, auto manufacturers, state and federal government agencies, non-government agencies, public-private partnerships, hydrogen equipment manufacturers, consultants, and academics. While there was significant overlap among the lessons learned and action items proposed, each breakout group provided unique perspectives and comments during the facilitated discussions. A high-level overview of the major themes is provided in Sections 3.1 and 3.2 below.

3.1 Key Lessons and Pitfalls

During the first breakout session, participants responded to the question: "What lessons are absolutely critical to pay attention to as we launch hydrogen refueling infrastructure efforts? What pitfalls must be avoided?" In answering these questions, participants were asked to

identify major stumbling blocks in past AFV efforts, and similar stumbling blocks that may impede hydrogen infrastructure development. As summarized in Table 1, six common themes emerged from these initial responses:

1. Policy commitment
2. Consumer focus
3. Number of stations
4. Geography
5. Funding
6. Stakeholder coordination.

About two-thirds of the key lessons and pitfalls reported could be categorized into these six themes. Although the groups addressed these themes from different perspectives, the fact that each one was acknowledged by each group confirms their general significance. The detailed results from each breakout group are shown in Appendix C. Within these key themes, the groups discussed a number of issues affecting the development of hydrogen refueling infrastructure, as summarized below.

Government Leadership and Outreach
Committed and ample government funding, as well as strong government policies and incentives that offer support for both the producers and consumers of hydrogen fuel and vehicles, are needed to build a robust refueling infrastructure. Risk, both technical and financial, is known to be an inherent barrier. However, strong, committed public-private partnerships have reduced risks in past AFV efforts and would be useful in reducing risks for hydrogen refueling station infrastructure as well.

Customer Experience
The most widely discussed lesson from previous AFV programs relates to customer expectations at refueling stations. The hydrogen station experience must be identical to the retail gasoline station experience in terms of convenience, 24/7/365 station availability, satisfaction, availability of credit card transactions, cleanliness, lighting, and overall ease of use. Unless this experience is a positive one, hydrogen vehicle owners will tend not to support stations or other refueling options. It was noted that this need for a strongly positive consumer experience at refueling stations is made more challenging due to requirements to ensure station safety and to mitigate liability and risk on the part of fuel providers, especially during the station demonstration phase.

Technical Barriers
While station developments have progressed significantly in recent years, technical barriers continue to exist. It is critical to manage expectations in light of these barriers so that the industry and its stakeholders do not over-promise. Some of the most important technical barriers for fueling infrastructure that still exist relate to fuel quality and consistency, monitoring and control of leakage, hydrogen storage, and station footprint size. Some participants emphasized that the number of potential hydrogen station locations could be severely limited unless a breakthrough in station footprint reduction is achieved; this is a limitation that requires additional analysis.

Costs
Station cost reductions continue to be achieved, and eventually hydrogen costs must be similar to gasoline to make hydrogen stations attractive and viable. The existing funding process for

stations and infrastructure can be improved and additional effort is required to minimize stranded investments, including capital and construction costs, liability costs, worker salaries, and permitting costs. Stranded capital is a very real concern for infrastructure providers. One energy company representative noted that investment decisions for fueling stations are made on a 20-year cash flow basis, with payback usually in the 10-15 year range. If a shorter cycle for payback on capital is required, or if the station is underutilized, the price of hydrogen would need to be increased to ensure an acceptable return. To complicate matters further, the "price point" for hydrogen—the price that consumers might be willing to pay—has not been clearly established.[10] This introduces an additional degree of uncertainty in the development of a viable business case for a typical hydrogen station.

Policy and Institutional Issues

A number of policy, strategy, institutional, and funding issues stand in the way of widespread refueling infrastructure development. Among them are "chicken and egg" problems, e.g., how will stations and vehicles be deployed over time? Industry and government agencies may partner to jump-start station refueling through large infrastructure investments, which would require supportive policies and incentives, as well as planning. There is some debate about exactly how large these initial investments must be, but participants tended to agree that they could be reduced with a lighthouse strategy focusing on early markets in key urban areas. In addition, policies that effectively engage the entrepreneurial community could facilitate these early investments. Continuing education on safety and codes and standards should be available to local officials, who are responsible for siting and permitting, environmental assessments, and land use approvals. Experiences with AFV programs provide a useful lesson for hydrogen refueling in the arena of public-private partnerships and the need for consistent and clear communications among vehicle manufacturers, energy companies, and government agencies. Successful communication will lead to better partnerships and business models for station installations, as well as clear pathways bridging demonstration and commercial stations.

"We want to avoid the 'field of dreams' problem. We want to build a station where there will be at least planned vehicles."

3.2 Key Action Items

Workshop participants were asked to identify action items needed to overcome the challenges facing successful hydrogen refueling infrastructure development over the next 10 to 20 years. A voting process was used to determine the five most critical action items proposed within each breakout group. A complete list of the proposed action items is included in Appendix C, and a summary of high-priority action items is provided in Table 2, where the percentage of votes cast for each item is shown by group, and the percentages for the top 15 action items are highlighted. The top 15 action items attracted 62% of all votes cast. Of these top action item votes, 34% fell into the category of *Station Design, Siting, and Availability* and 29% fell into the category of *Policy and Regulatory Issues.* Ten of the fifteen high priority action items fell into one of these two categories. Other categories included *Insurance and Liability*, *Consumer Focus*, and

[10] If consumers were willing to pay the same price for hydrogen as gasoline on a *per mile basis*, and if hydrogen vehicles are twice as efficient as gasoline vehicles, then an acceptable price for hydrogen would be twice that of gasoline on an energy equivalent basis (e.g., $8/kg hydrogen would be roughly equivalent to $4/gallon of gasoline).

Incentives (receiving 15%, 13%, and 9% of top 15 action item votes, respectively). Appendix C lists more than 70 additional action items that were proposed but were not voted as high priority.

To gather more detailed feedback, participants were asked to discuss the following aspects of each top-priority action item: scope, stakeholder roles, collaborators (leaders and supporters), timeframe, and first steps. The ensuing discussions were wide ranging in scope and level of detail. Seven themes common to the discussions in each group are summarized below.

Station Design, Siting, and Availability

As demonstrated with previous AFV programs, consumer support will depend heavily on the number, location, and design of refueling stations. Workshop participants placed a high priority on a number of actions related to station design, siting, and availability. Design issues included conducting more aggressive research and development to reduce station costs and footprint, and developing standardized modular station designs with pre-approved safety certifications which could be fast-tracked through the permitting process. Another design consideration is the development of co-production stations capable of providing both electricity and hydrogen, with the hydrogen potentially being used for applications other than just passenger vehicles. Related to station siting and availability are the following actions:

- Identifying and supporting hydrogen vehicles other than standard light duty vehicles, including commercial vehicles such as buses or mobile equipment such as forklifts
- Installing real-time station operating status systems in vehicles, with onboard data systems that track refueling opportunities and locations
- Identifying land partners and blighted lots, where state funds might be available for the latter as part of remediation efforts.

Leadership in accomplishing these actions centers on energy companies (or entrepreneurs), who presumably would design, build, and operate the stations, and on automakers, who build and sell the vehicles that create fuel demand. Support from state and local governments and from industry trade groups was identified as necessary to successful station design, construction, and management.

Coordinated National Plan for Hydrogen

Government leadership is critical in moving forward from past efforts to a more aggressive program for refueling infrastructure. A coordinated national plan for hydrogen infrastructure development would include establishing production goals, cost targets, market development plans and policies, and education and outreach.[11] Former and existing demonstration projects have been evaluated, and these lessons must be included in a national plan; knowledge of past successes, failures, and lessons learned should not be lost. Workshop participants supported evaluating our current national energy policy, including recently enacted energy legislation,[12] to ensure that a national plan for hydrogen is coordinated with the requirements of recent legislation. A national plan would also focus attention on research and development that is still needed in a number of areas, including station design and footprint issues, co-production, liability issues, and small-scale hydrogen production and storage.

[11] Components of this recommendation resemble the Department of Energy's Hydrogen, Fuel Cells & Infrastructure Technologies program (http://www1.eere.energy.gov/hydrogenandfuelcells)

[12] *Energy Independence and Security Act of 2007* and the *Energy Policy Act of 2005.*

Table 1. Common Themes - Key Lessons Learned and Pitfalls.

Group 1	Group 2	Group 3
POLICY COMMITMENT "Strong and consistent national leadership is needed"	"Need sustained government policy and financial support" "There must be commitment"	"Need a consistent long-term policy commitment"
CONSUMER FOCUS "Do not over-sell" "Fueling experience must be identical to retail gasoline station, experience, including convenience, ease of use, instructions, credit card payments, cleanliness, 24/7 service, lighting, safety, self-service. Consumer focus is critical."	"Consistent message vs. fuel of the month" "Focus on the customer - abundant fueling stations, abundant capacity, no restrictions on station use, compelling refueling experience" "Access to infrastructure, customer friendly, liability, technically suitable, balanced"	"Over-promising progress" (pitfall) "Belief that H2 is available to all" (pitfall) "Need realistic projections"
NUMBER OF STATIONS "Identify an appropriate number of fueling stations" "The number of vehicles must be matched with the size and number of stations" "*Jump start* the chicken/egg problem"	"Need for convenient refueling experience – number of stations" "Balancing station throughputs with network coverage" "[Execution] always takes longer than expected"	"Don't have to start with large scale hydrogen refueling infrastructure"
GEOGRAPHY "How do we get a coordinated 'lighthouse plan' for CA?" "Goals must be transparent, e.g., number of vehicles, target locations, etc. This is not the time to be competitive."	"Geographic focus - 'dense' network" "A few well placed, convenient access, 24/7 stations in a single region today are more important than serving multiple markets"	"Difficulty of implementation in urban core" "Need a focused geographic rollout" "Keep in mind the footprint (land cost)"
FUNDING "Lack of private funding" "We don't have a business case today" "Entrepreneurs matter in technology transitions"	"Government incentives [must] provide compelling cost advantage" "Government funding is critical and needs long legs"	"There is a fear of stranded assets" "There is competition for resources, funding, etc." "Existing funding process not conducive for H2"
STAKEHOLDER COORDINATION "Need for coordinated planning and commitment to public-private partnerships, which will minimize cost and risk" "Re-think current business processes - maybe use entirely new processes and alternative business models" "Cross-functional teams are required"	"Consistent coordination on infrastructure development strategy between government, industry stakeholders" "Formal communication between automakers fuels and government" "Early develop business model (due to different thinking of energy company vs. automaker)" "Need accountability for station execution"	"Coordination of timing and location - vehicles, stations, users" "Plan for stations to stay - avoid 'valley of death' outcome by rolling out a concise technical strategy" "Make sure manufacturing and standardization of station equipment is available for infrastructure build-out"

Table 2. Summary of High Priority Actions Items.

Recommended Actions Items (percent of priority votes by group, with top five items highlighted)	Group Number 1	2	3
Station Design, Siting and Availability (34% of all top five votes)			
Station R&D to reduce footprint, reduce costs, & develop standardized & modular designs with pre-approved safety certifications	21%		
Government to evaluate and document station development costs; regular updating; multiple data sources			16%
Develop co-production stations, e.g., electricity and hydrogen	11%		
Overbuild a limited number of attractive "flagship" stations to help create market pull; keep infrastructure ahead of demand		9%	
Establish stations in select metro areas with stations sized to early markets; 40 stations in 1-2 select metro areas by 2012		8%	
Identify, evaluate, prioritize siting issues (across the fuel chain)			9%
Create a central "Green Renewable Hydrogen" bulk location for delivery in key "critical mass areas"	4%		
More R&D on small-scale hydrogen production/storage		4%	
Real-time station operating status systems to feed on-board GPS/data systems		4%	
Policy and Regulatory Issues (29% of all top five votes)			
Develop a coordinated National Plan; incentives; education and outreach; explicit long-term goals and review points	12%		
National Energy Policy: establish clear short and long-term commitments; all levels government; identify forum "think tank"			17%
Facilitate a common, realistic plan and vision with coordination among stakeholders; 40-year vision, but start action now			13%
Adopt local policies and codes to facilitate station siting; identify local champions; build local communication and relationships		8%	
Hydrogen Lighthouse Plan: begin in CA; state government leads; support with public funding; public-private partnerships	5%		
Convince Congress that there is a fuel crisis looming		6%	
Develop and support anchor markets for early deployment: transit, airports, stationary applications, industrial gas, etc.	4%		
Insurance and Liability (15% of all top five votes)			
Create an insurance pool to share risk (immediate need)			16%
Temporary government sharing/limiting of liability; insurance agencies must understand risks; pool for first X stations		12%	
Develop insurance and indemnification support, e.g., establish ceilings and buy down, limits	5%		
Consumer Focus (13% of all top five votes)			
Discover consumer's wants and needs, position accordingly; need consumer research and behavior analysis			16%
Create same or better consumer experience as refueling at gasoline stations; 24/7; credit card access		9%	
Find best niche to start market expansion; ensure public access			7%
Incentives (9% of top all five votes)			
Create stable market opportunities for hydrogen: provide incentives "at the right time"; focus on early adopters	16%		
Develop consistent long-term incentives among fuels; tied to greenhouse gas performance		6%	
Federal government cost share to guard against underutilization		6%	
Create "enterprise zone" favorable to hydrogen infrastructure			6%
Provide 25% to 50% of station cost incentive based on station throughputs and siting		4%	
Require or reward "transformation" fuels with low-to-zero greenhouse gas emissions		4%	

The development of a national plan is seen as a top priority, and would involve a number of federal agencies, such as the Departments of Energy and Transportation, as well as a coalition of federal, state, and municipal policy-makers, interest groups such as the National Hydrogen Association and U.S. Fuel Cell Council, other non-government organizations, automobile manufacturers, technology developers, and entrepreneurs.

Workshop participants supported creating incentives to reduce the risk of investing in hydrogen fueling stations, including government sharing of liability; developing an insurance pool; and exploring financial support for hydrogen station development, design, and deployment. Incentives and financial support developed through such a national planning effort could be tied to greenhouse gas emission performance. Support is also needed to develop and disseminate best-practice information that can accelerate the adoption of local policies and codes for station siting, construction, and operation.

Lighthouse Deployment

Workshop participants generally agreed with the concept of a "lighthouse" strategy for deploying hydrogen stations. The lighthouse concept involves targeting a few key metropolitan areas or "hydrogen communities" and aggressively building fueling stations and deploying vehicles in those areas. In this strategy, markets are identified, a consensus is reached on regional development plans based on market data, municipalities are engaged to facilitate installations, and targets are set. In the early years, this strategy would likely result in an over-capacity of stations, with fewer vehicles than needed to support the stations in a profit-making mode. During this introductory phase it is critical to establish appealing hydrogen fueling stations that provide drivers with convenient access while demonstrating the viability, safety, and positive economic, social, and environmental impacts of hydrogen technologies. A Lighthouse Deployment Program might also provide support for passenger vehicle fleets, such as taxi cabs or government vehicles, whose use would help raise the visibility of hydrogen-fueled vehicles in the community and increase consumer awareness and acceptance. In some cases, public hydrogen stations may also be able to serve heavy duty vehicle fleets such as transit buses.[13]

Mark Ruth (NREL, Systems Integration) reporting breakout group results to the plenary session.

Industry and government must partner to progress this effort, with support from environmental groups and local champions. Together, these stakeholders would need to agree upon a number of issues, including proximity of stations to one another; locations of "flagship" stations vs. more modest network support stations; expected demand at particular stations; refueling availability along interstate highways; and coordination with state blueprints. Workshop participants

[13] The importance of coordinating vehicle and fueling station rollout was downplayed by at least one participant, claiming that: 1) small-scale, on-site hydrogen production systems can ramp up relatively rapidly to follow the introduction of vehicles, and 2) once public policy "settles on the final rules of the game" the marketplace will respond in a self-organizing manner.

generally support the Lighthouse Deployment strategy as a next step, using a phased approach that aligns vehicle sales and refueling station installations. This is an area where planning for economies of scale should be considered.

Liability and Insurance Issues

At the heart of many of the issues described above is the need to address liability and insurance for hydrogen refueling stations. There is a need to limit liability levels for station owners and managers by engaging and sharing information with insurance companies and by developing methods for sharing financial risk. Key stakeholders, such as automakers, energy companies, station operators, public research entities, and many others, need to work together with insurance commissioners to collect and compile the data needed so that insurance companies can create an "insurance pool" to support hydrogen refueling stations. Some participants anticipate that this support will be temporary and that less support will be needed over time as markets mature.

Consumer Focus

"You have to make it wildly popular. You need to thrill customers."

Consumer issues surfaced repeatedly throughout the workshop. Clarifying consumer wants and needs and meeting them effectively was identified by many participants as a top priority action item. Independent consumer research and behavior analyses need to be collected and coordinated with automaker data (such as GM's "Project Driveway" program and Honda's Clarity leasing program), data from the California Fuel Cell Partnership, and other national and international consumer research results.

The consumer experience at hydrogen refueling stations must be similar to or better than the experience at traditional gasoline stations. Refueling should feel "natural" for customers in terms of station operation, location, design, and services. Stations should be clean, attractive, user-friendly, and designed to impress customers—to create a very positive experience that will "wow" customers. Installing a number of appealing and impressive "flagship" stations will help to create market pull for hydrogen vehicles. Moreover, additional stations and production capacity need to be built at a pace such that hydrogen supply and station availability is always ahead of demand. Fuel providers, with support from government, station owners, local officials, and automakers, were identified as the key leads and supporters for this effort.

Codes, Standards, and Regulatory/Institutional Actions

Workshop participants support the development and adoption of state and local building, fire, and other types of safety codes and standards that facilitate rather than hinder station development and siting. In addition, policy or regulatory actions are needed to require or reward alternative fuels that have low- to zero-carbon impact, provide tax incentives to improve consumer affordability, provide financial support for early adopters and investors, and limit the financial liability for station development and construction.

Regulatory and institutional success requires involvement from a broad coalition of stakeholders, including the auto industry; station owners; energy companies; federal, state, and local governments; and insurance companies. Depending on the issue, one or more of these stakeholders would take the lead in developing and implementing hydrogen refueling infrastructure codes, standards, and regulatory policies. One specific recommendation is to

create a position for a "hydrogen ombudsman" in the office of the State Fire Marshal to facilitate communication on a local level.

Education, Training, and Marketing
The action items outlined in this report rely on education, training, and outreach to ensure success. All stakeholders (including consumers; policy-makers at the federal, state, and local level; station designers and developers; code officials; non-government organizations; financiers; automakers; and fuel providers) need to be reached with clear, consistent information on hydrogen availability, safety, environmental benefits, ease of use, station locations and deployment, and so forth. Policies at the Federal level supporting national hydrogen infrastructure development should also support efforts at state and local levels.

Many education, outreach, and marketing activities were recommended, including conducting a survey to find out exactly what consumers want and desire; developing and circulating advertisements on the financial and environmental benefits of hydrogen; providing training for local code officials on hydrogen safety and re-fueling stations; promoting consumer experience at existing hydrogen stations to engage a broader consumer base and raise awareness about station safety and ease of use; and engaging one or more well-known spokespersons as marketing and advertising "messengers."

"This is an evolving process; this takes time. There are not going to be big leaps and sudden expansion, but every phase is important. [We] need some kind of start at commercialization."

4 Next Steps

Looking forward at hydrogen refueling infrastructure development, there is a clear need to continue efforts to build grassroots relationships; improve the consistency and adoption of codes and standards; work toward exceeding customer expectations; and assure sufficient hydrogen refueling stations exist to support the deployment of hydrogen vehicles in select urban areas. These efforts will require ongoing communication and coordination among a range of stakeholders, as well as technical and institutional innovations. The expert feedback collected during this workshop can help to inform these efforts as stakeholders enter the next phase along the path towards commercialization.

We have accumulated a large base of experience with AFVs and supporting infrastructure since the first energy crisis in the 1970s. Many of the issues discussed at this workshop are similar to issues the AFV industry has struggled with for decades. This knowledge base can continue to be mined to improve our efforts to advance hydrogen, electricity, ethanol, and other alternative fuels for vehicles. Over time, some lessons are forgotten and need to be relearned. Open and ongoing discussions among multiple experienced stakeholders can facilitate this learning process. As we continue to expand our experience with hydrogen, it will be important to capture and disseminate lessons learned to the stakeholder community rapidly and efficiently.

The workshop identified two additional research areas for hydrogen infrastructure development. The first concerns the ownership of alternative fuel stations, which is significant for hydrogen due to the apparent gap between the future expectations of automotive and fuel provider stakeholders. Learning more about ownership experiences with natural gas or ethanol stations

may provide insights into the process of installing future hydrogen stations. Considering new business models for hydrogen stations and new types of market entrants may provide additional insights.

The second research area concerns potential bottlenecks due to equipment suppliers' capacity constraints as the number of station installations ramps up over time. This issue could be examined within the recent history of hydrogen station installations as well as within past experiences with other alternative fuels such as natural gas.

Additional lessons will continue to be learned from ongoing efforts with alternative fuel vehicles and refueling infrastructure. As several workshop participants noted, periodic reviews of past experiences can help to improve the effectiveness of these ongoing efforts. The approach taken in this workshop, gathering a diverse group of stakeholders to engage in open dialogue, is only one of many approaches to building upon and benefiting from past lessons learned.

APPENDIX A
WORKSHOP STRUCTURE AND AGENDA

WORKSHOP STRUCTURE

The workshop was designed to encourage discussion by a variety of different stakeholders on key issues related to hydrogen infrastructure development. While many presentations reviewed past or recent efforts to support hydrogen and other AFVs, participants were asked to discuss and provide input on current challenges. The one-day workshop included time for both informal panel discussions and structured discussions during facilitated breakout sessions as indicated in the agenda below.

Workshop Activity	**Time Allocated**
Panel Session I: Review of Lessons Learned	1 hour
Panel Discussion	20 min
Panel Session II: Station Demonstrations	1 hour
Panel Discussion	20 min
Facilitated Breakout Session #1	2 hours
Panel Session III: Innovation and Coordination	1.5 hours
Panel Discussion	20 min
Facilitated Breakout Session #2	1.5 hours
Plenary Reports	30 minutes

During the first facilitated breakout session, participants compiled and discussed key lessons learned, pitfalls, and near-term action items. The breakout groups prioritized key action items through a voting process. During the second facilitated breakout session, participants drilled down into the top five action items identified in their respective groups.

A draft version of these proceedings was circulated via email to all workshop participants, who were given two weeks to provide additional comments. The comments received have been incorporated into these proceedings. Direct quotations from the discussion and breakout sessions are interspersed throughout this report. To encourage open dialogue, no attributions have been made to specific comments or feedback provided during or after the workshop.

Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen

Sheraton Grand Sacramento Hotel
Sacramento, California
April 2-3, 2008

Agenda

WEDNESDAY, APRIL 2	
6:00–8:00 pm	**Registration and Networking Reception (light fare)**
THURSDAY, APRIL 3	
7:00 am	**Registration and Continental Breakfast**
8:00 am	**Welcome**
8:10 am	**Panel Session I: Lessons from the AFV Experience** **Moderator: Dan Sperling**, *UC Davis*
	▪ **Marc Melaina**, *National Renewable Energy Laboratory* ▪ **Stephe Yborra**, *NGV America* ▪ **Joan Ogden**, *US Davis* ▪ Discussion
9:25 am	**Break**
9:40 am	**Panel Session II: Lessons from Hydrogen Station Demonstration Projects** **Moderator: John Garbak**, *U.S. Department of Energy*
	▪ **Puneet Verma**, *Chevron* ▪ **Dean Fry**, *BP* ▪ **Analisa Bevan**, *California Air Resources Board* ▪ Discussion
10:55 am	**Breakout Group Instructions** **Jan Brinch**, *Energetics Incorporated*
11:10 am	**Parallel Breakout Groups: Lessons Learned for Hydrogen Refueling Infrastructure**
12:30 pm	**Luncheon**

(Continued next page)

Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen

Agenda (Continued)

Sheraton Grand Sacramento Hotel
Sacramento, California
April 2-3, 2008

THURSDAY, APRIL 3 (cont'd)

1:30 pm	**Parallel Breakout Groups: Actions and Strategies for Moving Forward**
2:00 pm	**Panel Session III: Innovation and Coordination** **Moderator: Stefan Unnasch**, *Life Cycle Associates*
	▪ **Tim Gerlach**, *American Lung Association of the Upper Midwest* ▪ **Britta Gross**, *General Motors* ▪ **Catherine Dunwoody**, *California Fuel Cell Partnership* ▪ **Ulrich Bünger**, *L-B-Systemtechnik* ▪ Discussion
3:35 pm	**Break**
3:50 pm	**Parallel Breakout Groups: Drilling Down on Priority Actions and Strategies**
5:15 pm	**Breakout Group Reports**
5:40 pm	**Closing Remarks**
6:00 pm	**Adjourn**

APPENDIX B
LIST OF WORKSHOP PARTICIPANTS

McKinley Addy
California Energy Commission

Timothy Armstrong
Oak Ridge National Laboratory

Nicole Barber
Chevron

Shannon Baxter-Clemmons
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National Renewable Energy Laboratory

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Stephe Yborra
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Michael Zack
California Energy Commission

APPENDIX C
DETAILED OUTPUT FROM
BREAKOUT GROUP DISCUSSIONS

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 1 - KEY LESSONS AND PITFALLS

- "Jump start" the chicken/egg problem
- Manage expectations, education is necessary
- Do not over-sell
- Identify an appropriate number of fueling stations
- H_2 price to consumer must not be much greater than gasoline cost
  - take advantage of other business models already developed
  - hear the voices of customers
- Cross-functional teams are required
- Cost-benefit analysis is required, including number of customers (vehicles, drivers); station suppliers; price of H_2 stations
- Don't get ahead of R&D that is required for H_2 refueling infrastructure
- Niche markets don't necessarily grow/expand
- Develop tracking database now. Do not lose lessons or equipment over time
- Identify the price point, e.g., the price that customers will to be willing to pay
  - customer demand varies
- The number of vehicles must be matched with the size and number of stations
- Refueling accessibility and ease of use, which will increase utilization
- Permitting needs to be streamlined
- Lack of private funding
- Flexibility is required to grow from 350-700 bars, to deal with stranded assets (e.g., stations), and capacity utilization
- R&D to reduce station cost
- We don't have a business case today
- Increase fuel demand with current available technology
- National codes and standards for infrastructure (permitting)
- Entrepreneurs matter in technology transitions
- Need for coordinated planning and commitment to public-private partnerships, which will minimize cost and risk
- Re-think current business processes - maybe use entirely new processes and alternative business models
- Customer demand is variable
- Strong and consistent national leadership is needed
- Manage expectations, e.g. scope, cost benefit, etc.
- Fueling experience must be identical to retail gasoline station, experience, including convenience, ease of use, instructions, credit card payments, cleanliness, 24/7 service, lighting, safety, self-service. Consumer focus is critical
- Goals must be transparent, e.g., number of vehicles, target locations, etc. This is not the time to be competitive
- "Lighthouse plan" - how do we get a coordinated "lighthouse plan" for CA
  - are two stations near one another acceptable for customers?
  - calculate driving distances
  - create demand along interstates
  - coordinate state blueprints

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 1 - KEY ACTION ITEMS NEEDED

STATION SITING AND AVAILABILITY	R&D	INCENTIVES AND FINANCIAL ISSUES	CONSUMER ISSUES
• Create standardized/modular station designs with pre-approved safety certifications ●●●● • Develop coordinated early market plan: – all players, new, old, big, small – support with resources, $, and policy – identify best practices and next phase strategy – educate - why-where-when-how – build test site in LA ●●●● • Create a central "Green Renewable Hydrogen" bulk location for delivery in key "critical mass areas" ●●● • Build on National Lighthouse concept - "gang" partners (fleets) to increase demand. Use current available technology in the interim. • Make land available	• R&D to reduce station footprint ●●●●●●●● • H_2 co-production - build hydrogen energy station with multiple co-products, electricity and H_2, H_2 for others ●●●●● • Parallel R&D on station technology to make it commercial ●●●	• Establish H_2 incentives in $/pound - direct use - financial incentive - , renewables - very good incentive - renewables plus waste - excellent incentive ●●●●● • Create tax incentives to make technology affordable for consumers ●● • Find a way to provide incentives "at the right time" for both vehicles and stations ●● • Provide incentives for early investors • Gas tax: invest in new efforts to make the case for early adopters ●● • Allow NO H_2 taxes until commercial onset • CARB solicitation: If no takers, then use money to support an existing station for insurance/legal fees so that these stations may be utilized	• Get "all ducks in a row" so there are ready answers for all the detractors) • Avoid "Daisy Cutter" approach

Red dots indicate votes cast.

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 1 - KEY ACTION ITEMS NEEDED (CONT'D)

REGULATORY POLICY ISSUES	LIABILITY ISSUES	BUSINESS MARKET ISSUES	CROSS-CUTTING
• Make stable market opportunities for H_2 ●●●●●●● – provide stable long-term incentives to involve established fuel providers in H_2 infrastructure development • Agree on National Plan – explicit vehicle and infrastructure production goals (short, medium, long term) – targeted areas (region/sector) – shared costs, (automaker, fuel, public incentives) – Go/no go review points – build expectations as test ●●● • Create a state (ultimately national) introduction plan (# of vehicles and infrastructure) that has an 8-10 year staying power to outlast political cycle ●● • National codes and standards ● • Develop public policy - tax credits, etc. for both infrastructure and vehicles ● • Increase (quality) deal flow ● • Make confident (agreement) that hydrogen becomes a major transport fuel • Government leadership is necessary – land for stations – space program a model for commitment of funds, clear mission, public outreach, etc. – fleet policies per EPAct 05	• Develop insurance and indemnification support, e.g., establish ceilings and buy down, limits ●●●●	• Develop anchor markets for early deployment – transit – airports – stationary uses – industrial gas – new market areas? – provide financial support and resources ●●● • Influence H_2 demand - focus on its benefits for advertisement ●● • Make a flexible business/ technical use of hydrogen ●● • Develop/support existing business cases from both auto, energy, stationary with real customer surveys to develop H_2 model stations with a "higher probability of success" ● • Develop a realistic business model - financial targets, cost benefit analysis, cost reduction targets, revenue stream • Develop cross-functional team to meet targets	• Determine a state and national level lead for infrastructure deployment "Lighthouse", and support with funding ●●●● • Synergize with other applications and organizations (state, local, federal government), including co-production of DG electric power with H_2 fuel; FC back up power with local H_2 station, FC MHE with local H_2 stations ●●● • Create centralized organization to facilitate H_2 station planning - beginning with CA, CaFCP/ CalStart as an organization; support with funding

Red dots indicate votes cast.

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 1 - TOP FIVE ACTION ITEMS

ACTION	COORDINATED NATIONAL PLAN FOR H_2 DEVELOPMENT	R&D ON STATION
Scope	A coordinated National Plan • Market Development Plan • Policies • Number of vehicles • Best Practices - incentives • Education and outreach • Production goals • Go/no go review • Long-term goals • Cost targets	• Central renewable "green hydrogen" bulk locations for delivery in key critical mass areas • Standardized/modular station designs with pre-approved safety certifications • Reduced "footprint" R&D
Stakeholder Roles	• Federal leadership working with states – DOE, DOT, and other agencies – Labs • Validation • Safety • Standards • Continuing relationship with private industry	• Energy companies - clarify the issues of their sites • Developers • Industrial gas technology leaders
Collaborators: Leaders and Supporters	• Legislators • National fuel cell caucus • FreedomCAR • Either national NGO or state organization	
Timeframe	• Now - allocate funding • A phased approach • Common target dates for each phase	
First Steps	• Understand demand • Prioritize scope • Develop a framework which gives independent entities the ability to self-select where they fit in	• Identify commercial paths to low cost H_2 • R&D to identify low-cost paths • Identify the business case

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 1 - TOP FIVE ACTION ITEMS (CONT'D)

ACTION	HYDROGEN CO-PRODUCTION STATIONS	INCENTIVES FOR H_2	H_2 LIGHTHOUSE PLAN
Scope	• Build H_2 co-production stations – multiple co-products – electricity and H_2 – H_2 for others	• Tax incentives to improve consumer affordability • Increasing levels of incentives based on inputs • Incentives "at the right time" • Incentives for early adopters and investors	• Create and identify existing centralized organization to facilitate H_2 station plan - a "Lighthouse" strategy • Begin with CA; 2-3 target areas • Enhance public - private partnerships • Coordinate with other organizations and H2 efforts • Support with funding
Stakeholder Roles		• Grassroots organizations – every type of organization – Ask for $	• State government the lead • Industry support • Public-private partnership
Collaborators: Leaders and Supporters			• Transparent effort - state agencies, national organizations, government support (high level), and cross-industry and consumers/advocacy groups
Timeframe			• Immediate effort - using a phased approach - get cars and refueling stations in alignment • Plan for economies of scale
First Steps		• Find a way to fund the plan/ infrastructure development - congressional imperative	CFCP and WESTSTART - should take the lead • Work with CALSTART • Identify organizations • Contact stakeholders • Identify work done - gaps - organizations • Plan in place to work with the state and private industry

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 2 - KEY LESSONS AND PITFALLS

- Access to infrastructure, customer friendly, liability, technically suitable, balanced
- Long-term planning [10-20 years]
- Focus on the customer - abundant fueling stations, abundant capacity, no restrictions on station use, compelling refueling experience
- Balancing station throughputs with network coverage
- Public education at station location (e.g., safety, benefits)
- There must be commitment
- Customers must be comfortable, satisfied with experience
- Need sustained government policy and financial support
- Government incentives provide compelling cost advantage
- Need for convenient refueling experience (# of stations)
- Ensure high station utilization by smart siting
- Consistent message vs. fuel of the month
- Compelling consumer and environmental/energy benefit
- Geographic focus - "dense" network
- A few well placed, convenient access, 24/7 stations in a single region today are more important than serving multiple markets with less ? taken to build volume
- Consistent coordination on infrastructure development strategy between government, industry stakeholders
- Early liability relief
- Stations must provide vehicle deployments (mandate timing clear)
- Clear and implementable transition path from demo to commercial
- Contracting, liability, and other execution issues always take longer than expected
- We always go out to bid
- Local official education and support
- Early develop business model (due to different thinking of energy company vs. automaker)
- Government funding is critical and needs long legs
- Formal communication between automakers fuels and government
- Define kg/day
- Need accountability for station execution (in addition to funding)

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 2 - KEY ACTION ITEMS NEEDED

STATION LOCATION	STATION DESIGN	TECHNOLOGY COMPATIBILITY	INCENTIVES AND FINANCIAL ISSUES
• Establish H_2 fueling stations in a few metropolitan areas with stations sized to early market ●●●●●● • Get fleets to use public stations ●● • Find strategic partners with land for siting stations (out of the box) • Identify blighted lots in target areas for H_2 stations - state to provide funds for any remediation required • Distribute stations across cities • Develop a station siting business model to account for the customer refueling experience	• Assume H_2 will be successful and over-build attractive, commercial station networks that help create market pull for H_2 ●●●●●●● • Improve C&S to allow application of advanced technologies (i.e., composite storage) ●● • Build station volume around stationary and mobile uses ●● • Leverage co-production systems ● • Reduce station footprint to address land constraints	• More R&D on small-scale H_2 production/storage ●●● • Real-time station operating status systems to feed on-board GPS/ data systems ●●● • Recognize/anticipate evolving technologies and potential need to update station technology, station appeal, access.....● • Define onboard fuel storage standard (5K psi vs. 10K psi)	• Develop consistent long-term incentives among fuels tied to GHG performance ●●●●● • Federal government cost share to all who bear undue costs to prevent dead end when volume costs are high ●●●●● • Provide 25% to 50% of station cost incentive based on station throughputs and siting ●●● • Properly value the lost vehicle mileage accumulation due to lack of H_2 availability ● • Provide mechanisms to reduce/ share risks of stakeholders (esp. station owner/ operators) ● • Early develop company consortiums/joint ventures to share cost, risk, loss (short-term), revenue (long-term) ● • Find out what incentives will work best; ask • Franchise system for early stations (with bidding) • Commitment to long-term support for R&D and implementation (stations) storage, compressors, etc.) • Evolve - build on success and attract investments from business community • Streamline the process for mailing funding or incentives available

Red dots indicate votes cast.

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 2 - KEY ACTION ITEMS NEEDED (CONT'D)

REGULATORY ISSUES	LIABILITY ISSUES	MARKETING	CONSUMER ACCESSIBILITY
• Convince Congress there really is a fuel crisis looming ●●●●● • Adopt local policies and codes to facilitate siting of stations ●●●●●● • Require or reward transformation fuels (low-to zero-carbon) ●●● • Focus on benefits - policies and incentives to address benefits ●● • Fix broken model of energy companies providing fuel to limited number of cars with near-term profit potential	• Government sharing/limiting liability ●●●●●●●●● • Engage insurance industry to share learnings on safety and operations ● • Address risk/liability of hydrogen quality	• Understand market drivers - you can't foresee technology acceptance ●● • Vehicles and infrastructure must coincide . Focus on fleets for both • Open dialogue on state of technology to enable technology advancements and C&S • Develop a realistic sense of urgency to drive market	• Create same consumer experience as refueling with gasoline ●●●●●●● • Eliminate fueling agreements

Red dots indicate votes cast.

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 2 - TOP FIVE ACTION ITEMS

ACTION	CREATE SAME/BETTER CONSUMER EXPERIENCE AS REFUELING WITH GASOLINE	GOVERNMENT SHARING/ LIMITING LIABILITY (E.G., INSURANCE, FINANCIAL)	ASSUME H_2 WILL BE SUCCESSFUL AND OVER-BUILD ATTRACTIVE, COMMERCIAL STATION NETWORKS THAT HELP CREATE MARKET PULL FOR H_2
Scope	• Excellent access, 24/7, credit card	• Find mechanism to offset liability until maturity negates the need	• Keep hydrogen infrastructure always ahead of demand
Stakeholder Roles	• Auto industry – get cars in consumer hands • Station owner – respond to consumer needs	• Government – fund offsetting liability • Insurance – understand risk • Station owner – buy insurance when it matures	• Design, build and operate stations • Automaker demand
Leader	• Energy companies	• Government	• Energy companies and automakers
Supporter	• Government • Station owners • Local officials • Automakers	• Insurance companies • Station owners	• Government - state and local • Industry trade group
First Step	• Change mind set to early-market	• Establish liability pool for first X number of stations	• Select locations and build several flagship stations

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 2 - TOP FIVE ACTION ITEMS (CONT'D)

ACTION	ESTABLISH H_2 FUELING STATIONS IN A FEW METROPOLITAN AREAS	ADOPT LOCAL POLICIES AND CODES TO FACILITATE STATION SITING
Scope	• Target key urban areas - "hydrogen communities"	• Take codes and standards to local level and find local champions
Stakeholder Roles	• Municipalities – facilitate installations • Automakers – specify markets, consensus on regions	Project participants: • Provide information • Communicate on a local level • Build relationships
Leader	• Automakers and energy companies	• State government
Supporter	• Government • Local champions • Industry groups • Environmental groups	• Project developers • Industry stakeholders • Local champions
First Step	• 40 stations in one or two selected major metro areas (e.g., LA, etc.) by 2012	• Hire a hydrogen ombudsman in office of State Fire Marshall

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 3 - KEY LESSONS AND PITFALLS

- Need realistic projections
- We have an opportunity to re-think our approach using electricity as a model
- There is competition for resources, funding, etc.
- Need consistency for permitting
- Difficulty of implementation in urban core
- Existing funding process not conducive for H_2
- Gas utilities built many of the CNG/electric stations - transportation fuel market share
- (pitfall) Belief that H_2 available to all
- Don't have to start with large scale H_2 refueling infrastructure
- Need a focused geographic rollout
- (pitfall) Over-promising progress
- There is a fear of stranded assets
- Construction material resources can be significant
- Data availability (e.g., leak testing)
- Energy density
- Keep in mind the footprint (land cost)
- Fuel price is NOT a critical issue for the average citizen
- Need public/private partnerships to overcome challenges
- Liability for small/mid-size operators
- No fueling agreements - WDC example
- Operator reliability is an issue
- Need a consistent long-term policy commitment
- Need regulations, codes and standards
- There are other, non-technical issues, e.g., availability of workers, permitting
- Plan for stations to stay - avoid "valley of death" outlook by rolling out a concise technical strategy
- Make sure manufacturing and standardization of station equipment is available for infrastructure build-out
- Need long-term policies - avoid stranded investment
- Coordination of timing and location - vehicles, stations, users
- People who plan alternative fuel infrastructure/policy must drive alternative fuel vehicles first
- Government support for caps on liability/insurance coverage
- Fuel quality and consistency is important
- Fuel metrics and uniform product code (UPC) is important

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 3 - KEY ACTION ITEMS NEEDED

POLICY ISSUES	INCENTIVES AND FINANCIAL ISSUES	REGULATORY/ LIABILITY ISSUES
• Establish clear short and long-term commitments to H_2 technology - to give clear signal ●●●●●●●●●●●● • Facilitate a common, realistic plan and vision with coordination among shareholders ●●●●●●●●● – AFV rollout • Define cost impact (on portfolio) • Relax rules (production of H_2) • Short term commitment (fiscal timeline vs. project timeline) • "To the moon" long-term commitment - policies/ regulations • Understand effects of policy on adoption by consumer – Consider both consumers and producers	• Government to evaluate and document station development cost ●●●●●●●●●	• Create insurance pool - share risk (government) ●●●●●●●●●●●

SUPPLY CHAIN (INITIAL)	SUPPLY CHAIN OVERALL	CONSUMER ISSUES
• Find best niche to start market expansion ●●●●● – Force public access component • Create "enterprise zone" favorable to H_2 infrastructure ●●●● – Link industries (e.g., China) – H_2/fuel cell "zones" incentivize early stations/vehicles	• Identify, evaluate, prioritize siting issues ●●●●●● – Regulatory – Policy – Financial, etc. • Build fueling stations like mobile home ●● • Create educational avenues, e.g., academic curriculum ● – Skilled people to feed supply chain • Land allocation – Existing DOE sub-committee involvement	• Discover consumer's wants and needs and position accordingly ●●●●●●●●●●●

Red dots indicate votes cast.

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 3 - TOP FIVE ACTION ITEMS

	ESTABLISH/RE-EVALUATE CLEAR SHORT AND LONG-TERM COMMITMENTS TO H_2 TECHNOLOGY IN OUR NATIONAL ENERGY POLICY	CREATE INSURANCE POOL - SHARE RISK	DISCOVER CONSUMER'S WANTS AND NEEDS AND POSITION ACCORDINGLY
Interested Parties	• Executive Branch • Congress • State • Local/regional	• Automakers • Energy companies • Operators of demonstrations • Insurance commissioners • Everyone dealing with H_2 - LNG and CNG ports • Steve Weimer (PNNL) • Everyone dealing with H_2	• National Auto Dealers Association • Coordinated through automakers – GM's driveway project – Honda's - leasing program – Fuel cell partnership – Automakers (Japanese)
Barriers/ Challenges	• Democracy	• Unwillingness to share data	• Unwillingness to share data
Timeframe		• Immediate	
First Step	• Identify forum "think tank"	• Collect and compile data to give to insurance companies (encourage data sharing)	
Scope	• National Advocacy		• Qualitative consumer research and behavior analysis (e.g. JD Powers, UC Davis studies)

REFUELING INFRASTRUCTURE FOR ALTERNATIVE FUEL VEHICLES

GROUP 3 - TOP FIVE ACTION ITEMS (CONT'D)

	FACILITATE A COMMON, REALISTIC PLAN AND VISION WITH COORDINATION AMONG STAKEHOLDERS	GOVERNMENT TO EVALUATE AND DOCUMENT STATION DEVELOPMENT COST
Interested Parties	• Define stakeholders via a plan/document – For example: national (big companies), regional (small enterprises) – AFV – Energy companies – FCV – NHA, USFCC – Utilities	
Barriers/ Challenges	• Competition about what is the right plan	• Size of data pool
Timeframe	• Long term vision - 40 yrs (but start action now)	
First Step	• Mapping to understand different activities going on • Define strategy/approach, LDV (e.g., LA) or Buses (e.g., Europe)	• Find information from: NREL database, Europe, CAFCP, Japan • Cost report needs to be updated on a regular basis
Scope	• Start from government recommendations and work down to local/regional – Market development plans at local/regional level	• Need to benchmark costs “unexpected costs” • Take information from DOE demonstration projects and build into next projects

APPENDIX D
BACKGROUND INFORMATION

BACKGROUND INFORMATION

Analysis of the Transition to Hydrogen Fuel Cell Vehicles and the Potential Hydrogen Energy Infrastructure Requirements. Greene, D, et al. 2008. Oak Ridge National Laboratory, ORNL/TM-2008/30. Available at http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf (accessed June 2, 2008).

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
July 2008	Workshop Proceedings	

4. TITLE AND SUBTITLE
Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen; Workshop Proceedings

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
M. Melaina, S. McQueen, and J. Brinch

5d. PROJECT NUMBER
NREL/BK-560-43669

5e. TASK NUMBER
H2782350

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/BK-560-43669

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
DOE sponsored the Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen workshop to understand how lessons from past experiences can inform future efforts to commercialize hydrogen vehicles. This report contains the proceedings from the workshop.

15. SUBJECT TERMS
alternative fuel vehicles; hydrogen vehicles; hydrogen infrastructure; Energetics; workshop; Sacramento; AFV

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UL		

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18