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National Renewable Energy Laboratory

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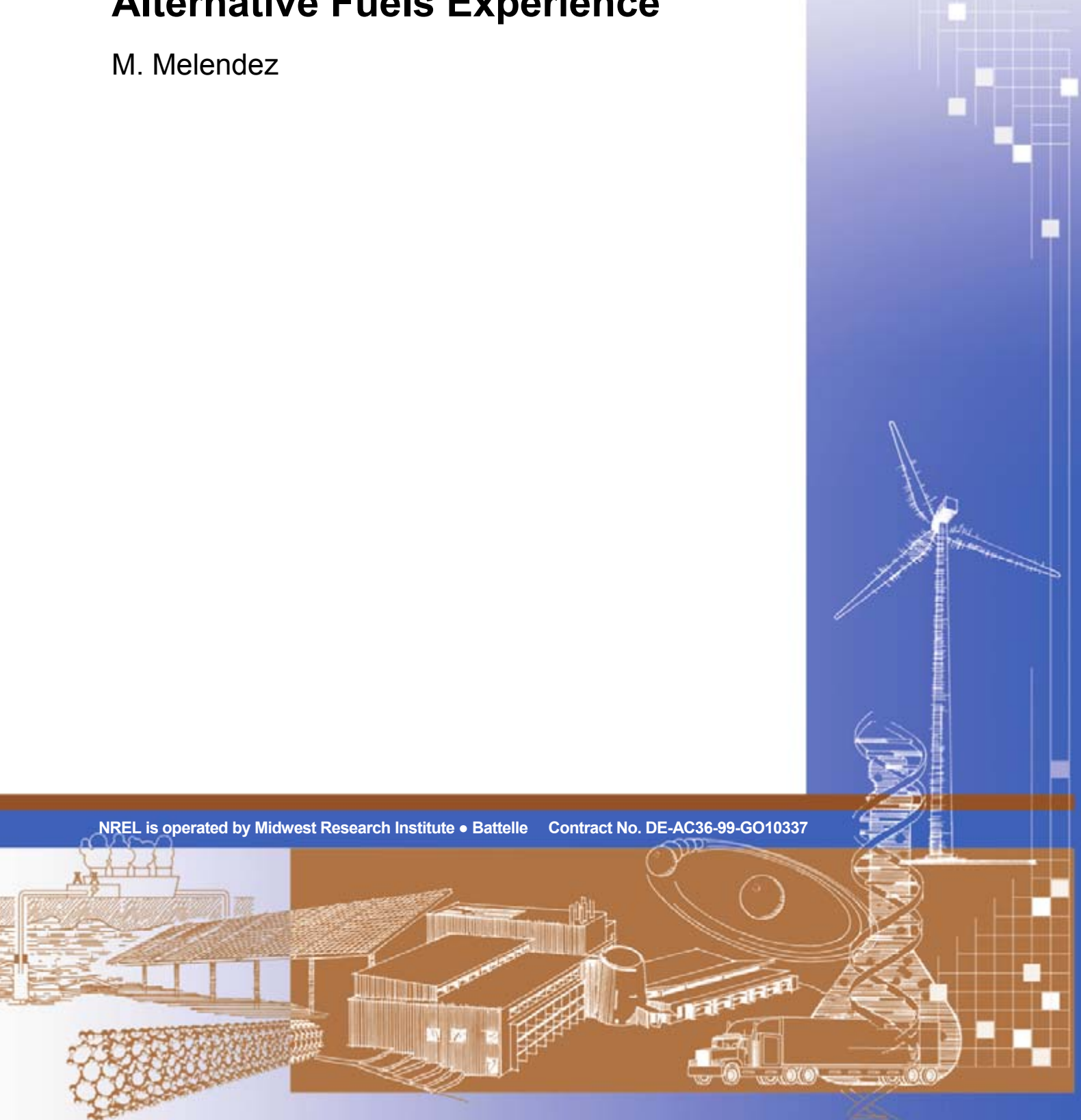
Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience

M. Melendez

Technical Report
NREL/TP-540-39423
February 2006



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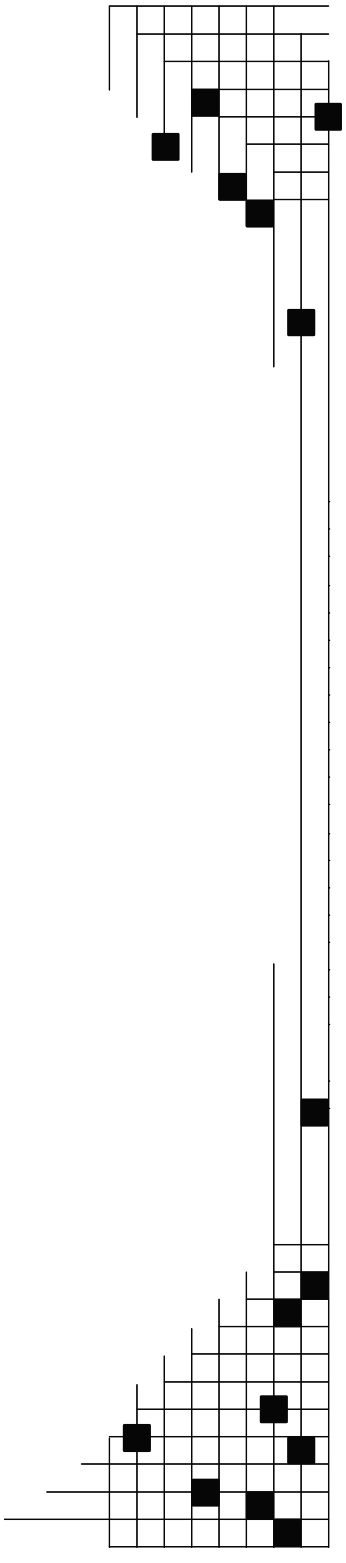

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Contract No. DE-AC36-99-GO10337

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Background

In 2003, President George W. Bush launched the Hydrogen Fuel Initiative, which envisions a future hydrogen economy for the United States. A hydrogen economy would increase U.S. energy security, environmental quality, energy efficiency, and economic competitiveness. Transitioning to a hydrogen economy, however, presents numerous technological, institutional, and economic barriers. These barriers apply not only to the development of fuel cell vehicles and stationary fuel cells but to the development of a hydrogen fueling infrastructure. The President asked the U.S. Department of Energy (DOE) to lead the efforts to overcome these barriers. This effort is managed through the Office of Energy Efficiency and Renewable Energy (EERE) and spearheaded by the Hydrogen Fuel Cells and Infrastructure Technologies Program (HFC&IT)

Since 1977, the National Renewable Energy Laboratory (NREL) has worked closely with DOE to develop and evaluate advanced transportation technologies, such as alternative fuels and hybrid electric vehicles. This work has been done in partnership with EERE's FreedomCAR and Vehicle Technologies (FCVT) Program. NREL's work with alternative fuels programs, such as Clean Cities, the Advanced Vehicle Testing Activity, and others has resulted in extensive knowledge in and experience with the implementation of alternative fuels. Because hydrogen vehicles face many of the same implementation challenges as other alternative fuel vehicles (AFVs), the lessons learned in this arena can guide the transition to hydrogen.

This project was funded by the Systems Integration Program at NREL. It was designed to identify key concepts and lessons learned through the evaluation and deployment of alternative fuels. It marries the experience of FCVT programs with the technologies of the HFC&IT programs to suggest the most and least successful implementation strategies to pursue in the transition to a hydrogen-based transportation system.

Project Description and Goals

The challenges faced by alternative fuels during the last 20 years have much in common with those that face hydrogen (i.e., building markets simultaneously for new vehicle technologies, new fuels, and new infrastructure to support them both). The United States set goals in the 1980s and 1990s to derive a substantial portion of its fuel for transportation from non-petroleum alternative fuels by the early 2000s (10% in 2000, 30% in 2010). Although progress has been made through government and private efforts, these goals have not been met for a variety of reasons. To increase the chances for a timely and successful transition to hydrogen, the experiences of the alternative fuels industry must be understood and used to shape hydrogen transition strategies.

The National Academy of Science (NAS) once suggested that "DOE might have its greatest impact by leading the private economy toward transition strategies rather than to ultimate visions of an energy infrastructure markedly different from the one now in place.[1]" The NRC also encouraged DOE to build upon past experience with alternative fuel technologies and their introduction into the marketplace.

[1] "The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs," pages 2-10, 2004, National Academies Press

A wealth of practical knowledge concerning alternative fuel technologies, products, national policies, and market introduction exists within industry, regulated fleets, and voluntary programs. Issues relating to consumer choice, capital investment, business decision making, manufacturing, and infrastructure construction will need to be understood in the alternative fuels context if the hydrogen transition is to occur efficiently.

The overall objective of this project is to assess relevant knowledge within the alternative fuels community and recommend transitional strategies and tactics that will further the hydrogen transition in the transportation sector and help avoid stranded assets in the alternative fuels industry.

Transportation Transition

Transitioning personal transportation in the United States is a daunting challenge. The country has been firmly entrenched in petroleum-based, internal-combustion technology for nearly 100 years, encompassing not only the vehicle systems and refueling infrastructure but in vehicle maintenance and parts, fuel production and distribution, and in government policies. Because of this, movement away from a petroleum-based system to one of alternative fuels (including hydrogen) requires many changes or decisions to occur in parallel. For instance, not only would a vehicle manufacturer need to offer AFVs for sale but the fuel needs to be produced and distributed to a new refueling location to support the vehicles. In addition, laws and tax issues need to be worked out to allow for the use of such alternatives. The greatest challenge of the transition is to get all the critical elements spatially and temporally aligned.

Table 1 shows the broad range of critical decision makers involved in transportation transition. In some cases, one person may fulfill two decision-making roles (such as when drivers make their own purchase decision versus when central fleet purchasers control the vehicles others operate). Table 1 also shows whether these decision makers are required to make behavioral changes to allow for the transition to various types of alternative transportation fuels.

Table 1. Critical Decision Makers Involved in the Hydrogen Transition

Decision Maker	Alternative Transportation Technology						
	Hybrid	Biodiesel	Ethanol Blends	E85	CNG	LPG	H2
Auto Manufacturer	X			X	X	X	X
Auto Purchaser	X			X	X	X	X
Auto Driver					X	X	X
Auto Regulator	X			X	X	X	X
Fuel Producer		X	X	X			X
Fuel Deliverer		X	X	X	X		X
Fuel Station Operator				X	X	X	X
Fuel Regulator		X	X	X	X	X	X
Fuel Purchaser		X	X	X	X	X	X

Finally, Table 1 illustrates the complexity of coordination of each of these decision makers—so many people are required to make various transitions occur. For example, hybrid vehicle deployment requires that an auto manufacturer produce a hybrid vehicle, that a regulator certifies that vehicle for safety and

emissions, and that a consumer chooses a new vehicle technology. With E85 vehicles, not only must the manufacturer, regulator and consumer select the new technology, but a fuel producer and distributor must decide to participate in the emerging market, fuel regulators must establish codes and standards for the new fuel, stations must elect to offer the fuel for sale, and the person purchasing the fuel must elect to refuel their vehicle with E85. Hydrogen has the challenges of coordination of these stakeholders, plus potential issues with driving differences and utility of the hydrogen vehicle that affect the driver. With each additional decision maker the coordination to make the transition becomes more challenging.

Project Phases

The first step in understanding lessons learned in the deployment of alternative fuels and their application in the hydrogen transition was a review of topical literature (Phase I). Literature results were used as the basis for collecting input from experts involved in the deployment of alternative fuel and advanced technology vehicles (Phase II). These experts would ideally include technology developers, auto makers, alternative fuel providers, technology advocates, fleet customers, non-fleet customers, and policy makers. Because of limited resources and timing, this analysis focuses on two groups of stakeholders: in-house NREL engineers and scientists with expertise in the development and deployment of advanced technology vehicles (technology developers) and Clean Cities coordinators with expertise in building support for advanced vehicle technologies at the local level (technology advocates).

Phase I—Literature Review

A literature search for topics related to lessons learned in alternative fuels deployment was conducted. Nearly 40 relevant papers from an array of organizations—such as universities, government agencies, and environmental groups—were reviewed (Table 2).

The majority of papers were written by authors well known in the alternative fuels industry. Their analyses were based upon up to 15 years of observations in the alternative fuels transition. Most papers relied on this experience to draw conclusions about the effectiveness of various strategies utilized in AFV deployment activities. To most effectively summarize literature results for this study, a compilation of the each paper's main conclusions were documented and weighted based upon the number of references in the literature. The complete breakdown of paper content is shown in Table 3.

Literature Highlights

- Universities—Past 15 years addressed technology but not market factors
- U.S. Government/National Laboratories—Anchor fleets led to most stable infrastructure; fleets alone are not enough
- Non-Governmental Organizations (NGOs)—Infrastructure incentives are critical
- Private Sector—Need public support
- Other Government—Government should share risk/stations should be located near fleets and along interstates

Table 2. Summary of Organizations Represented in Literature Review

Organization	Number
Universities	5
U.S. Government/National Laboratories	12
NGOs	9
Private Sector	4
Other Government	3

Table 3. Summary of Paper Perspectives/Content in Literature Review

Source	Number
Data Analysis	2
Personal Insights	25
Modeling Results Analysis	4
Human Factors	2

Most of the literature reviewed emphasized specific barriers that are critical to overcome to successfully deploy AFVs. The most noted barriers from the literature are:

- Availability of alternative fuel refueling infrastructure
- Inconsistency in public policy and leadership messages
- High costs of constructing refueling infrastructure
- Low oil prices
- Poor perceived or actual performance of AFVs (safety, power, attributes, range, reliability, etc.)
- Competition against conventional fuel economies of scale
- High costs of purchasing AFVs (compared with conventional vehicles)
- Availability of AFVs
- Lack of customer awareness and market acceptance
- Lack of economic incentives
- Alternative fuel availability
- Lack of AFV service and maintenance training and technicians
- Lack of trained fueling station operators
- Poor fuel properties of alternative fuels
- Inconsistent codes and standards

The overall perspectives and outlooks from the literature were as varied as the authors. Government authors tended to focus more on the policy issues necessary for transition, while private sector writers addressed market factors and government support. In particular, much of the literature wrangled with the fleet concept that was the basis for alternative fuel deployment and how it related to consumer market development.

The authors also identified and evaluated strategic focus areas used by the alternative fuels industry to overcome these barriers. The following list represents key activities that could be valuable in coordinating decision-makers and promoting advanced transportation technologies.

- Fleets (private, state, federal)
- Niche markets (airports, taxis, school buses, transit vehicles)
- Outreach and education
- Partnerships
- Tax incentives
- Grants and other financial incentives
- Regulatory incentives
- Research and development
- Demonstration projects
- Alternative fuel blends
- State and federal leadership and program messages

Barriers and strategies were ranked by the total number of times they were mentioned in the literature. They were then used as the basis for collecting feedback on AFV lessons learned feedback from two stakeholder groups. Results for the barriers are shown in Table 4 and the strategies are discussed below.

Phase II—Collecting Expert Feedback: Barriers

The literature search identified a set of barriers and strategies that were of particular concern to the deployment of AFVs. This information was used as a basis for gathering information from experts in the AFV arena—in this case NREL scientists and Clean Cities coordinators.

NREL Transportation Technology Engineers/Scientists

Working in partnership with public and private organizations, NREL researches, develops, and demonstrates innovative vehicle and fuel technologies that reduce the nation's dependence on imported oil, and improve our energy security and air quality. NREL's goal is to help industry introduce advanced, low emission, economically competitive vehicles and fuels into the marketplace. Work in this area supports several NREL programs and is led by the Center for Transportation Technologies and Systems, which has a staff of more than 50 transportation-related engineers and scientists.

NREL personnel involved in this data gathering were engineers and scientists who approached the issue from both a scientific and strategic management point of view. Participants represented professionals who have been involved in alternative fuels research, development, and deployment for up to 20 years. The objective of the NREL input was for a scoping of the work and initial validation of the barriers and strategies identified in the literature review. To assist with this scoping, six research scientists participated in a meeting to discuss the literature findings.

The barriers were discussed in detail and prioritized by participant vote, which determined the top five barriers most critical to the deployment of advanced transportation technologies. The barriers were ranked based on the total number of votes they received. In addition, the NREL scientists identified two barriers that were not identified in the literature:

- Lack of dealer/sales staff knowledge
- Complexity of change is large

The NREL ranked barriers are shown in Table 4.

Local Clean Cities Coordinators

Clean Cities was developed in 1993 in support of the goals of the Energy Policy Act (EPAct) of 1992. It is a network of 88 volunteer coalitions, which develop local public/private partnerships to promote alternative fuels and vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. Through its coalitions, Clean Cities draws local stakeholders from the public and private sectors. Stakeholders include local, state, and federal agencies; public health and transportation departments; transit agencies; auto manufacturers; car dealers; fuel suppliers; public utilities; and professional associations. Clean Cities believes that by building strategic partnerships on the local and national levels, it's possible to align the most critical elements and decision-makers to transition from petroleum-based motor fuels.

Clean Cities has been successful at implementing a national goal at a local level. Through their affiliation with Clean Cities, stakeholders have learned a lot about deploying AFVs and advanced technologies.

Clean Cities coordinators are supporters of alternative fuel technologies that work in local and regional communities and organize local efforts to advance the goals of Clean Cities. From science and engineering to marketing and grant writing, these individuals have diverse backgrounds. Their common thread is that each coordinator supports advanced vehicle technologies on the local level, working closely with the key decision makers in their area.

To collect input from coordinators, presentations were made at the following four regional Clean Cities meetings.

- Midwest and southeast regions (July 2005)
- Western region (August 2005)
- Central region (September 2005)
- Northeast region (October 2005)

During each meeting, the overall project and objectives were presented, as well as the results from the literature review. General discussion was encouraged as time permitted and followed up with a questionnaire to quantify the significance of each (see Appendix B). Respondents were asked to rate each barrier from 1 to 5 (least to greatest) on the importance on their deployment activities. Barriers were ranked from these results by averaging the ratings of each barrier. Overall, more than 65 coordinators participated in the discussions, and 20 (of 88) coordinators responded to the questionnaire. In addition to the barriers identified in the literature, Clean Cities' coordinators identified one additional barrier:

- No real commitment from original equipment manufacturers (OEMs).

Complete results from the questionnaire barrier ranking are shown in Table 4.

Table 4. Barrier Ranking Results

Barriers	Literature Rank	NREL Rank	Coordinator Rank
Availability of alternative fuel infrastructure	1	1	1
High cost of constructing infrastructure	3	8	2
Availability of AFVs	8	3	3
Inconsistent in public policy and leadership messages	1	5	4
Competition against conventional fuel economies of scale	6	8	5
Lack of economic incentives	10	5	5
High cost of purchasing AFVs	6	2	7
Lack of customer awareness and market acceptance	8	8	8
Lack of AFV service and maintenance training and technicians	10	8	9
Lack of trained station operators	10	8	10
Poor perceived or actual performance of AFVs	3	8	11
Alternative fuel shortages	10	8	11
Low oil prices	3	3	13
Poor fuel properties of alternative fuels	10	5	14
Inconsistent codes and standards	10	8	15

Of the top eight results for each group (which represents the top 50% of barriers), five barriers were common for each group. In particular, availability of alternative refuel infrastructure was identified as the number one barrier by all groups. These five common barriers include:

- Availability of alternative fuel infrastructure
- High cost of constructing infrastructure
- Availability of AFVs
- Inconsistent public policy and leadership messages
- Higher cost of purchasing AFVs

Phase II—Collecting Expert Feedback: Strategies

A short questionnaire was used to collect information on strategies from both groups of experts (see Appendix C). The NREL scientists and coordinators were given the questionnaire and asked to evaluate the impact of each strategy on their top two to four barriers they identified in this study.

NREL experts were allowed to discuss the topic prior to and during the time they took to complete the questionnaire. Clean Cities coordinators filled in the questionnaire individually following the meetings when the topic was presented and discussed.

Strategies were evaluated in terms of their ability to make a positive impact on the barriers. This is important because each strategy may impact each barrier to a different degree. Following is a summary of the results for the five common barriers identified by the experts.

Barrier: Availability of Alternative Refueling Infrastructure

Today, there are 770 natural gas stations and 550 E85 stations in the United States. Comparatively, there are more than 170,000 gasoline stations nationwide. This means that consumers that purchase vehicles intended to run on natural gas and E85 must make a greater effort to refuel than those who

utilize conventional vehicles. To address this barrier, experts identified the following strategies as the most effective:

1. Grants (for incremental vehicle cost and/or infrastructure)
2. Tax credits (for vehicles and/or fuel)
3. Regulations
4. Partnerships

Barrier: High costs to purchase AFVs (compared with conventional vehicles)

A typical light-duty, natural gas vehicle costs roughly $3,000 or 10%-15% more than a conventional vehicle. Similar values are true for propane vehicles, and hydrogen fueled vehicles are anticipated to have even higher incremental costs initially (although they should be partially offset by operating costs due to higher efficiency). To address this barrier, experts identified the following strategies as the most effective:

1. Tax credits (for vehicles)
2. Grants (for incremental vehicle cost)
3. Regulation
4. Research and development (R&D)

Barrier: Availability of AFVs

Currently, approximately 15 million vehicles are sold annually in the United States. This includes passenger cars and light trucks. There are nearly 1,000 models that operate on conventional fuel. In contrast, there are roughly 20 models of alternative fuel vehicles available from OEMs – in limited quantities. To address this barrier, experts identified the following strategies as the most effective:

1. Grants (for incremental vehicle cost)
2. Regulations
3. Tax Credits (for vehicles)
4. Partnerships

Barrier: Inconsistency in Public Policy and Leadership Messages

Because of the complexity of the transition of the transportation to alternative fuels, there are many different messages and goals. There are two main areas where public policy consistency is important. The first is the overall message related to the significance of transition, including energy security, enhancement of domestic economy, and environmental stewardship. While all are good reasons for the transition of our transportation system, each one carries a different set of implementation strategies. The second message relates to the priorities of specific initiatives, such as specific fuels or technologies (eg: natural gas, ethanol, hybrids). Add to these continually shifting priorities, the different goals and objectives of state and local policy makers, and the challenge becomes even more complex. To address this barrier, experts identified the following strategies as the most effective:

1. Tax Credits
2. Regulation
3. Grants
4. Management and Coordination and Outreach (tie)

Barrier: High Cost of Constructing Infrastructure

Construction of alternative refueling infrastructure ranges from a few thousand dollars to add an ethanol pump to an existing station to up to $1 million for a new natural gas refueling island. Because of low sales volumes for alternative fuel relative to gasoline and diesel, the economic benefits are difficult to realize. To address this barrier, experts identified the following strategies as the most effective:

1. Grants (for refueling infrastructure)
2. Tax Credits (for fuel and infrastructure)
3. Regulation
4. Partnerships

Figure 1 summarizes the overall results for each of the strategies for the preceding barriers. The majority of respondents believed that financial incentives (grants and tax credits) were of major importance for all the barriers. This does not seem surprising, as financing new technologies is a major issue across most industries. However, monetary support was not the only item of importance. The experts also indicated that partnerships, demonstrations and regulations were important.

Every strategy was determined to be at least moderately valuable at addressing at least one variable. A full table showing the results for which strategies were important to each barrier is shown in Appendix D.

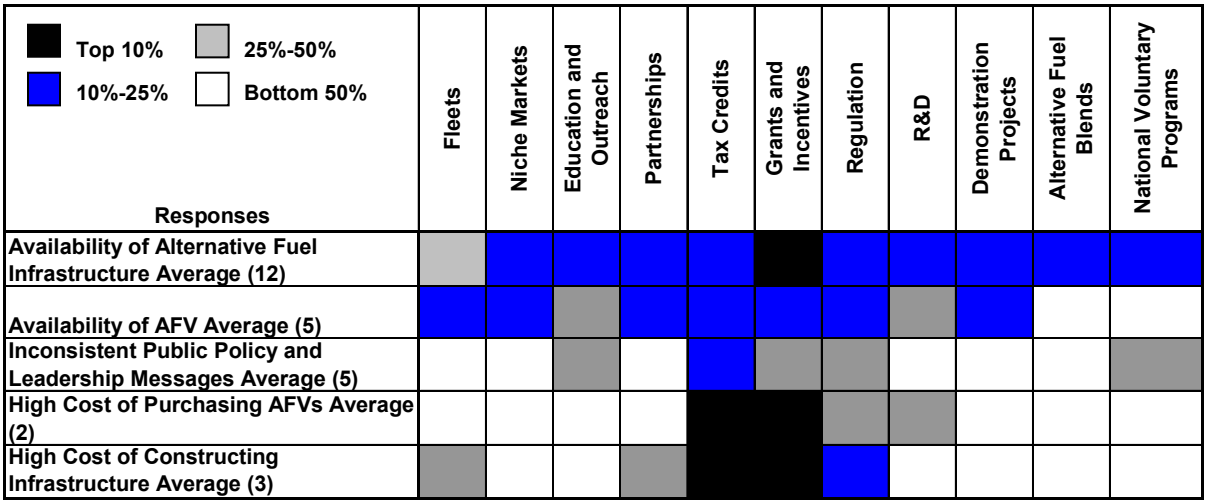

Figure 1. Summary of Strategic Impacts for the Critical Barriers

Issues and Questions from the data

R&D scored relatively low in four of the five barriers shown in Figure 1. This low score is likely due to the sample size and composition of stakeholders (many of the Clean Cities coordinators do not have a research or technical background). It can also be because much of the research on vehicle and infrastructure development has been done in the past 15 years, and that vehicles and infrastructure operate reliably today.

Blends were not considered a highly effective strategy by the respondents. This is possibly due to the fact that a blend strategy (utilizing low-level blends as a way to build the biofuels production and

delivery market) is relatively new to Clean Cities. Blends have only been considered part of the initiative since 2004. For example, coordinators generally consider B20 an alternative fuel instead of a blend.

Surprisingly, participants did not consider fleets a particularly effective strategy. This departs from the literature results, which on many occasions (by several different authors) cited the fleet strategy as productive. This conflicting perspective could be the result of frustration on the part of coordinators that the technologies did not progress *beyond* fleets. Fleets seem to fall into the category of "critical but not sufficient."

It is unclear why respondents felt that grants, tax credits, and regulation helped address the barrier of inconsistent policies and leadership messages. This relationship is not intuitive, and should be explored further in future work.

Major Messages from the Analysis

During the course of data collection, several themes or insights were collected beyond the barriers and strategies. These insights could be of value to the hydrogen transition and are described in this section.

Combination Fleet and Consumer Focus May be Best

Alternative fuels efforts focused on deployment to fleets. Regulations affecting federal, state, and alternative fuel provider fleets spurred AFV sales, however they still represent less than 1% of the vehicles on the road today. Clearly, this limited fleet market was not sufficient to generate significant sales for vehicle manufacturers. However, the fleet focus was important as a learning tool for vehicle and refueling technologies, codes and standards, safety, and rollout and implementation issues. For these reasons, the experts strongly believed that a fleet introduction strategy was important but not sufficient to the widespread deployment of new vehicle technology. Finding a way to transition from fleets to consumers is equally critical.

Analysis is an Important Tool

Analysis is a critical piece of the transition strategy that was not well developed in the alternative fuels deployment process. Analysis is important to assess what strategies were and were not successful and to quantify those benefits, so limited resources can be spent on initiatives with the greatest impacts. Key measures were noted as environmental impacts, economic impacts, and oil displacement. In addition, experts believed "societal" impacts, such as less noise and clearer views, that affected consumer demand were not well communicated in the alternative fuels experience.

Specific analytic tools that allow consumers and fleets to evaluate their own costs and environmental impacts, are critical for transition. Examples of these tools include fleet tools that discuss overall cost and/or emissions impacts of various (such as the Clean Cities' Fleet Buyer's Guide or EPA's Freight Logistics Environmental and Energy Tracking Performance Model). Another example is a tool that evaluates operating costs over the life of a vehicle to help consumers understand economic benefits or penalties of purchasing advanced technology vehicles.

Total Funding was Small and Inconsistent

Funding related to the barrier of inconsistent policies and messages is also a challenge. As priorities shift from, say, an emphasis on environmental protection to energy security, funding for specific

activities also shift. This discontinuity in programs was detrimental to transportation fuel transition, and experts cited a strong need for consistent messages and funding on initiatives. Additionally, funding in the alternative fuel transition tended to be based on specific activities and given a certain amount of funding instead of based on specific goals. Programs need to work from the goal back to funding requests, rather than start with funding requests and figuring out where the money will go.

Need a National Plan for Transition

A national plan with support at the local level is a good model for deployment of advanced vehicle technologies. The national plan needs to address goals and transition strategies that adjust with time and vehicle penetration. AFV deployment strategies were effective at the 0%-1% levels, but not at breaking into mainstream market. Transition strategies at 1% are different than strategies at 10%, and whatever plans for deployment are developed need to adjust at various levels to address different concerns at each level.

Local Efforts Can Help When Funding is Limited

Given that funding is always limited for any project or initiative, the ability to organize and strategize at a local community level is critical. From organizing partners to co-fund projects to arranging for vehicle users to fuel at a new station so that it can be profitable, the power to organize people and resources is an asset to transportation transition. The national plan/goals provides the motivation for local efforts, and targeted programs to pull local partners together seals the deal.

Behavior to Purchase/Use AFVs is Often not Rational

Overall, when considering cost, convenience, and familiarity, the rational consumer would generally choose against the alternative fuel or advanced technology vehicle. Building a case for change that overrides the comfort-level concerns of consumers is a big challenge that many of the activities discussed in this paper will be addressed. Developing projects and programs that quantify benefits and/or demonstrate intangible benefits are important.

Conclusions and Recommendations

The barriers identified in this study indicate that the hydrogen transition should focus on projects that address both vehicle and infrastructure availability and costs. A clear, consistent vision for the transition from petroleum-based fuels should also be established and communicated to hydrogen stakeholders.

The list of suggested strategies to address these barriers indicates that economic support is a big factor, but not the whole story. Partnerships and leadership are also important, as is research and development. This partnership and coordination theme is especially important in relation to early transition, where having vehicles and infrastructure transition in parallel is critical to market success.

To complete this analysis, and fully understand the most challenging barriers and effective strategies to address them, it is critical to collect input from a broader array of stakeholder groups, such as:

- Manufacturers (vehicles, fuels)
- Government regulators
- Regulated fleets
- Non-regulated fleets

Housed at NREL, DOE's Alternative Fuels Data Center features a wealth of information on current and historical policy and vehicle and infrastructure statistics, which could be analyzed to understand trends and market reactions to various programs. This data was collected to meet reporting requirements of EPAct of 1992. Additionally, data collection on specific projects or issues related to alternative fuel or advanced technology vehicles, such as hybrid or biofuels deployment patterns, would also be beneficial. This could help us understand the influence of policies and strategies on market development. In 2001, the National Conference of State Legislatures did this for states, and an update of that work—as well as an expansion beyond state fleets—could shed light on more current transition issues.

Finally, to quantify the benefits of a fleet strategy, a detailed analysis of fleets answers to the following questions would be helpful:

- What makes a critical mass?
- Can fleets ever get us there?
- Which fleets have most potential?
- How do you transition from a fleet strategy to a consumer strategy?

Acknowledgements

This report was completed with the cooperation of many colleagues at the National Renewable Energy Laboratory. Thank you to:

Paul Bergeron
Ann Brennan
Wendy Dafoe
Dale Gardner
Barb Goodman
Maggie Mann
Bob McCormick
Vicky Putsche
Mark Ruth

And special thanks to the Clean Cities coordinators who submitted questionnaires for this report.

Acronyms

AFV	Alternative fuel vehicle
B20	Fuel blend of 20% biodiesel, 80% petroleum diesel
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EPAct	Energy Policy Act of 1992
FCVT	FreedomCAR and Vehicle Technologies Program
E85	Fuel blend of 85% ethanol, 15% gasoline
CNG	Compressed natural gas
HFC&IT	Hydrogen, Fuel Cells, and Infrastructure Technologies Program
H2	Hydrogen
LPG	Liquefied natural gas
NRC	National Research Council
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
R&D	Research and development

Appendices

Appendix A: AFV Lessons Learned Literature Summary

Author	Affiliation	Title	Date	Summary
Wells, Jim	Natural Resources and Environment	Alternative Motor Fuels Impact on the Transportation Sector, Testimony before Committee on Finance, US Senate	7/10/01	Overview of status of AF and AFVs. Lists basic barriers of low oil prices and inadequate incentives/funding
Wells, Jim	Natural Resources and Environment	Research and Development, Lessons Learned from Previous Research Could Benefit FreedomCAR Initiative, Testimony to the HR	6/6/02	Lessons learned, including be sure that the activities will impact the goal (i.e., AFV acquisitions when the goal is to reduce petroleum use), reevaluate regularly
Brown, Matthew H.; Breckenridge, Leah	National Conference of State Legislatures	State Alternative Fuel Vehicle Incentives: A Decade and More of Lessons Learned	2/1/06	Review of State incentives and which work: Focused, Large, Easy to Administer, Include infrastructure, grant based
DeCicco, John M.	Society of Automotive Engineers	Fuel Cell Vehicles: Technology, Market, and Policy Issues	11/1/01	To deploy fuel cell vehicles we'll need technology advancement for vehicles, cost reduction, resolution of infrastructure barriers
Jackson, Michael D.; Kaahaaina, Nalu; Fable, Scott	Arthur D Little, Acurex Environmental	Lessons Learned from Past Strategies to Reduce Petroleum Dependence	9/17/01	Strategies include improved efficiency, advanced technologies, alternative fuels, affecting consumer behavior, and laws and incentives
Patterson, Phil; Alson, Jeff; Lance, Linda; Brown, Kelly; Hawkins, David; Ditlow, Clarence; Dana, Greg	Various	Lessons from 30 Years of Automotive Energy and Air Quality Policy: An Interactive Round Table	6/21/05	Asilomar proceedings: Congestion is number one concern of consumers, consumers don't know about the technology of their vehicles
McCormick, Gary L.; Russell, Richard B.	Gannett Fleming, Inc.	Alternative Bus Fuels: What Have We Learned		Successful AF bus fleets: Investigate fuels, Understand costs and budget, plan for today and future use, research long-term fuel contracts, assemble team of experts, work with local officials, training
Leiby, Paul; Rubin, Jonathan	ORNL, U of ME	Transition Modeling of AFVs and Hybrids: Lessons Learned	7/3/05	Key transition barriers: vehicle and infrastructure, fuel availability, poor economies of scale, poor diversity of choice, low oil prices
Nesbitt, Kevin; Sperling, Daniel	University of California, Davis	Myths Regarding Alternative Fuel Vehicle Demand by Light-Duty Vehicle Fleets	6/20/05	Review of fleets as early adopters
Leiby, Paul; Rubin, Jonathan	ORNL, U of ME	Understanding the Transition to New Fuels and Vehicles: Lessons Learned from Analysis and Experience of Alternative Fuel and Hybrid Vehicles	10/31/03	AFVs are mature technology, but not in the marketplace; review of issues in the deployment of AFVs
Baxley, Phillip; Verdugo-Peralta, Cynthia; Weiss, Wolfgang	CA Hydrogen Highway	California Hydrogen Highway Network Rollout Strategy Topic Team	11/28/04	Niches worked but it is difficult to translate that into widespread commercial acceptance
Zhao, Jimin; Meliana, Marc W.	University of Michigan	Transition to Hydrogen-Based Transportation in China: Lessons Learned from Alternative Fuel Vehicle Programs in the US and China	7/4/06	Experience, Barriers, and recommendations: focus on hybrids near term, review and balance options, specify goals, education and marketing are key, coordinate vehicles/infra/maintenance
Santini, Danilo J.; Vyas, Anant D.	ANL	How is Technology Adopted? A Discussion of Hybrid-Electric and Diesel Technology Consumer Preferences	1/10/04	Review of hybrid buyers preferences
Parish, Richard	NREL	Implementing Alternative Fuels in Transportation Vehicles	6/27/05	List of factors affecting market penetration of AFVs
Wells, Jim	Natural Resources and Environment	Energy Policy Act of 1992: Limited Progress in Acquiring Alternative Fuel Vehicles and Reaching Fuel Goals, GAO Report	2/1/00	Overview of EPAct progress and issues with EPAct mandates
Schulte, Inga; Hart, David; van der Vorst, Rita	Imperial College Center for Energy Policy and Technology	Issues Affecting the Acceptance of Hydrogen Fuel	9/2/03	Review of market research on what consumers think of H2 vehicles and fuel and what motivates purchase decisions

US DOE	Clean Cities Program	Clean Cities 2004 Roadmap	6/26/05	Overview of Clean Cities portfolio and barriers to the implementation of each technology/strategy
McNutt, Barry; Rodgers, David	US DOE	Lessons Learned from 15 Years of Alternative Fuels Experience, 1988 to 2003	6/25/05	Lessons learned, including niches don't translate into broader market; economies of scale of conventional fuels a difficult barrier
Robertson, Bernard I.; Beard, Loren K.	Chrysler	Lessons Learned in the Deployment of Alternative Fueled Vehicles	6/26/05	Must have broad/accepted goals, rely on total life cycle analysis, viewed as a system (vehicles and infra), government must level playing field with conventional fuels
DeCicco, John M.	Environmental Defense	The "Chicken or Egg" Problem Writ Large: Why a Hydrogen Fuel Cell Focus is Premature	6/26/05	
Sperling, Dan; Cannon, James S	UC Davis	Hydrogen Hope or Hype	6/26/05	
	Research Reports International	The Market for Alternative Fuel Vehicles	12/4/06	Review of mfg. Activities, federal and state programs, progress in AF to date.
Gross, Tom			5/5/06	Current federal policy for R&D is not enough. Need to develop marketplace. Start with distributed generation then transfer to APU and Vehicles.
Baxter-Clemmons, Shannon	Cal EPA	California Hydrogen Highway Network Rollout Strategy	5/5/06	Steps to implementation: Top down leadership, implementation strategy, stakeholder buy-in, phased approach
	CONEG Policy Research Center	Refueling Alternative Fuel Vehicles: Lessons Learned from the Marketplace	5/1/95	
DeCicco, Johm M. etc.	ACEEE	Transportation on a Greenhouse Planet: A Least-Cost Transition Scenario for the United States		
	US DOE	A National Vision of America's Transition to a Hydrogen Economy - to 2030 and Beyond	2/1/02	
	US DOE	National Hydrogen Energy Roadmap	11/1/02	
	US DOE	Hydrogen Posture Plan	2/1/04	
	10 CFR Part 490	Alternative Fuel Transportation Program: Private and Local Government Fleet Determination	1/29/04	Review of program status and potential for petroleum displacement. Options described briefly
Lovins, Amory B.; Williams, Brett D.	Rocky Mountain Institute	A Strategy for the Hydrogen Transition	4/1/99	Focus on decentralized production of H2 for max. benefits. Distributed power applications first with transportation to follow.
Greene, David L.	ORNL	Climate Change Policy for Transportation while Waiting for H2		Need incentives to stimulate GHG reductions to promote H2 as an energy carrier for transportation.
	Cal EPA	California Hydrogen Blueprint Plan, volume 1	5/1/05	Background, rational, and phase-in plan description for CA H2H

Appendix B: Barriers Questionnaire

Below is a list of barriers to the transition to widespread introduction of alternative fuels. Using the ranking system below, prioritize these barriers. This includes how important it is to transition and how challenging it is to overcome.

5 - Very Significant
4 - Effective
3 - Somewhat Significant
2 - Not Significant
1 - Not a Barrier/Not Applicable

Barriers	Degree of Difficulty
Availability of alternative fuel refueling infrastructure	
Inconsistency in public policy and leadership messages	
Poor perceived or actual performance of AFVs (safety, power, attributes, range, reliability, etc.)	
High costs to construct refueling infrastructure	
High costs to purchase AFVs (compared with conventional vehicles)	
Competition against conventional fuel economies of scale	
Availability of AFVs	
Lack of customer awareness and market acceptance	
Alternative fuel shortages	
Poor fuel properties of alternative fuels	
Lack of AFV service and maintenance training and technicians	
Lack of trained fueling station operators	
Lack of economic incentives	
Inconsistent codes and standards	
Low oil prices	

Appendix C: Strategies Questionnaire

Below is a list of strategies that have been used to promote alternative fuels. Please fill in two to four barriers you think are the most significant in the far left column. Then, using the ranking system below, enter the effectiveness of each strategy in addressing that barrier.

5 - Very Significant
4 - Effective
3 - Somewhat Significant
2 - Not Significant
1 - Not a Barrier/Not Applicable

Most Significant Barriers	Fleet Focus	Niche Market Focus	Outreach & Education	Partnerships	Tax Incentives	Grants & Other Financial Incentives	Regulatory Incentives	R&D	Demo Projects	Alt. Fuel Blends	Overall Coord. & Project Mgmt.

Please list any other comments or issues related to barriers or strategies to address them that have been most or least effective.

Appendix D: Strategies Most Important for Each Barrier

Most Significant Barriers (Number of Responses)	Fleet Focus	Niche Market Focus	Outreach & Education	Partnerships	Tax Incentives	Grants & Other Financial Incentives	Regulatory Incentives	R&D	Demo Projects	Alt. Fuel Blends	Overall Coord. & Project Mgmt.
Availability of Alt. Fuel Infrastructure (13)	3.50	3.25	3.23	3.83	4.25	4.50	3.92	2.62	3.00	2.58	3.18
Availability of AFVs (5)	3.80	3.80	3.40	4.00	4.00	4.00	4.00	3.60	4.20	2.60	2.60
Competition against conventional fuel economies of scale (3)	4.33	3.33	3.33	3.33	4.67	3.67	3.00	2.67	4.00	3.67	4.00
High costs to construct refueling infrastructure (3)	3.00	2.67	2.33	3.33	4.33	4.67	4.00	2.67	2.67	2.00	2.00
Inconsistency in public policy and leadership messages (5)	2.40	2.00	3.20	2.80	3.80	3.40	3.40	2.80	2.60	2.00	3.20
Inconsistent codes and standards (2)	2.00	1.00	3.50	4.00	4.00	4.00	4.50	4.50	4.00	3.50	4.00
Lack of Consuemr Awareness (5)	3.40	3.40	5.00	4.20	3.60	3.40	3.40	3.20	3.40	3.40	3.80
Poor percieved or actual performance (4)	3.75	3.75	4.25	2.75	3.25	3.25	2.50	3.50	3.75	2.25	3.25
Higher relative fuel costs (2)	3.00	3.00	2.00	3.00	3.50	3.50	3.00	2.00	1.50	2.50	2.50
High costs to purchase AFVs (3)	2.50	1.50	2.00	2.00	4.67	4.50	3.50	3.00	1.00	1.00	1.00
Lack of available grant funding at all levels for development of compliant prototype heavy duty alt. fuel vehicles	5.00	5.00	2.00	5.00	5.00	5.00	5.00	5.00	5.00	2.00	5.00
Real OEM Commitment (2)	4.00	N/A	5.00	4.00	4.50	5.00	5.00	5.00	N/A	N/A	5.00
Irrational Behavior/Not a good business case (2)	3.00	3.00	2.50	2.00	3.50	3.00	3.00	1.00	2.00	3.00	2.00
Inconsistent fuel properties (1)	3.00	3.00	4.00	2.00	2.00	2.00	4.00	4.00	4.00	1.00	1.00
Complexity of change (1)	N/A	N/A	3.00	N/A	3.00	4.00	N/A	N/A	N/A	N/A	N/A
OEM/Dealer education and knowledge (1)	5.00	5.00	5.00	5.00	5.00	5.00	1.00	1.00	4.00	N/A	5.00
Lack of local fuel supplier (1)	5.00	5.00	2.00	5.00	5.00	5.00	5.00	5.00	5.00	2.00	5.00

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)*
February 2006	Technical Report	

4. TITLE AND SUBTITLE
Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience

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

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
M. Melendez

5d. PROJECT NUMBER
NREL/TP-540-39423

5e. TASK NUMBER
HS06.1002

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/TP-540-39423

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)*
This paper assesses relevant knowledge within the alternative fuels community and recommends transitional strategies and tactics that will further the hydrogen transition in the transportation sector.

15. SUBJECT TERMS
Hydrogen; infrastructure; transition; alternative fuels; vehicles; hydrogen transition

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		