Title

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Publication Date
2009-04-01

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

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California PATH Research Report
UCB-ITS-PRR-2009-26

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

Final Report for 6114

April 2009

ISSN 1055-1425

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April 9, 2009

Final Report

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Acknowledgements

The authors would like to thank the California Department of Transportation (Caltrans) and California Partners for Advanced Transit and Highways (PATH) for funding this research. In particular, Randell Iwasaki, Larry Orcutt, Nancy Chinlund, Lindsee Tanimoto, and Marcus Evans of Caltrans made this study possible. Our deep appreciation also goes to Mercedes-Benz Research and Development North America, Inc. for the opportunity to employ the F-Cell in this study. In particular, we thank Eric Larsen, Katerina Tsasis, Michele Ventola, Peter Friebe, and Lora Renz. Thanks also go to Catherine Dunwoody, Juan Contreras, and Chris White at the California Fuel Cell Partnership and Jamie Levin and Mallory Nestor at AC Transit for making the hydrogen-fueling demonstrations possible. We also thank our research team at the Transportation Sustainability Research Center and the Innovative Mobility Research group of UC Berkeley for their tireless efforts in supporting the ride-and-drive clinics, including Rachel Finson, Denise Allen, Charlene Kemmerer, Melissa Chung, Keith Brown, Judy Liu, Cynthia Phan, Kate Reimer, Jaako Immonen, Amanda Chou, Danl Martinez, and Tagan Blake. Finally, we greatly appreciate the support we received for this project from Steve Campbell of the Institute of Transportation Studies at UC Berkeley. The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented.

Abstract

Over the last several decades, hydrogen fuel cell vehicles (FCVs) have emerged as a zero tailpipe-emission alternative to the battery electric vehicle (EV). There are key questions about consumer reaction and response to operations and refueling of FCVs. This report presents the results of a "ride-and-drive" clinic series (n=182) held in 2007 with a Mercedes-Benz A-Class "F-Cell" hydrogen FCV. The clinic evaluated participant reactions to driving and riding in an FCV, as well as witnessing a vehicle-refueling event. The respondents entered the clinic with a strong interest in alternative fuels, but less than 15 percent had any prior experience with hydrogen. Roughly 95 percent of respondents finished the clinic with either a positive or very positive impression of the F-Cell. More than 80 percent left with a positive overall impression of hydrogen. The majority expressed a willingness to travel five to ten minutes to find a hydrogen station. More than 90 percent of participants would consider an FCV driving range of 300 miles (480 kilometers) to be acceptable. Fifty percent stated that they would pay at least a $4,000 purchase price premium for a zero-emission vehicle over a similar gasoline vehicle. The techno-economic barriers to FCV deployment are still considerable, but recent progress has been made in several key areas. Remaining issues that require improvement include fuel cell system cost reduction and durability, hydrogen storage, as well as the costs and technical complexities associated with developing a hydrogen-refueling infrastructure. In addition, and arguably less well recognized, are potential challenges for consumer exposure and acceptance. This study explores these latter issues with a sample population that is mostly reflective of early adopters. The results show that short-term exposure can improve consumer perceptions of hydrogen performance and safety among people who are more likely to be early adopters of hydrogen.

Key Words: Hydrogen, fuel cell, infrastructure, drive clinic, behavioral response, before-and-after, longitudinal, survey

Executive Summary

Concerns over air pollution, energy dependence, and now climate change have motivated the exploration of cleaner alternative transportation fuels for several decades. Hydrogen fuel cell vehicles (FCVs) have recently emerged as a zero tailpipe-emission alternative to the battery electric vehicle (EV). Like battery vehicles, FCVs produce no tailpipe emissions (other than water vapor) and also have the potential to be near zero-emission on a full fuel-cycle basis when coupled with renewable energy sources.

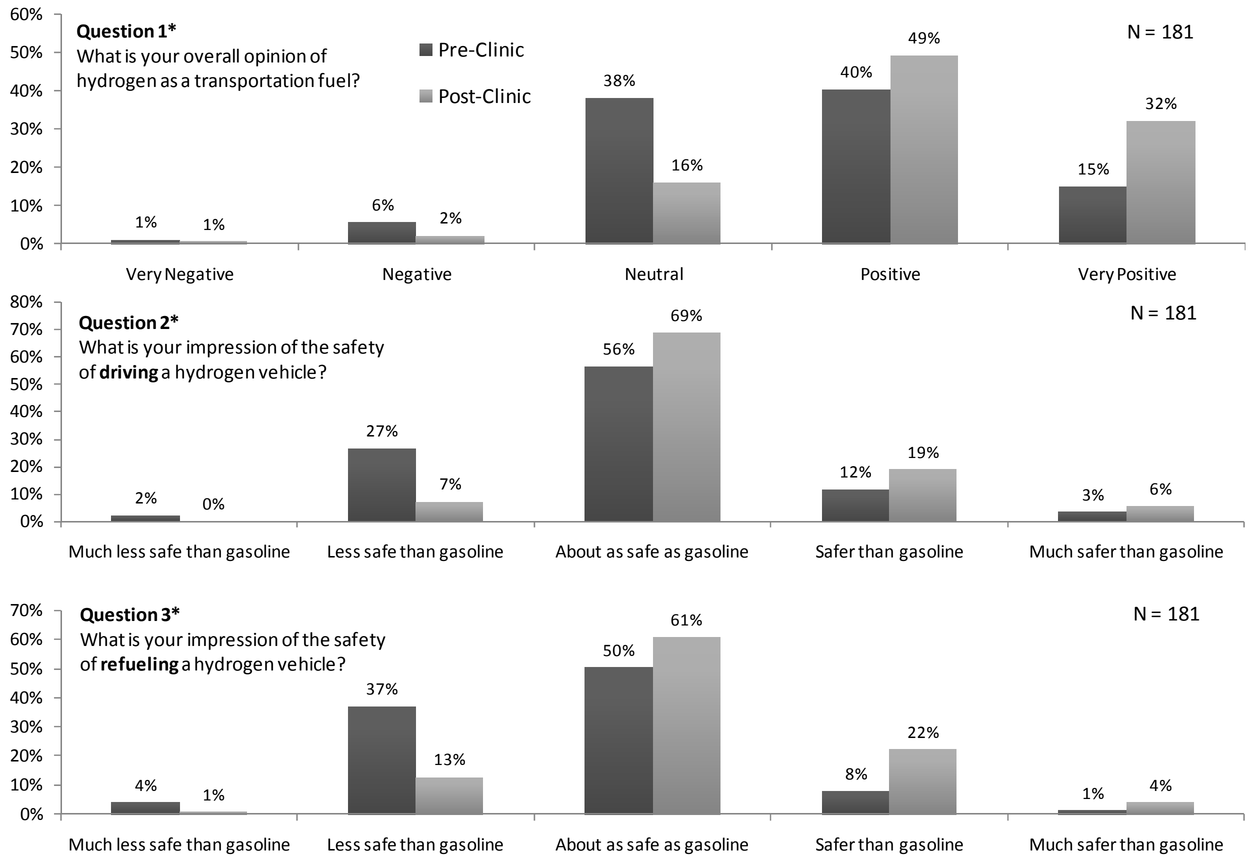
The techno-economic barriers to FCV deployment are still considerable, but recent progress has been made in several key areas. Remaining issues that require improvement include fuel cell system cost reduction and durability, hydrogen storage, as well as the costs and technical complexities associated with developing a hydrogen-refueling infrastructure. In addition, and arguably less well recognized, are potential challenges for consumer exposure and acceptance.

Researchers at the University of California, Berkeley conducted a ride-and-drive clinic in Sacramento and Richmond, California with the Mercedes-Benz “A-Class” FCV known as an “F-Cell.” The participants of the drive clinic included employees from the State of California and the University of California who volunteered to participate. The nature of the sample population is not random and demographically more reflective of early adopters. The ride-and-drive clinic deployed a pre-clinic and post-clinic survey to evaluate the change in the response of the participants to driving and refueling a hydrogen vehicle. In addition, the study also conducted a single focus group with six University employees that had previous experience driving the F-Cell during a separate longitudinal study. The results of the study offer insights into consumer response and reaction to using hydrogen as a transportation fuel.

Drive and Refueling Clinic Results

The clinic evaluated participant reactions to driving and riding in a FCV, as well as witnessing a vehicle-refueling event. The respondents entered the clinic with a strong interest in alternative fuels, but less than 15 percent had any prior experience with hydrogen. Roughly 95 percent of respondents finished the clinic with either a positive or very positive impression of the F-Cell. More than 80 percent left with a positive overall impression of hydrogen. Perceptions regarding the safety of driving and refueling hydrogen were found to change as a result of clinic exposure. Safety was assessed in comparison to the benchmark of gasoline safety. Shifts in the distribution of pre- and post-safety assessment illustrate an overall positive shift. The greatest changes are found with the respondents who felt that hydrogen is less safe than gasoline. The shifts in the distribution of response were all found to be statistically significant.

Figure ES-1: Before-and-after vehicle and refueling safety response



***** Paired Sign Test significant at ($p < 0.001$)

In addition to these general impressions, participants were also asked to assess their opinions of several hydrogen vehicle performance metrics. As with the questions in Figure ES-1, researchers designed the performance questions to assess response metrics calibrated to participants' gasoline vehicle perceptions. In the pre-clinic survey, respondents were asked to provide their hydrogen vehicle performance expectations in comparison to a typical gasoline vehicle with the following metrics: acceleration, braking, handling, and ride comfort. Respondents were asked whether they anticipated that the hydrogen vehicle would perform worse, better, or about the same as a typical gasoline vehicle. In the post-clinic survey, participants were asked to assess whether the vehicle had met, exceeded, or failed to meet their expectations. Table ES-1 illustrates the cross-tabulation of responses to two key metrics: acceleration and braking.

Table ES-1: Pre-Clinic and Post-Clinic Survey Responses to Vehicle Performance

Acceleration						
Pre \ Post	Greatly Disappointed	Slightly Disappointed	Met Expectations	Slightly Exceeded	Greatly Exceeded	Total
Much Worse	0%	1%	2%	1%	1%	4%
Slightly Worse	0%	5%	9%	12%	7%	34%
About the Same	1%	11%	16%	5%	9%	42%
Slightly Better	0%	3%	5%	4%	1%	13%
Much Better	0%	2%	3%	1%	1%	7%
Total	1%	23%	35%	23%	19%	100%

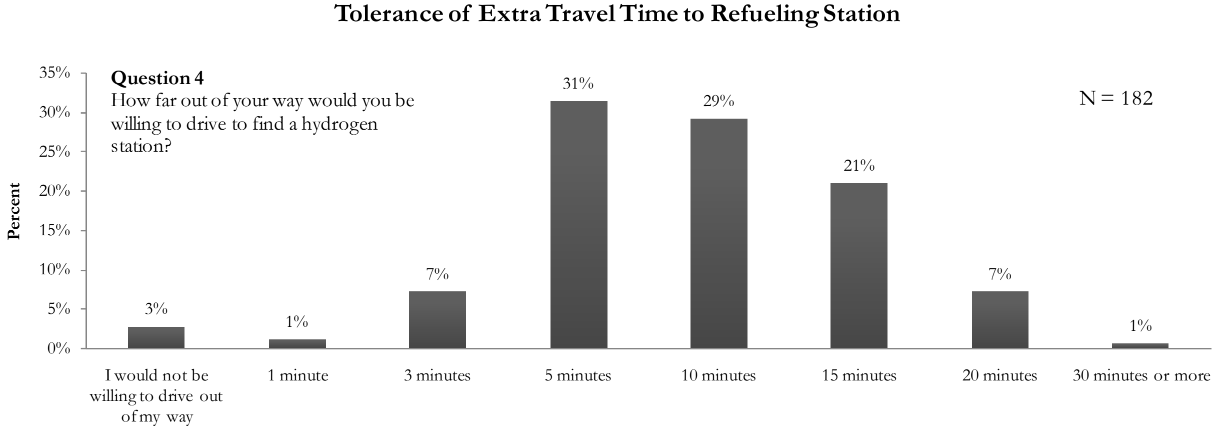
Braking						
Pre \ Post	Greatly Disappointed	Slightly Disappointed	Met Expectations	Slightly Exceeded	Greatly Exceeded	Total
Much Worse	0%	0%	0%	0%	0%	0%
Slightly Worse	0%	0%	1%	1%	0%	2%
About the Same	1%	3%	55%	21%	8%	88%
Slightly Better	0%	1%	6%	0%	1%	7%
Much Better	0%	1%	1%	0%	1%	3%
Total	1%	4%	64%	22%	9%	100%

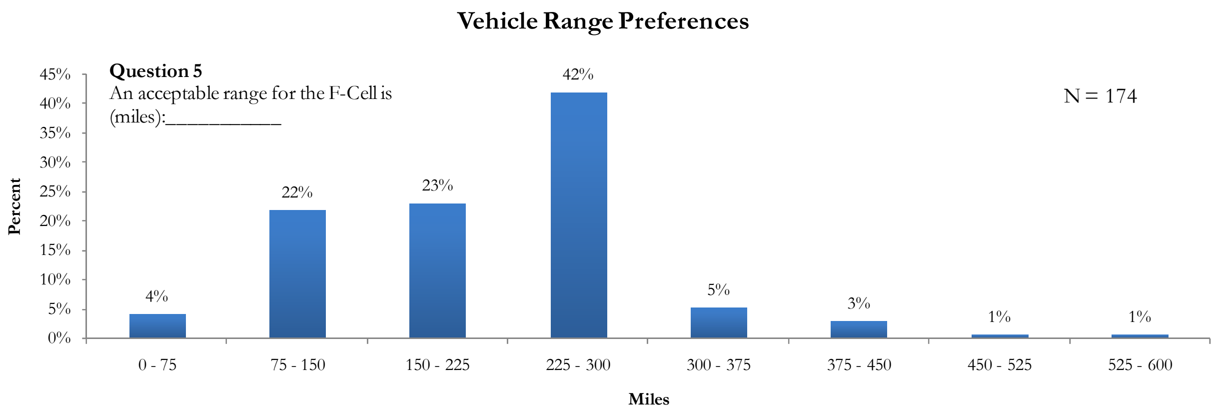
[i]Pre-Survey Question: How do you expect the hydrogen vehicle to compare to a typical gasoline vehicle within the following performance categories?
[ii]Post-Survey Question: How did the following attributes meet, fail to meet, or exceed your expectations?

As a performance metric, "acceleration" illustrated the widest distribution of prior expectations, with nearly 40 percent of respondents expecting the vehicle to perform worse than a gasoline vehicle, and 20 percent expecting it to perform better. The results of the post-clinic survey revealed that 25 percent of respondents considered acceleration to perform below their expectations, while the expectations of roughly 40 percent were exceeded. Braking exhibited far less variance in expectations, as most respondents anticipated braking to perform about the same as gasoline vehicles. A little more than 30 percent found braking to exceed expectations, far more than the five percent that indicated disappointment in braking performance.

Participants also were asked about range and refueling preferences, which are critical to vehicle and station network design as well as overall alternative fuel vehicle acceptance. The response distributions to both questions are illustrated in Figure ES-2.

Figure ES-2: Distribution of Range and Refueling Preferences

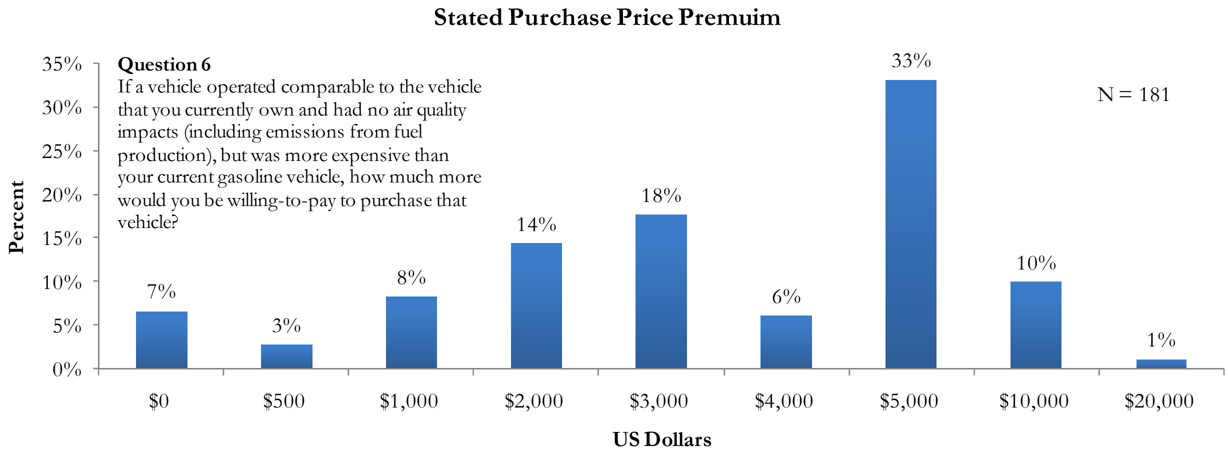




The majority of respondents would be willing to travel between five and ten minutes out of the way to find a hydrogen station. A sizable minority also expressed a willingness to drive at least 15 minutes to find a station. Also shown is the distribution of range preferences, in which roughly half of respondents would consider a vehicle with a range between 225 to 300 miles (360 to 480 kilometers) or greater to be acceptable for a vehicle like the F-Cell.

Respondents were also asked about the purchase price premium that they would pay for an emission-free vehicle similar to their own. Similarly, they were asked about their willingness-to-pay annual operating cost premiums to drive such vehicles. The questions were asked sequentially, leading with the purchase price premium. Figure ES-3 illustrates the response distribution of both questions.

Figure ES-3: Response Distribution to Willingness-to-Pay Questions



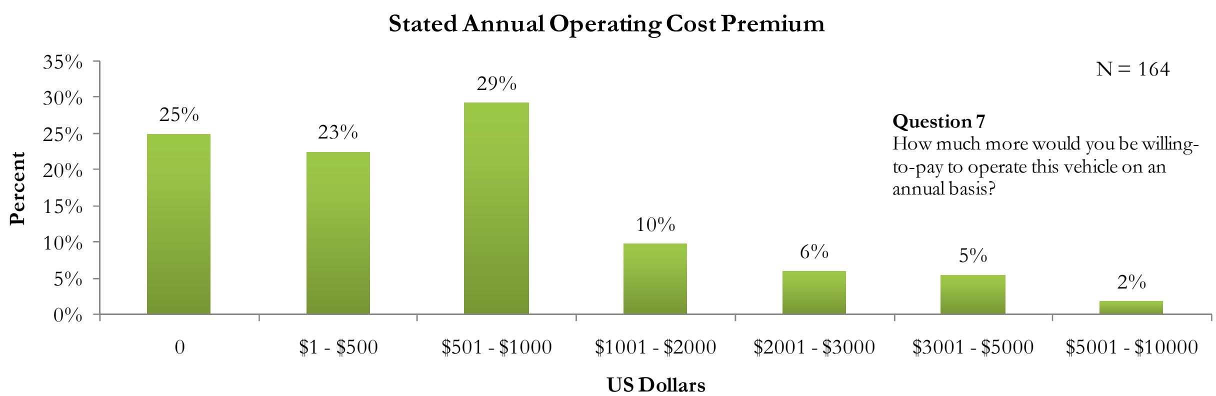


Figure ES-3 shows that 50 percent of respondents indicated that they would pay no more than a $3,000 US premium over a similar gasoline vehicle. The remaining 50 percent would be willing to pay at least $4,000, but few suggested premiums over $10,000. The distribution of the annual operating cost premium suggests that a higher proportion of consumers have an aversion to paying more for operating costs. A quarter of respondents stated a willingness-to-pay of zero, and 75 percent indicated that they would pay no more than $1,000 US per year to operate a cleaner vehicle over what they would pay to operate a conventional vehicle.

Conclusions

Key conclusions from the ride-and-drive clinics include the following findings:

- Perceptions of hydrogen safety, clinic respondent impressions shifted towards feeling safer after exposure to a refueling event.

- Perceptions of vehicle performance, impressions were generally positive, and shifted more positive after exposure—for example, in the pre-survey nearly 40 percent of respondents felt that vehicle acceleration would be worse than that of a gasoline vehicle, but after exposure slightly more than 50 percent of those participants found that the F-Cell equaled or exceeded their expectations.
- Most respondents were willing to travel five minutes out of their way to find fuel, and a sizeable proportion appeared willing to drive up to fifteen minutes.
- Driving range considerations indicate that vehicles designed to travel around 250 to 300 miles (400 to 480 kilometers) on one tank would meet the needs of most respondents.
- Willingness-to-pay parameters illustrate that consumers generally consider premiums of $5,000 US to be the upper limit of what they would personally pay for a clean fuel vehicle similar to that which they currently drive, and premiums in operating costs exceeding $1,000 US would be unattractive to most.

In addition, the results of the clinic suggest that for dedicated fuels such as hydrogen to succeed, some pre-exposure could assist in educating the public and would seem to be likely to improve their impressions. Hydrogen is among the most distinct fuels competing for future viability. Hence, adaptation strategies that account for exposing the public to vehicles in a neutral setting may help to expand the potential market. Of course, other techno-economic challenges that address driving range, limited infrastructure, and vehicle cost still must be addressed. The information provided in this study and in the other studies cited in this report offers an early proxy of vehicle and infrastructure specifications that would be required for the proliferation of FCVs and other dedicated alternative fuel vehicles in the future.

Introduction

Concerns over air pollution, energy dependence, and now climate change have motivated the exploration of cleaner alternative transportation fuels for several decades. Hydrogen fuel cell vehicles (FCVs) have recently emerged as a zero tailpipe-emission alternative to the battery electric vehicle (EV). Like battery vehicles, FCVs produce no tailpipe emissions (other than water vapor) and also have the potential to be near zero-emission on a full fuel-cycle basis when coupled with renewable energy sources. As the lightest element in existence, hydrogen has several intrinsic characteristics that make it an attractive transportation energy carrier. It has a high energy density by weight, and it can be produced in large quantities from a diverse array of primary energy sources. Furthermore, in contrast to battery recharging, hydrogen can be refueled at speeds comparable to gasoline. These advantages have generated considerable interest in FCVs among governments and the automotive industry. This has led to the controlled deployment and testing of several hundred fuel cell cars and buses around the world.

The techno-economic barriers to FCV deployment are still considerable, but recent progress has been made in several key areas. Remaining issues that require improvement include fuel cell system cost reduction and durability, hydrogen storage, as well as the costs and technical complexities associated with developing a hydrogen-refueling infrastructure. In addition, and arguably less well recognized, are potential challenges for consumer exposure and acceptance.

Hydrogen FCVs have some important differences from gasoline internal combustion engine (ICE) vehicles. Their recent introduction to U.S. roads presents key questions about consumer reaction and response to their use and limited public knowledge of the dynamics and nature of response to operations and refueling. Overcoming potential consumer acceptance issues will require an understanding of values and perceptions, as well as the pace at which vehicle users develop their opinions.

This study presents the results of a “ride-and-drive” clinic (n=182) held in August and September 2007 with a Daimler AG/Mercedes-Benz A-Class “F-Cell” hydrogen FCV that is currently in operation in Northern California. The clinic evaluated the reactions of participants to driving and riding in a passenger FCV, as well as witnessing a vehicle-refueling event. In this study, FCV response is measured on a short-term basis through a before-and-after survey taken on the same day. The survey assessed consumer perceptions of safety, vehicle performance in contrast to gasoline vehicles, and willingness-to-pay (WTP) for clean fuel vehicles.

Although extensive research has been conducted on the behavioral response of commercial taxi and bus drivers to hydrogen technology, this study and its predecessor are among the few that contribute to behavioral research on hydrogen passenger cars (Shaheen *et al.*, 2008). Notable work has recently emerged on consumer response to hydrogen buses in Europe (O’Garra *et al.*, 2007; Saxe *et al.*, 2007). While customer experience with buses and passenger cars is clearly different, comparisons of this research indicate some similar trends in reaction.

This study's results are intended to advise policymakers and the auto industry on the relative challenges of introducing a new vehicle propulsion system to consumers who are accustomed to ICEs. This paper consists of four main sections. First, the authors present a background on alternative fuel acceptance research, with an emphasis on electric drive trains and hydrogen acceptance. Next, the study methodology is reviewed. Third, results from the pre- and post-clinic survey are presented. Finally, the authors offer conclusions on what the observed shifts in perception of hydrogen found within the ride-and-drive clinic mean for long-term deployment.

Literature Review

While research on hydrogen FCVs and fuel acceptance has largely coincided with recent vehicle deployment, related work on consumer response to electric drive trains has been active for nearly twenty years. The two are related in that they both face driving range and infrastructure challenges, and both vehicle types rely on an electric motor powered by a unique and dedicated fuel source. Much of the EV consumer response research occurred during the 1990s. Many of these studies focused on understanding how consumers could address fundamental EV limitations. This included the exploration of the "hybrid household" hypothesis, which considers households that incorporate EVs as part of their fleets alongside gasoline vehicles (Kurani *et al.,* 1994; Kurani *et al.*, 1996). Other research put EVs in households for a few weeks to study household travel behavior (Golob and Gould, 1998). Through the analysis of travel diaries, researchers corroborated components of the hybrid household hypothesis in effect. Participants in the vehicle trial were able to use the EV vehicle for much of their daily travel, but they switched to gasoline vehicles on days with longer trips. However, in spite of the demonstrated utility of the EV, respondents still desired driving ranges to be similar to that of a gasoline vehicle (Golob and Gould, 1998). While travel diaries employed in this study suggested that daily tripmaking rarely exceeded about 80 kilometers a day, exposure to the EV did not change participant expectations that the vehicle should have a range of 160 kilometers or more (Golob and Gould, 1998). In a companion study produced shortly after, researchers employed data from both a longitudinal survey in California and the same vehicle trial. It focused on the response to EV technology as correlated with opinions on the ability of EVs to bring environmental benefits (Gould and Golob, 1998). Among other things, the authors found that exposure to EVs did not decrease the opinion of participants with respect to the environmental benefits of EVs, but at the same time, those perceived environmental benefits became a lower priority in the stated preference for buying EVs (Gould and Golob, 1998). The range restrictions of EVs have been found to turn off some buyers. In related work, one study in Europe found that interest in owning EVs actually decreases after a few months of use due to concerns over range and daily travel (Gärling, 2001).

Consumer interactions with hydrogen buses have been the source of most hydrogen response studies. One of the earliest hydrogen acceptance studies occurred nearly a decade ago in Germany (Altmann and Graesal, 1998). This study evaluated the perception of hydrogen by bus passengers, as well as the general response of students to the idea of using hydrogen for transportation. It assessed Likert-scale responses of secondary school students to eight statements gauging their acceptance of hydrogen use in transportation. It then evaluated the sentiments of adults and students traveling on the first hydrogen bus to be deployed worldwide in Munich. Overall, the study did not find significant barriers to hydrogen acceptance. Researchers found that direct contact with the technology was correlated with more positive assessments. Concern over negative associations with the Hindenburg dirigible accident in 1937 and the hydrogen bomb were not present. Interestingly, researchers also noted that a high personal priority on environmental issues or an elevated general knowledge of hydrogen did not have a clear influence on overall acceptance.

Schulte *et al.* provide a good review of acceptance literature with an emphasis on hydrogen, as well as a conceptual framework for acceptance studies (Schulte *et al.,* 2004). This work also interpreted the results of an earlier German study that evaluated the sentiments of BMW employees in which roughly 600 respondents provided feedback on their opinions of hydrogen technology (Dinse, 2000). Researchers in this study found that high technical knowledge corresponded with more positive opinions of the technology, whereas those less knowledgeable perceived risks to be higher. In addition, BMW participants who considered vehicles to be "all-around cars" were more likely to buy a hydrogen vehicle, whereas those who considered hydrogen vehicles to be "city cars" were less enthusiastic of hydrogen.

In 2003, hydrogen bus deployments began in Luxembourg and quickly expanded to Berlin, Perth, and London and offered an opportunity to explore consumer response on a broader scale. The final report to the European Commission evaluating passenger response to the buses found that safety was not a concern, prior (positive) knowledge of hydrogen increased acceptance, and in contrast to the Munich study, suggested that direct exposure was not necessarily associated with acceptance or willingness-to-pay (WTP) (O'Garra, 2005). The definition of acceptance in this study was "unconditional support for large-scale introduction of hydrogen buses in each city," which was found to have increased in all cities receiving a bus during the trial period. In this context, the study determined that simply riding in a hydrogen bus did not result in acceptance.

At about the same time, a study of London taxi drivers operating prototype FCVs found WTP for the technology was correlated with higher education levels, hydrogen knowledge, and air pollution concerns. Taxi drivers also stated that they did not have safety concerns with respect to driving hydrogen-powered cars (Mourato *et al.*, 2004). Another study conducted in London explored the determinants of awareness and acceptability of hydrogen vehicles through a 414 person socio-economic survey in London. The authors found that hydrogen awareness was a function of gender, age, and environmental knowledge, while acceptability was primarily determined by previous knowledge of hydrogen technologies (O'Garra *et al.,* 2005).

In addition, several studies based on the deployment of fuel cell buses in Europe, Australia, and Canada have greatly expanded knowledge of consumer response to hydrogen vehicles (O'Garra *et al.*, 2007; O'Garra, 2005; Saxe *et al.*, 2007; Hickson *et al.*, 2007). Through a variety of methodologies, all of these studies evaluate the respondent reaction to riding or witnessing a hydrogen bus. O'Garra *et al.* (2007) report on a contingent valuation survey of bus riders in the cities of Berlin, London, Luxembourg, and Perth. The Berlin and Luxembourg surveys asked riders if they would be willing to pay an increased fare to support a large-scale hydrogen bus deployment within their city. The mean WTP of surveyed riders was €0.32 per fare. The London and Perth surveys took a different approach, where both riders and non-riders were randomly surveyed to discern their WTP for hydrogen bus deployment in the form of additional taxes. The surveyors found that citizens of London and Perth had a positive WTP for hydrogen bus deployments of €24 and €15 in annual taxes per year, respectively. Across all cities, roughly 85 percent of respondents were willing to pay for hydrogen buses.

Hydrogen vehicle marketing experts have observed that exposure through media stories can impact public acceptance, especially general opinions of safety and quality of the hydrogen driving experience (Zachariah-Wolff and Hemmes, 2006). To better understand potential consumer response to new vehicle types, marketing researchers support test drives to raise consumer familiarity with new vehicle types, especially driving experience and safety attributes (Gärling and Thøgersen, 2001). However, some vehicle features, such as range restrictions and fuel-efficient driving potential, may take more time for consumers to understand and accommodate.

Research addressing consumer response to hydrogen has expanded significantly in the past few years. Almost all of these studies, however, have focused on agents within the public transportation system, including bus passengers, bus drivers, and taxi drivers. They reveal that a sizable portion of public transit riders would be willing to pay higher fares to run buses on hydrogen fuel. Across these studies, it appears that public transit riders and drivers generally feel safe with the technology, and passengers overwhelmingly consider hydrogen buses to be as good, or better, than regular buses across a variety of performance metrics. This report builds on this growing research by exploring similar response metrics among state and university employees in California to FCV passenger vehicles.

Study Methodology

Ride-and-Drive Clinic

The purpose of the ride-and-drive clinic was to gain feedback from a range of individuals who were provided an opportunity to drive the F-Cell vehicle under real-world driving conditions and view a fueling demonstration. After completing a pre-clinic questionnaire, participants drove the vehicle in groups of two on a three-mile route in West Sacramento or Richmond, California with a researcher to direct them. The maximum speed along the routes was 50 to 55 miles per hour (80 to 88 kilometers per hour). The route permitted respondents to personally test the acceleration, braking, and handling capabilities of the vehicle.

Participants had the opportunity to drive the vehicle and to ride as a front-seat passenger to maximize their exposure. In addition to driving the F-Cell, subjects were also directed to a hydrogen refueling station where they witnessed an F-Cell refueling demonstration. The participants could not refuel the vehicle themselves due to Human Subjects regulations. Thus, as an alternative, they partook in what is called an "assisted fill," in which an operator trained in the hydrogen refueling process would refuel the vehicle as the participants watched. Some fuel was placed in the vehicle, but the vehicle was not always low on fuel, so in some cases the refueling was approximately only half a tank. Once participants had driven the vehicle and witnessed the refueling, they completed a post-clinic questionnaire.

Employees from the California Department of Transportation (Caltrans), the California Air Resources Board (CARB), and the California Energy Commission (CEC) participated in the ride-and-drive clinic at the California Fuel Cell Partnership from August 8 to 17, 2007. University of California, Berkeley (UC Berkeley) employees attended the clinic at the Richmond Field Station and witnessed the fueling demonstration at the AC Transit hydrogen fueling station in Richmond between the dates of September 22 to 27, 2007. Research subjects were recruited from within UC Berkeley, Caltrans, CARB, and CEC via an email soliciting participation. Total participant time ranged between 1.5 to two hours. An incentive raffle for a small digital music player was used to encourage participation. In addition, each respondent received a small gift, such as an F-Cell writing pad, upon session completion. A total of 107 individuals participated in the Sacramento drive clinic and 75 in Richmond. Each drive clinic had a goal of 100 participants, but recruitment proved to be somewhat more challenging for the UC Berkeley/Richmond location. Potential participants who had previously driven an FCV for other studies or had extensive knowledge of the F-Cell vehicle were not allowed to participate in the ride-and-drive study.

“Before-and-After” Survey Design

Researchers administered questionnaires to evaluate initial impressions of participants to hydrogen as well as their response to experience with the F-Cell and the refueling event. The initial questionnaire assessed experience with alternative fuels, impressions of hydrogen as a transportation fuel, expectations of vehicle performance and hydrogen safety, challenges of hydrogen vehicles, and attitudes toward the environment and experimentation.

The post-clinic questionnaire documented F-Cell impressions including acceleration, braking, handling, fuel economy, and ride comfort; hydrogen vehicle and fuel safety; range acceptability; fueling difficulty; WTP; and questions about participant demographics. When asked to provide their impressions of hydrogen safety, respondents were asked for their assessment relative to their gasoline safety impressions. For example, one question read: “What is your impression of the safety of driving a hydrogen vehicle?” Responses included: “Much less safe than gasoline,” “Less safe than gasoline,” “About as safe as gasoline,” “Safer than gasoline,” and “Much safer than gasoline.” Fuel response benchmarking to gasoline is a recommended approach for two reasons. First, it grounds the answer relative to vast prior consumer gasoline experience. Second, it permits a more accurate assessment of impressions to the vehicles and fuel with which hydrogen (and perhaps other technologies) would likely compete. This approach also was employed for assessing consumer response to vehicle performance.

Ride-and-Drive Clinic Study Limitations

A primary limitation of this study consists of the participant self-selection bias from a restricted study population (i.e., state agency and university employees). In addition, the individuals participating in the clinic were volunteers, and hence, the sample is not random. These two key components are important to note with respect to the sample population. The reason for these limitations is primarily driven by the extensive liability support required for placing non-research staff within vehicles that are considered experimental. For this reason, the demographic distribution of the respondents unequivocally departs from the general population. However, it is likely that the respondent pool is far more congruent with the population of early adopters, which will drive the marketing and proliferation of any FCVs in the early years of expansion. But even within this population, only 55 percent of respondents entered the clinic with a positive hydrogen fuel impression, with much of the remaining sample classifying their opinion as “Neutral.” In addition, only 15 percent of the respondents had any prior direct experience with hydrogen. Therefore, the dataset generated for this study reflects an exploratory analysis, but these study limitations do not prevent the use of the dataset to obtain insights into consumer response to hydrogen vehicles and fueling, especially among likely early adopters.

Focus Group

Focus groups were planned as part of the study with the intention of supporting the conclusions drawn from the ride-and-drive clinic. Two focus groups were planned with state and university employees who had experience driving the F-Cell during a previously conducted longitudinal study. The study was conducted as a longitudinal survey of 65 drivers of 24 F-Cell vehicles in California and Michigan (*1*).

Drivers were drawn from for-profit companies in California and Michigan—where 10 vehicles were placed. An additional 14 vehicles were deployed with governmental agencies, non-profits, and universities in those states (two of the 24 vehicles were located in Michigan). Participant criteria required that qualifying drivers: 1) drove the F-Cell once or more a month, 2) drove it at least 65 kilometers per month, and 3) were willing to complete the three-phase survey. The longitudinal survey was administered online at three discrete times over the seven months. There was some attrition over the study: 54 participants completed two of the three survey phases, and 49 completed all three phases.

Participants of this study, employed by the University and the California Department of Transportation (Caltrans), were offered an opportunity to discuss their experiences with the F-Cell in more depth. Two focus groups were planned, one with university participants and one with state participants. However, only one focus group was actually conducted with participants employed with the university. In spite of several attempts to coordinate schedules with drivers of the F-Cell at Caltrans, efforts to conduct the second focus group were eventually terminated. Highlights of the focus group are discussed in Appendix A.

Research Results

In this section, the authors present the research results. There are five key sections: 1) demographics, 2) F-Cell and refueling response, 3) response to vehicle performance metrics, 4) response to range and refueling distance, and 5) WTP responses.

Demographics: Sacramento and Richmond Study Populations

Table 1 presents the demographics of the drive clinic participants. They were mostly male (63 percent) and married (55.2 percent). The Sacramento clinic was more heavily weighted with males than the Richmond clinic. The difference between the two clinics was not large enough to be statistically significant, according to the Fisher Exact Test. Similarly, while there were perceptible differences between age and marital status distributions across the two samples, the relative differences were not statistically significant. However, survey respondents in Richmond had higher education levels (p=0.0038), but more respondents had relatively low incomes (p=0.025). This reflects the participation of graduate students employed by the university. Clinic demographics are summarized in Table 1. Since differences between the populations were not substantial, researchers have combined responses in the analysis that follows.

In comparison with the general population, the combined sample is not representative of the U.S. or California populations (p<0.001 for all). A summary of the demographic comparisons of the sample with both the U.S. and California appears in Table 1. The study sample has a higher percentage of males, is younger, more often single, more educated, and has a higher household income than either the U.S. or California populations.

Table 1: Demographic Attributes of Survey Respondents

Demographic Attribute	Richmond	Sacramento	Total	*p*-value	US 18+	CA 18+	*p* Tot-US	*p* Tot-CA
Gender	N=75	N=106	N=181					
Male	57.3%	67.0%	63.0%	0.21 *	48.6%	49.6%	<0.001 *	<0.001 *
Female	42.7%	33.0%	37.0%		51.4%	50.4%		
Age Category	N=75	N=106	N=181					
22-34	44.0%	25.5%	33.1%	0.0049 **	24.8%	27.3%	<0.001 **	<0.001 **
35-49	22.7%	40.6%	33.1%		31.6%	32.7%		
50-59	21.3%	29.2%	26.0%		18.6%	17.7%		
60+	12.0%	4.7%	7.7%		25.0%	22.3%		
Marital Status	N=74	N=107	N=181					
Single	39.2%	29.9%	33.7%	0.094 **	26.9%	30.6%	<0.001 **	<0.001 **
Married	55.4%	55.1%	55.2%		50.1%	46.6%		
No Longer Married	5.4%	15.0%	11.0%		23.0%	22.7%		
Education N=	75	N=107	N=182					
Associate Degree or Less	9.3%	10.3%	9.9%	0.0038 **	75.0%	73.5%	<0.001 **	<0.001 **
Bachelor's Degree	41.3%	64.5%	54.9%		16.2%	17.4%		
Graduate Professional Deg.	49.4%	25.2%	35.2%		8.8%	9.1%		
Income (HH, $ US)	N=72	N=102	N=174					
Less than $50,000	29.2%	10.8%	18.4%	0.025 **	49.2%	42.4%	<0.001 **	<0.001 **
$50,000 to below 75,000	13.9%	20.6%	17.8%		18.9%	18.0%		
$75,000 to below 100,000	18.1%	25.5%	22.4%		12.2%	12.7%		
$100,000 to below 150,000	23.6%	31.4%	28.2%		11.7%	14.6%		
More than $150,000	15.3%	11.8%	13.2%		8.0%	12.2%		

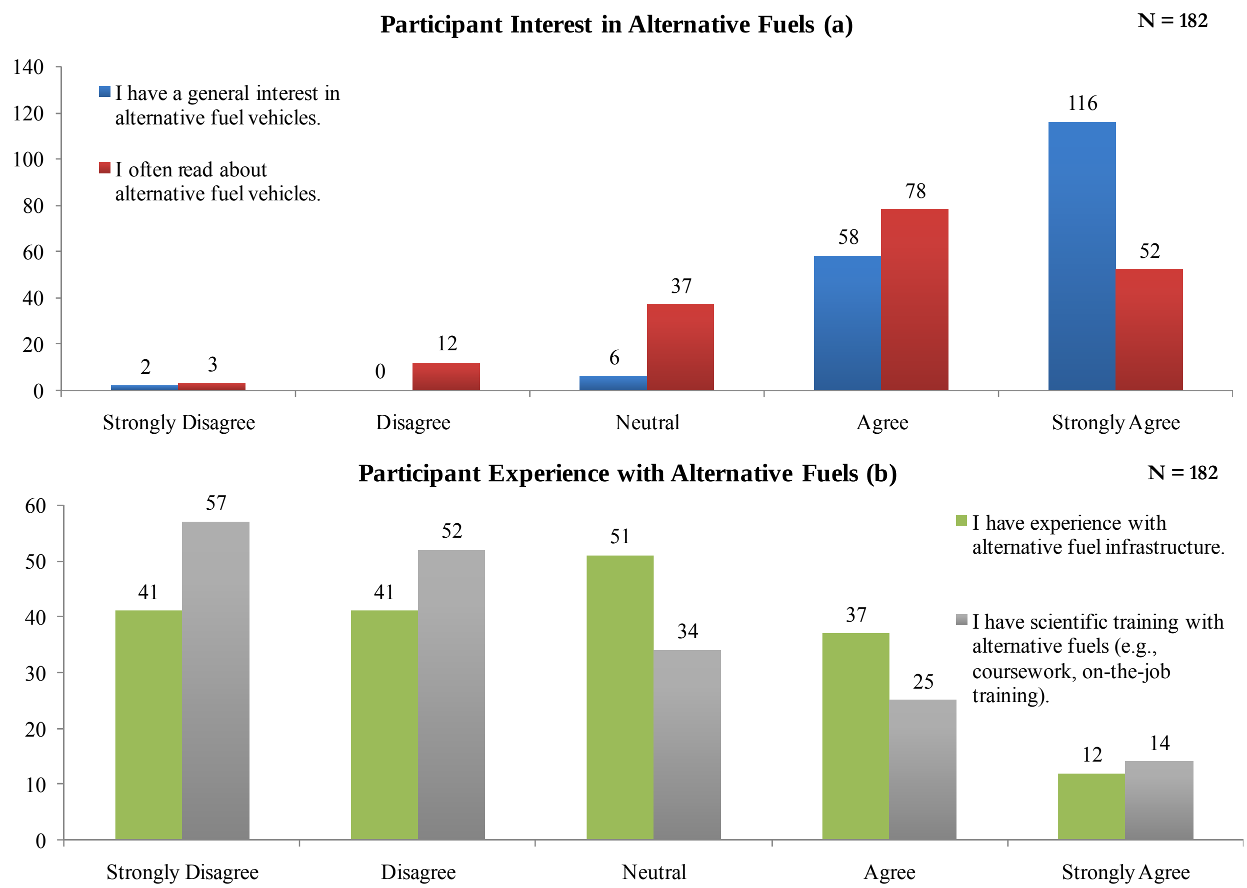
* Fisher's Exact Test Source: American Community Survey, 2007

** Chi-squared Test

Prior Experience with Alternative Fuels of Participants

Questions within the pre-clinic assessed the degree of prior experience that participants had with alternative fuels. Four questions gauged participant interest as well as training in subjects pertaining to alternative fuel vehicles or infrastructure. Not surprisingly, the results found that a significant majority of participants exhibited a strong interest in alternative fuels. However, additional questions illustrate that experience with alternative fuel vehicles and infrastructure was far more mixed. Figure 1 illustrates the series of questions that profiles the self-assessed prior exposure of participants to alternative fuels.

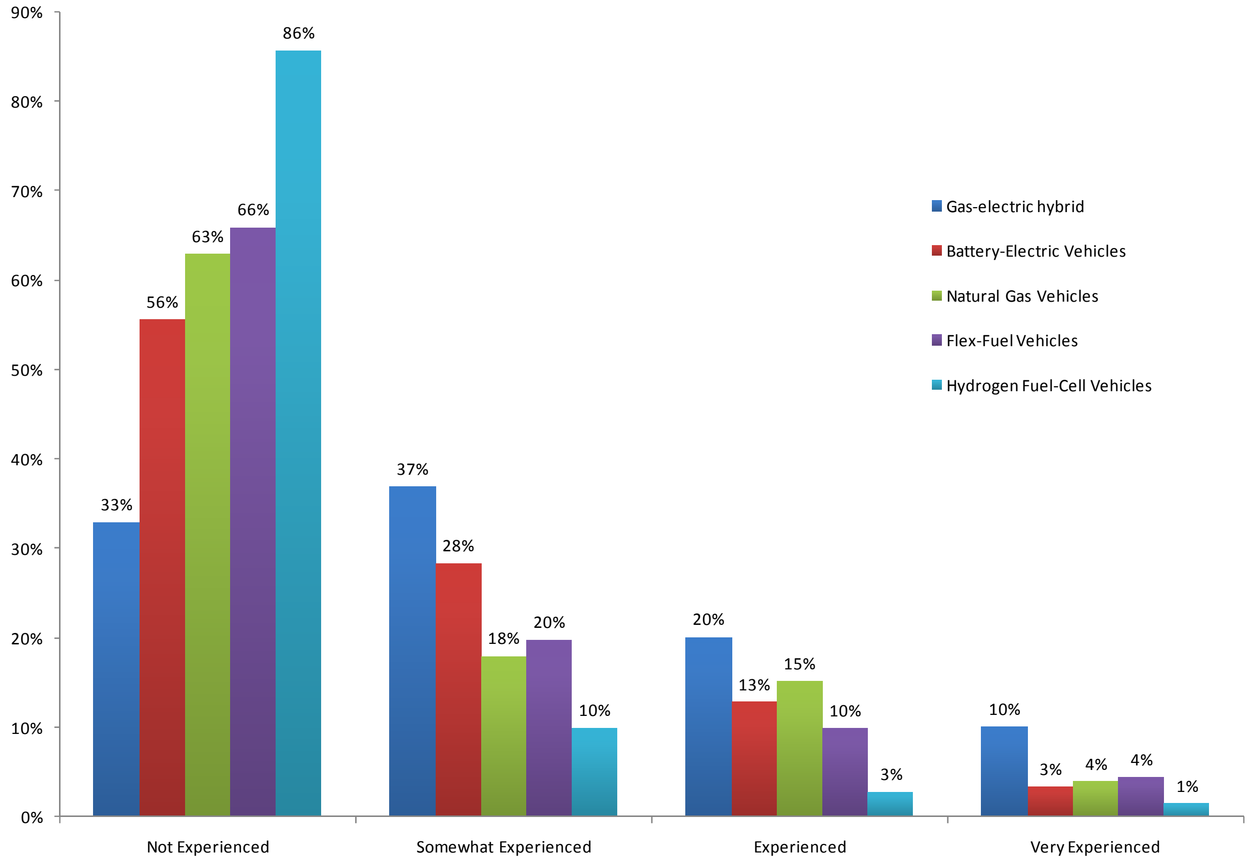
Figure 1: Profile of Participant Interest and Experience with Alternative Fuels



In Figure 1 (a), the distribution of responses show that the questions profiling interest in alternative fuels are markedly skewed to the right. At the same time, interest in alternative fuels did not translate into experience. The distribution of responses in Figure 1(b) illustrate that a majority of respondents did not consider themselves to have significant experience with alternative fuel infrastructure or training in alternative fuels. Those with self-assessed experience with alternative fuels constituted between 20 and 25 percent of the participant population. Though a minority, this share of the sample is likely larger than that of the general population. Such a result would be expected from a sample population recruited with state agencies and a large research university. However, the profile indicates that interest in alternative fuels governed who showed up for the ride-and-drive clinic. Experience was less of a factor, and it was clear that the vast majority of respondents were not among those with extensive knowledge of alternative fuels.

But while experience with alternative fuels was present, this did not translate into experience with hydrogen. Among the leading alternative fuels, hydrogen was the least familiar of all fuels as a smaller proportion of respondents indicated any previous exposure to hydrogen vehicles. During the pre-clinic survey, participants were asked to rate their general experience level with the prevailing advanced or alternative fuel vehicle technologies on the road today. This experience was solicited in the context of a specific vehicle, in that those respondents who had experience with a fuel list the vehicle to which they had been exposed. Figure 2 presents the distribution of self-assessed experience with specific technologies and fuels with which participants potentially could have familiarity.

Figure 2: Experience Profile with Specific Vehicle Technologies



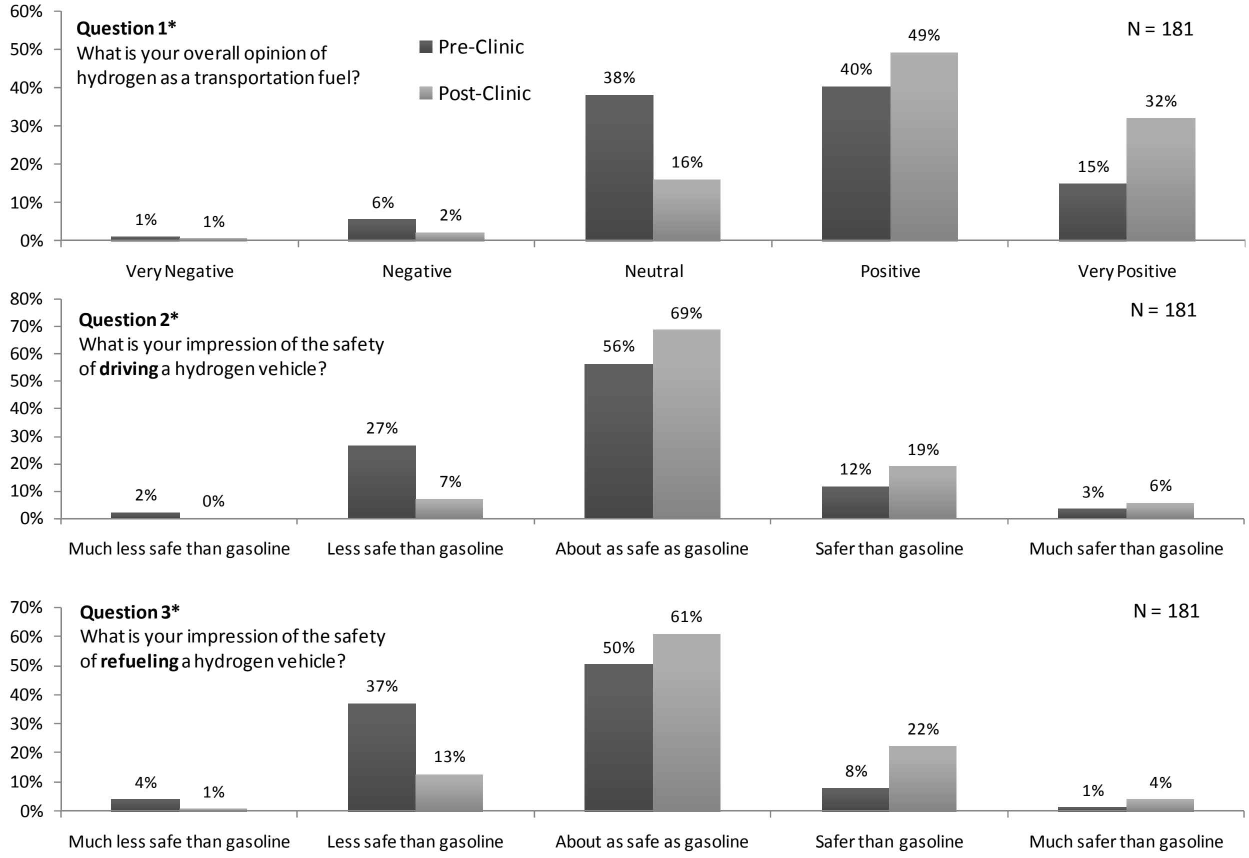
The graph illustrates the relative experience of participants of five leading vehicle technologies. As indicated in the previous figure, the results show that most of the 182 participants were not experienced with many of the leading alternative fuel technologies. The respondent population indicated a fair spread in experience with gasoline electric hybrid vehicles, an expected result given the market proliferation of hybrids. The experience profile of respondents with battery-electric vehicles, natural gas vehicles, and flex-fuel vehicles followed a similar profile. Most notably, roughly 86 percent of respondents considered themselves to have no experience with hydrogen. Among the remaining 14 percent, only four percent of the respondents considered themselves to have considerable experience with hydrogen fuel. Hence, the results from Figure 1 and Figure 2 show that the study population was for the most part inexperienced with alternative fuels. But the proportion that did express experience was likely larger than that which would be found in the general population. Furthermore, Figure 2 indicates that of all technologies, hydrogen was the fuel with which respondents were the least familiar. Thus overall, the sample population was a well-educated, well-informed collection of people interested in alternative fuels, but their prior exposure to hydrogen fuel and vehicle technology was limited.

F-Cell and Hydrogen Refueling Response

The response of drive clinic participants to the F-Cell was evaluated from several perspectives. Pre-clinic survey questions were designed to assess preconceptions of the hydrogen fuel, hydrogen vehicles, and refueling. Post-clinic survey questions discerned how impressions shifted as a result of direct exposure to the vehicle and refueling process. The post-clinic survey also elicited respondent opinions of vehicle safety and operation. By the end of the clinic, most participants left with a good impression of the F-Cell. When asked of their opinion given the options of "Very Negative," "Negative," "Neutral," "Positive," and "Very Positive," roughly 95 percent of respondents finished the clinic with either a positive or very positive impression of the F-Cell. When asked of their overall feelings of vehicle safety, 89 percent reported that they "felt safe" with the F-Cell. Finally, 85 percent who witnessed the F-cell refueling considered it to be safe, and 82 percent did not consider it to be difficult to do.

To gain insights into short-term exposure impacts, the survey sought to measure whether technology exposure during the clinic had any effect on respondent safety and hydrogen fuel impressions. With respect to safety, respondents were asked to give their opinion of hydrogen safety relative to gasoline safety. Results indicate that short-term exposure to hydrogen technology can shift hydrogen and fuel safety opinions. Figure 3 illustrates the before-and-after response distributions to three paired questions. Sample size is indicated within each figure for the appropriate question. Some sample sizes vary slightly due to missing or invalid responses from a handful of respondents.

Figure 3: Before-and-After Vehicle and Refueling Safety Response



* Paired Sign Test significant at (p < 0.001)

These paired distributions illustrate several important points. Question 1 assesses respondents' before-and-after opinions of hydrogen as a transportation fuel. The pre-clinic survey distribution illustrates that a small majority (55 percent) entered the clinic with favorable hydrogen views, while the remaining respondents either had negative or neutral opinions. The shift after the clinic is evident from the post-clinic survey response distribution, which skews to the right. More than 80 percent of participants finished the clinic with a positive overall hydrogen impression. The Sign Test—a two-tailed non-parametric test applicable to paired responses—can assess whether paired response distributions are different to a degree that is statistically significant. When applied to the distributions of Question 1, the Sign Test generates a z-score of -5.8, indicating that the opinion shift is statistically significant.

Question 2 evaluates respondent safety impressions of driving a hydrogen-powered vehicle. The answers to this question were posed relative to gasoline as a familiar benchmark. The distribution of pre-clinic survey responses better approximates the shape of a normal distribution, with roughly 70 percent believing that hydrogen is equally safe or safer than gasoline. However, the remaining 30 percent believed that driving a hydrogen vehicle is less safe than gasoline. The post-clinic survey reveals a considerable impression shift, as the proportion of respondents feeling less safe with hydrogen than with gasoline dropped to seven percent. Opinions mostly shifted towards the belief that gasoline is as safe as hydrogen, with some gains in the opinion that hydrogen is safer than gasoline. Question 2 had a z-score of -4.9 with the Sign Test, meaning that the difference between the distributions is statistically significant.

Finally, Question 3 illustrates a similar assessment of hydrogen refueling safety normalized to the impressions of gasoline refueling safety. Here, stronger safety reservations exist in the pre-clinic survey prior to exposure, as over 40 percent considered hydrogen refueling to be less safe than gasoline. As with the driving assessment, responses shifted in the post-clinic survey, with only 15 percent leaving the clinic with the impression that hydrogen refueling is less safe than gasoline refueling, while 60 percent felt that it was as safe, and 25 percent believed it was safer. The z-score of the Sign Test on the paired responses for Question 3 was -6.7, also showing statistical significance. Thus, the response shift clearly demonstrated that short-term exposure to hydrogen vehicles and refueling can make some people feel more comfortable with hydrogen fuel.

Response to Vehicle Performance Metrics

Participants were asked to assess their opinions of several hydrogen vehicle performance metrics. As with the questions in Figure 1, researchers designed the performance questions to assess response metrics calibrated to participants' gasoline vehicle perceptions. In the pre-clinic survey, respondents were asked to provide their hydrogen vehicle performance expectations in comparison to a typical gasoline vehicle with the following metrics: acceleration, braking, handling, and ride comfort. Respondents were asked whether they anticipated that the hydrogen vehicle would perform worse, better, or about the same as a typical gasoline vehicle. In the post-clinic survey, participants were asked to assess whether the vehicle had met, exceeded, or failed to meet their expectations. Table 2 illustrates the cross-tabulation of responses to two key metrics: acceleration and braking.

Table 2: Pre-Clinic and Post-Clinic Survey Responses to Vehicle Performance

Acceleration						
Post / Pre	Greatly Disappointed	Slightly Disappointed	Met Expectations	Slightly Exceeded	Greatly Exceeded	Total
Much Worse	0%	1%	2%	1%	1%	4%
Slightly Worse	0%	5%	9%	12%	7%	34%
About the Same	1%	11%	16%	5%	9%	42%
Slightly Better	0%	3%	5%	4%	1%	13%
Much Better	0%	2%	3%	1%	1%	7%
Total	1%	23%	35%	23%	19%	100%

Braking						
Post / Pre	Greatly Disappointed	Slightly Disappointed	Met Expectations	Slightly Exceeded	Greatly Exceeded	Total
Much Worse	0%	0%	0%	0%	0%	0%
Slightly Worse	0%	0%	1%	1%	0%	2%
About the Same	1%	3%	55%	21%	8%	88%
Slightly Better	0%	1%	6%	0%	1%	7%
Much Better	0%	1%	1%	0%	1%	3%
Total	1%	4%	64%	22%	9%	100%

[i]Pre-Survey Question: How do you expect the hydrogen vehicle to compare to a typical gasoline vehicle within the following performance categories?
[ii]Post-Survey Question: How did the following attributes meet, fail to meet, or exceed your expectations?

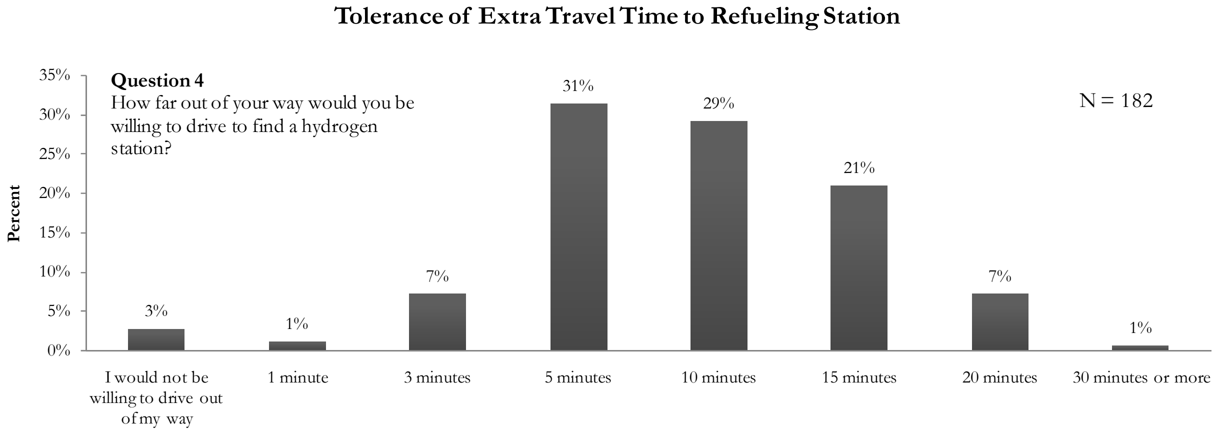
The cross-tabulation illustrates both the distribution of respondent expectations prior to exposure and how those relative expectations were met or unmet by the vehicle. As a performance metric, "acceleration" illustrated the widest distribution of prior expectations, with nearly 40 percent of respondents expecting the vehicle to perform worse than a gasoline vehicle, and 20 percent expecting it to perform better. The results of the post-clinic survey show that on balance respondent expectations were exceeded by the F-Cell as 25 percent of respondents considered acceleration to perform below their expectations, while the expectations of roughly 40 percent were exceeded.

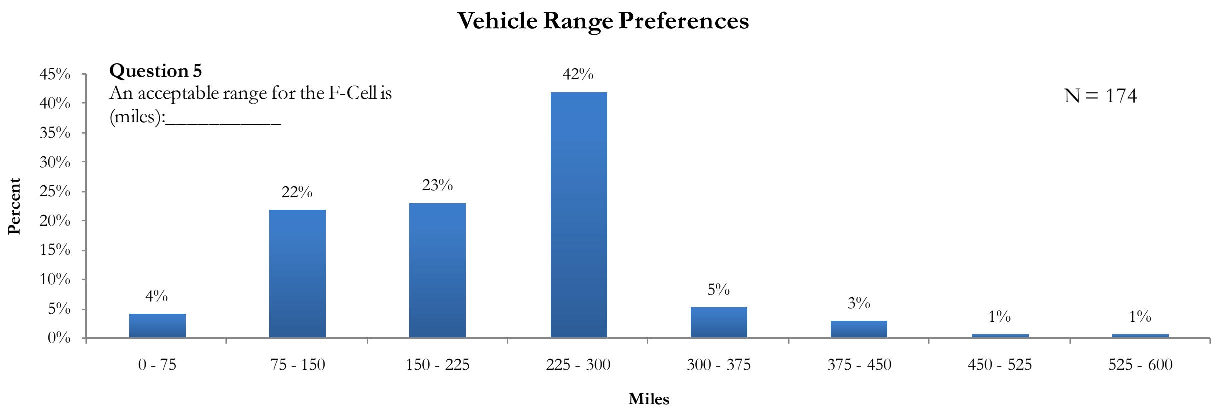
Braking exhibited far less variance in expectations, as most respondents anticipated braking to perform about the same as gasoline vehicles. A little more than 30 percent found braking to exceed expectations, far more than the five percent that indicated disappointment in braking performance.

Response to Range, Refueling Distance, and Refueling Behavior

Participants also were asked about range and refueling preferences, which are critical to alternative fuel vehicle acceptance. Both aspects are important because restricted range and limited refueling infrastructure have long hindered alternative fuel vehicles. Results of two questions from the survey illustrate a distribution of preferences across these two parameters. In the post-clinic survey, respondents were asked to write-in a vehicle range (in miles) that they would consider acceptable for the F-Cell (which currently has a range of 100 miles/160 kilometers). Additionally, respondents were asked to characterize their tolerance in terms of extra travel time to drive to a fueling station. The response distributions to both questions are illustrated in Figure 4.

Figure 4: Distribution of Range and Refueling Preferences



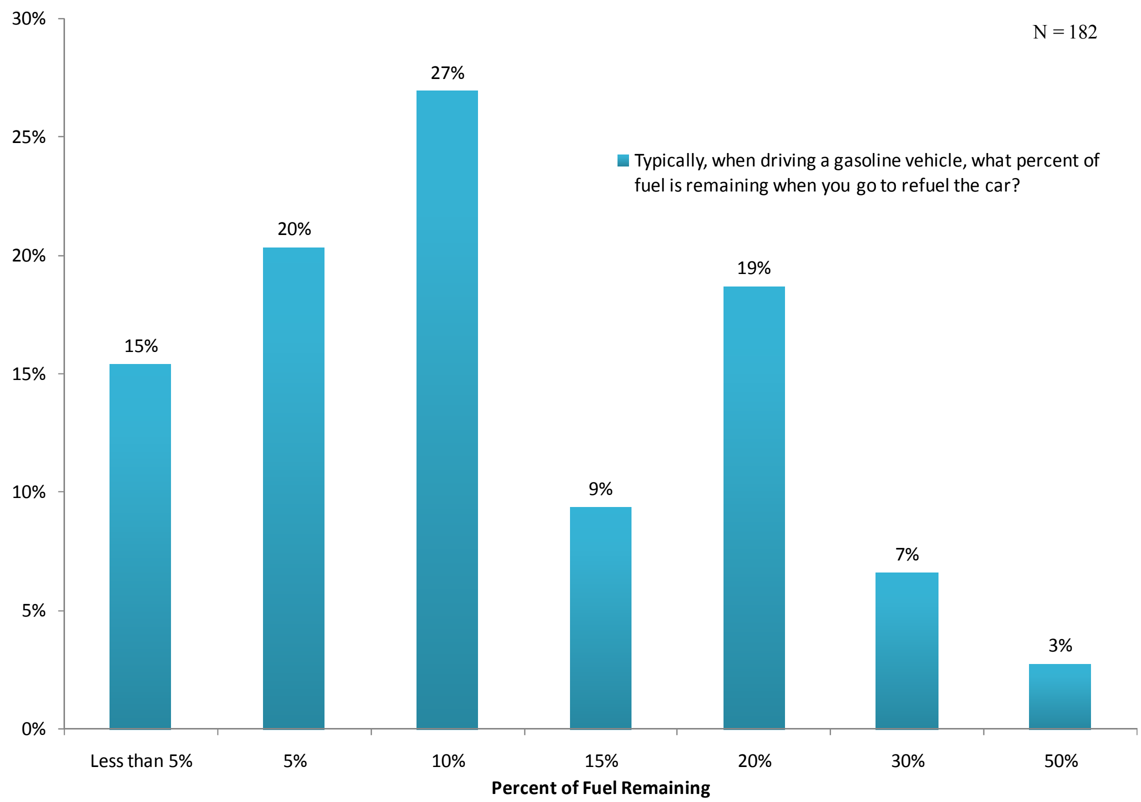


Question 4 illustrates the refueling distribution and reveals that the majority of respondents would be willing to travel five to ten minutes out of the way to find a hydrogen station. A sizable minority also expressed a willingness to drive at least 15 minutes to find a station. The value of this information is applicable to informing time-distance tolerances for planning potential station networks and assessing whether consumers within a particular municipality are within an acceptable range of a refueling station.

Question 5 presents the distribution of range preferences and shows that roughly 90 percent of the respondents would consider a vehicle with a range of between 225 to 300 miles (360 to 480 kilometers) to be acceptable for a vehicle like the F-Cell. This result is consistent with the range preferences of a respondent within a previous study conducted with the F-Cell (Shaheen *et al.*, 2008).

An additional question in the post-clinic survey sought to understand the distribution of respondent preferences for refueling gasoline vehicles. Specifically, the question sought to gauge the degree to which respondents self-assessed their tolerances for running the tank of gasoline to empty before considering refueling. Such information could be useful for understanding travel behavior in range constrained alternative fuel vehicles. The effective range of a vehicle for many people is not the capacity of the tank, but the distance that they think they can travel without feeling the need to refuel. Hence, understanding the profile of tolerances for refueling can potentially inform station network planning as well as vehicle design. Figure 5 illustrates the distribution of responses that describe the percent of the gasoline tank remaining before participants consider refueling their own vehicle.

Figure 5: Refueling Tolerances with Gasoline Vehicles

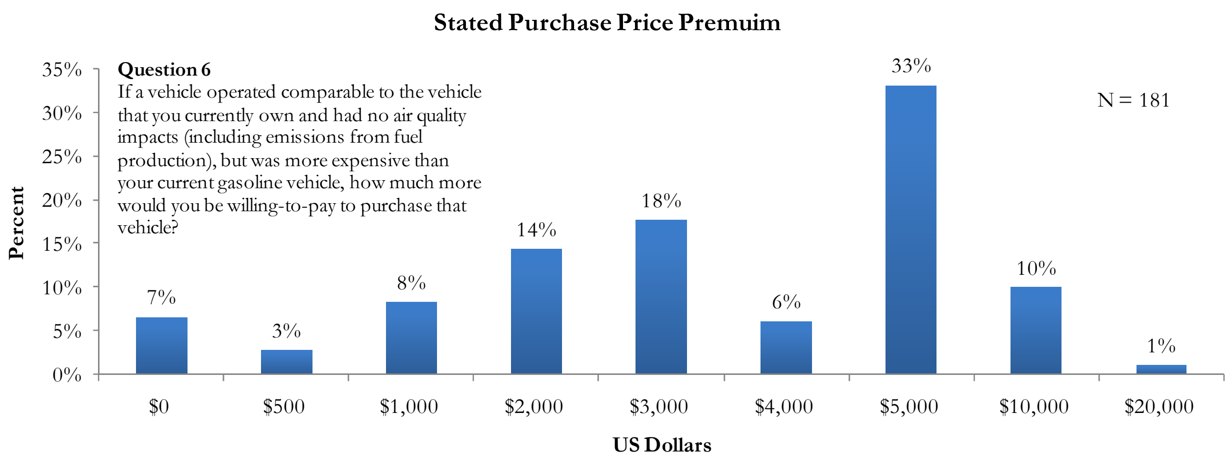


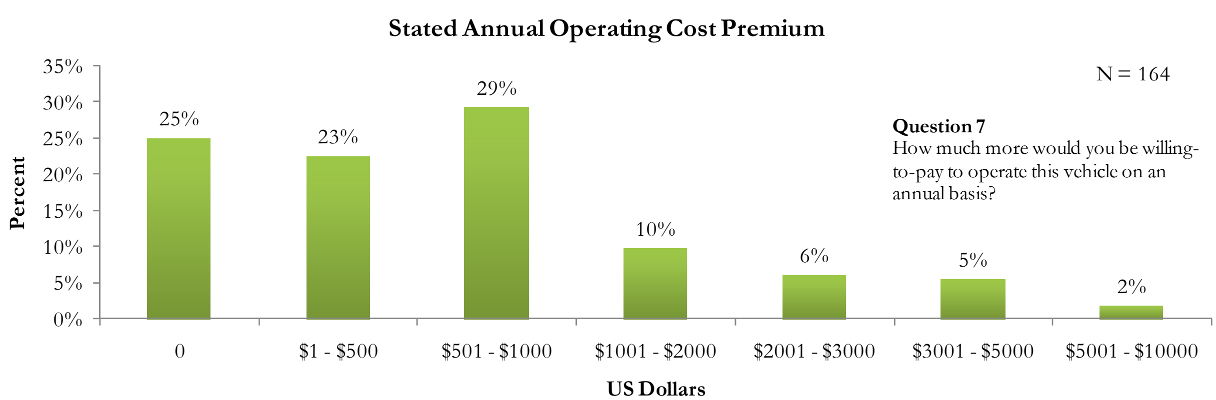
It is important to note that the distribution of responses reflect driver perceptions. That is, the responses reflect driver behavior based how much fuel the driver *thinks* remains in the vehicle before they take action to go refuel. The reality is likely different because consumers usually do not receive accurate information with respect to how much fuel is in the vehicle. Most fuel meters do not inform the driver of a reserve of fuel, which can carry the vehicle an additional 20 to 40 miles. Future commercial vehicles will likely take the same approach in providing driver information. But the effective range of a vehicle is informed by the degree to which a consumer can travel without developing concern for lack of fuel, especially in an environment with a sparse refueling network.

Willingness-to-Pay Responses

The ride-and-drive clinic offered a forum to query respondents about their WTP for vehicles powered by clean fuel technology. Participants were made aware (if they did not already know) that hydrogen is only as clean as the primary energy sources from which it is made. Questions sought to gauge a more generalized personal valuation with respect to clean vehicle technology. The post-clinic survey queried respondents about the purchase price premium they would be willing-to-pay for a vehicle and fuel that effectively has zero emissions, such as an FCV powered by hydrogen generated mostly from renewable resources. The fuel and vehicle were theoretical so as to establish a scenario as devoid from internal respondent assumptions as possible. There is a natural limit to which consumers are willing to pay private costs to offset public externalities (e.g., air pollution). To explore this issue, respondents were asked the purchase price premium that they would pay for an emission-free car similar to their own, as well as a stated annual operating cost premium that they would be willing to accept. The questions were asked sequentially, leading with that of the purchase price premium. Figure 6 illustrates the response distribution of both questions.

Figure 6: Response Distribution to WTP Questions





The WTP distribution suggests several points about how consumers value the benefit of clean vehicles and fuels. In terms of purchase price premiums, 50 percent of respondents indicated that they would pay at least $4,000 over the purchase price of a similar gasoline vehicle. The mode is $5,000 US, and WTP drops off significantly at greater values. The distribution for the annual operating cost premium suggests that consumers have a higher stated aversion to paying more for operating costs than purchase price premiums. A quarter of respondents stated a WTP of zero, and only 25 percent indicated that they would pay some amount more than $1,000 US per year to operate a cleaner vehicle over what they would pay to operate a conventional vehicle. The drop in sample size observed in Question 7 is due to the fact that some respondents interpreted the question in percentage rather than absolute terms (e.g., "10 percent more" was a common response) and therefore their responses were not included in the analysis for this question.

The main objective of assessing WTP is to appreciate the difference in price and anticipated operating costs that would have to exist between conventional and cleaner vehicle options for consumers to consider such alternatives. Stated WTP—reflecting the responses given here—is distinct from empirically revealed WTP, which is observed through actual behavior. Revealed WTP is preferred if its available, but stated WTP is useful when the product in question either does not yet exist or is not widely available. Respondents answering these questions are not held to their answers or accountable to actual financial circumstances. Nevertheless, the response still offers a proxy as to what range of additional expenses would be tolerable to the consumer.

Conclusion

The clinic results indicate that short-term exposure to FCVs and refueling can improve participant hydrogen vehicle impressions. This conclusion is consistent with the results of many previous studies. Over the past decade in which hydrogen vehicles have been available to the public in some form, a strong consensus has emerged within the literature that the perceived the safety of hydrogen fuel is not a concern for consumer deployment. Many of the past studies have been conducted in the context of hydrogen vehicles in public transportation, including taxis. This study exploring passenger cars finds similar results with respect to the safety perception of hydrogen. A sizeable minority of participants (30 percent) entered the study believing that driving with hydrogen was less safe than gasoline. After exposure to the vehicle, this proportion dropped to seven percent. A similar result was found with the safety perception of refueling as more than 40 percent considered refueling with hydrogen to be less safe than gasoline. After exposure to refueling, only 13 percent considered it to be less safe. These trends not only indicate that perceptions of safety are not a major inhibitor to hydrogen, but that consumer exposure to the hydrogen vehicle environment can help to improve to hydrogen acceptance among populations that may harbor reservations. It is important to point out this these results exist at a time when the safety record of hydrogen has been demonstrated to be quite good.

Additional results provide potential parameters for station network planning of dedicated fuels outside of gasoline. In the clinic, most respondents were willing to travel five minutes out of their way to find fuel, and a sizeable proportion appeared willing to drive at least 15 minutes. In addition, range considerations indicate that vehicles designed to travel around 250 to 300 miles (400 to 480 kilometers) on one tank would meet the needs of most respondents. Similar range results were found among longitudinal study participants. Finally, WTP parameters illustrate that consumers might pay more to drive a vehicle that emits less air pollution. The WTP distribution of the stated purchase price premium suggests that half the participants would be willing to pay $4,000 more for a zero-emission vehicle that is similar to their own. This distribution offers some proxy of the limits that private consumers would place on premiums to purchase a vehicle that eliminates personal air emissions on behalf of the public. Premiums on operating costs are understandably lower. Interestingly, nearly a quarter of all clinic respondents indicated no tolerance for operating cost premiums. Operating cost premiums exceeding $1,000 would be unattractive to 75 percent of the respondents.

Overall, for dedicated fuels such as hydrogen to succeed, some pre-exposure could assist in educating the public and improving impressions. A similar approach may be taken with other fuels that have challenges similar to hydrogen in gaining public acceptance. Hydrogen is among the most distinct fuels competing for future viability in that consumers have little prior exposure to it with any other application. In addition, hydrogen powers a drive train that has been previously unfamiliar to consumers. Hence, adaptation strategies that account for exposing the public to vehicles in a neutral setting may help to expand the acceptance of consumers that are likely to be in the early potential market. Further research could help inform whether similar patterns of response exist within broader populations in which interest in alternative fuels is not as high. In addition, further research is needed to understand how the limitations of the new set of alternative fuel vehicles and advanced drive trains impact travel patterns and environmental impacts. Of course, other techno-economic challenges that address driving range, limited infrastructure, and vehicle cost still must be addressed. The information provided in these studies offers an early proxy of vehicle and infrastructure specifications that would be required for the proliferation of FCVs and other dedicated alternative fuel vehicles in the future.

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Appendix A: PATH Focus Group Summary

This Appendix provides a summary of the results of a focus group that preceded the implementation of the drive clinic. As methodology, focus groups are useful for gaining detailed impressions of a particular issue from a small set of respondents. Focus groups rarely exhibit large sample sizes and can rarely provide in-depth quantitative results. Rather, they are useful for generating more in-depth opinions through extended discussion. These opinions can provide additional insight as to the basic factors behind specific consumer sentiments and help shape future research questions. This focus group was intended to supplement and support the development of the survey by reflecting on the experiences of drivers who participated in a previous longitudinal study with the F-Cell. The focus group touched on many of the issues explored by the drive clinic surveys, including satisfaction with the vehicle as well as feelings of safety with hydrogen. Overall, the sentiments found in the survey and the focus group was similar. The drivers within the focus group felt safe with it and had a good impression of it overall. In addition, the drivers had similar expectations with respect to the range and other vehicle limitations. The discussion that follows presents the results of this session in more detail, including specific features that participants felt were beneficial as well as those features that could use improvement.

The focus group was conducted on May 17, 2007, and consisted of six participants who worked at California PATH. These participants had access to driving the F-Cell for about a year. Four of these respondents had experience refueling the vehicle. The focus group began with the moderator soliciting the overall experiences of the participants with the F-Cell vehicle. Four of the six participants had used the vehicle for commuting home and back on occasion. One of the commuting participants lived locally, and in addition to commuting home used the vehicle for grocery shopping, mainly through city driving. For the remaining three of the commuting four, the commute involved significant highway travel. For two of those three, the distance of the round trip commute tested the limit of the vehicle's 100-mile range. These participants conducted their commutes in the F-Cell as well planned trips on a full tank, but they conducted the trip several times a week. The two non-commuting participants typically used the vehicle for lunch excursions and running PATH errands.

The respondents were asked to characterize their experience accessing the vehicle, and several respondents said that accessing the vehicle was a challenge. The group had set up an online Google calendar that was used for signing out the vehicle. However, a few noted that the calendar was not employed perfectly and often provided limited information on the timing of scheduled maintenance and on the level of fuel remaining in the vehicle. Participants noted that the location of the car was sometimes inconveniently distant, and the phone within the vehicle was difficult to turn on. Two of them stated that the calendar always worked for them in their case.

Participants were asked what they liked most about the vehicle. Among the elements appreciated included the vehicle size, which enhanced its parking ease, the separated back seats, that it was a zero emissions vehicle, and that it had carpool lane privileges. Participants were queried on what they thought of the vehicle performance. They mentioned that the suspension and braking was very good. In addition, one participant noted that it handled well in the wind. Two appreciated the fuel gauge providing a percentage number on remaining fuel and stated that it was more useful than the dial. Other appreciated attributes included the style, roomy interior, and in-vehicle navigation system.

Of all the features listed, respondents were asked to vote on which feature they thought was the best, second best, and third best of the vehicle. The following table illustrates the breakdown of votes. Unlisted categories garnered zero votes or were never brought to a vote if six votes were cumulatively tallied by previous categories.

Best Feature	
Size	2
Zero Emissions	4
2nd Best Feature	
Size	1
Zero Emissions	1
Carpool Lane Sticker	1
Suspension	1
Roomy Interior	2
3rd Best Feature	
Navigation System	1
Style	1
Size	1
Suspension & Handling	2
Roomy Interior	1

Participants were then asked to list the features that they liked the least about the F-Cell. One participant immediately said that he thought the start-up acceleration was weak. Two other participants mentioned the lag in start-up time of the vehicle with general agreement among others. A similar feature that received critical attention was the wait to turn the car off. Participants were referring to a "WAIT" signal on the dashboard that would arise once the ignition switch was turned off. This would last about 10 to 15 seconds. One participant said that in fact a person did not need to wait, and he regularly ignored the instruction. Another feature unanimously considered unfavorable included the short range of the F-Cell. Everyone considered the cup holders to be unusable. One participant complained that the in-vehicle navigation system and the radio could not be turned on at the same time. Another was bothered by the constant hum of the vehicle, while several mentioned issues with the controls. This included a complaint about the driving controls, which one participant said were difficult to figure out. Another participant felt that the controls for the windows and doors were in an odd location. The keyless remote also received complaints, as it was considered to have such a short range that it had to be held right up next to the car to operate. The fuel cover was also criticized for being difficult to open because it did not have a finger lip. Another participant complained that the car had to be unlocked at every door (using the keyless remote, as opposed to the regular key) for the fuel cover to open. Finally, one participant said that he considered the style to be an unfavorable feature. Similar to before, voting ensued on the most disliked features mentioned during the discussion above; the results are summarized in the following table.

Most Disliked Feature	
Weak start up acceleration	2
Long start up ignition time	1
Short range	3
2nd Most Disliked Feature	
Weak start up acceleration	1
Long start up ignition time	1
Short range	2
Cupholders unusable	1
Controls in an odd place	1
3rd Most Disliked Feature	
Lagged turn off time	2
Long start up ignition time	1
Controls in an odd place	1
Range on keyless remote	1
Fuel cover required all doors unlocked to operate	1

Participants were then asked what they would like to see in the F-Cell in the future. The first response was a sunroof. Another suggested longer range. One participant chimed in to suggest that he would like to see the entire dislike list fixed, as well as an ipod dock. After this comment, the focus shifted to refueling issues. This shift in content was unprompted by the moderator. The participant leading this shift suggested that he would like to see communication capabilities with the refueling station such that he could know whether there was fuel at the station. This may be an early issue with hydrogen stations as there had been a number of times in which the fuel station was down for maintenance or had low pressure, meaning that refueling would be very slow or not possible. Advanced communication within the vehicle to deal with this issue was suggested and supported by other participants. Another participant suggested that refueling stations need to be more abundant, and refueling station locations should probably be added to the in-vehicle navigation system.

The moderator then shifted the discussion from the aspects of the vehicle to specifics of hydrogen to gauge the degree of comfort that respondents had with the fuel. Participants were asked whether they felt comfortable shutting down the vehicle. All respondents affirmed that they were. One mentioned that he had a little trouble at first, but this dissipated. Another mentioned that there was an energy drain on the car, and that twice he could not take it because it was totally dead. The reasons for this were debated briefly, it was speculated that at times the tail lights would not turn off, and this could have been the cause. In fact, a later discussion suggested that the dial for turning the lights off was confusing. Some participants thought that it had to be turned all the way to the left when in fact it had to be vertically centered.

Participants were asked to assess the range of the F-Cell. The first response was 80 to 85 miles, but another said that that range includes a safety margin; the real range was between 90 to 95 miles. He followed on to mention that the lowest percentage he ever had was nine percent, while another said he once had it with a fuel level of two percent. Participants were then asked to assess how the range impacted them. One woman suggested that she would have taken the F-Cell to Monterey, but the range and the positioning of the fuel stations made going south a risky proposition. Another participant said that when the local station was only providing 50 percent fills that he would only go as far as the UC Berkeley campus, about seven miles away. A third participant said that range considerably impacted his decision to use the car. This included learning whether he would have to refuel the car before making the actual trip. In addition, he considered taking the car to Davis, but sometimes the fuel station there was inoperable, making the trip infeasible. One participant, who primarily used the car for lunch excursions, said that the range did not specifically impact his experience with the vehicle, but he would not buy a vehicle with such a range. The fueling situation was just "too iffy," he said. The discussion was capped with a comment suggesting that the hoops that one had to go though to refuel made the process a real hassle.

Participants were then asked what an acceptable range for a vehicle was. The first answer was 250 miles, which received group agreement. One woman suggested that 100 miles would be okay if station density was high, but the acceptable range depended on station density. Finally, one person suggested that 350 miles would be better for a multipurpose vehicle.

The discussion then shifted to safety, and participants were asked whether they felt unsafe with vehicle. Everyone said that they felt safe with the F-Cell. One participant said that he did not feel safe when driving the vehicle around trucks. Another participant said that he would like to know more information about the tanks containing the fuel. He said that it would be nice to know that they have been tested. There were no other comments that followed on this matter, so moderator then asked whether respondents felt as safe in the F-Cell as with a gasoline vehicle. The first issues that came up in this regard involved the danger of getting stranded from running out of fuel. Getting lost in a sparse network was a major concern to a few. Another issue that was brought up was collision danger because not much was known about how the hydrogen car would perform in a collision. This was the same person who wanted to know more about the tanks. The final comment on this issue was by a participant who felt safer with the F-Cell; he thought the hydrogen gas would disperse quicker than gasoline. After this comment, the session took a five-minute recess.

Upon returning, participants were asked when they started driving the vehicle. Most had been trained to drive in Spring 2006. Those that could refuel were trained to refuel at various points throughout the year. Participants were asked to discuss what the most exciting aspect of the vehicle was to them. One comment was that it was not the participant's car, but someone else's (i.e., a fleet vehicle). Another mentioned that he felt special because very few had access to this new technology, and one participant mentioned that he was excited by the fact that it was a gasoline alternative.

Exploring vehicle expectations, participants were then asked whether their expectations of the car were met after using it for a while. One respondent mentioned that his expectations dropped a bit when he began to appreciate how tight the leash of the car was (i.e., the vehicle range). One of the women participants also mentioned that her expectations dropped when she learned that she would not be able to make a trip to Redwood City from Richmond given the sparse infrastructure and vehicle range. Another said that simply getting access to the vehicle was a little tougher than expected, and this sentiment was supported one other person. The supporting participant said that it was difficult to get to the car, and then to figure out if it could be taken (due to the scheduling system). By the time this was this could be achieved, he could have been where he wanted to go. However, he continued to say that the range did not surprise him because all alternative fuels have limited range.

Participants were asked what concerns they had back when they first were exposed to the car. Getting into an accident with such an expensive vehicle was a concern. Participants were then asked if they had different concerns now that they had driven the vehicle. The first respondent stated that he had the same concerns over range and accessibility now as he did then. Another participant said that collectively no one knew how the vehicle would hold up in a crash; there was no knowledge about how it would perform. After this comment, one participant suggested that he later learned that the fuel can evaporate from the vehicle even if it is not being driven, and this was a new concern. Another followed up with a question regarding the impact ambient temperature would have on the car.

Participants were asked whether they felt that they were more or less likely to purchase a hydrogen vehicle. The first comment was that one participant felt as though he was more likely to purchase the vehicle because he had some extended experience trying it out and typically needs to know what he is getting into. The moderator asked whether this experience had influenced people's propensity to consider other alternative fuel vehicles. The same person mentioned that he would be okay with biodiesel, but he would need more experience with electricity. Another participant stated that he was not affected either way. A third stated that he would be more likely to look into this given his experience. When asked about how this experience had influenced his likelihood, he followed up by saying that his experience opened his awareness because he saw that the F-Cell operates like something that he was accustomed to. He stated that it would take some adjustment but that it would not constitute a huge change using a hydrogen vehicle. The participant was pressed to think about the vehicle options that he would consider purchasing given his experience. He responded by saying that he was not aware of what else could be purchased besides gasoline-electric hybrids, and he thought the choices were really limited. Another said that with the current price of gas she would consider it, and her experience driving the hydrogen car would make her more likely to consider it if hydrogen was more widely available. Then another participant mentioned that this experience reinforced her propensity to favor cleaner automotive technologies. A fourth participant stated that if infrastructure and costs were "okay," then he would purchase a hydrogen vehicle as well. He took this opportunity to reflect on a recent vehicle design that he made in considering the Prius, which he ultimately decided against because the Prius cost is more in total, so a gasoline car was chosen. But he reemphasized that if the infrastructure was there and the costs were at parity, he would go with the hydrogen vehicle.

The moderator then shifted the conversation to the refueling experience of people, asking how often they refueled. The first participant to speak said that he refueled 80 percent of the time that he used it, and he liked to leave it with fuel. The routine became easier to him, but that it was always a bit onerous to sign in, ground the vehicle (electrically), etc. Two other respondents said that they had not refueled the vehicle; one of them had observed the refueling, while another said that he would not sign a waiver. One of the commuting participants said that he would refuel it at least twice a month, and that if the station was down that he could not use the vehicle for his commute. He complained that there were a lot of maintenance issues with the station, and when other cars were using the station that pressure was frequently lower. A female participant then opined that she went through the training with others but was nervous about doing it alone. She never refueled the vehicle. The other female participant said that she did it half the time she took it out, and she would try to refuel it if it had less than one-half a tank.

The moderator then asked the group whether they felt safe refueling the vehicle. Most people said that they did, but two of them never refueled it. All those who did refuel the vehicle said that they felt safe doing so, and there was little further comment. The moderator then asked those who did refuel what was the most challenging issue. The first comment on this matter criticized the logistical time it took to refuel at the AC Transit station. This included a 50-yard walk, checking in, etc. These steps needed to be taken before refueling could begin. Another person who refueled said that he did not like the nozzle, and he thought it went on differently each time. The first commenter who said there were times when the nozzle was locked supported this comment. There were other times when it seemed locked, but it was not. Other issues that were collectively raised included the difficulty in remembering the steps to refueling and not tripping on the ground line.

The moderator asked what people thought was the easiest thing about refueling. The three responses were that turning on the pump was easy, that you did not have to smell gasoline, and you did not have to pay. The moderator then asked the group how low they would let the tank go before driving to the refueling station. This question caused the group to pause for a bit. The participant who had let the fuel run down to two percent said that that was too low. He said that five percent would be acceptable, if he knew where the nearest station was. Another participant agreed saying that if he was familiar with the area five percent would be fine.

Next, the moderator asked the group how far they would be willing to drive to a refueling station assuming there was a network in the area. The first commenter, who was not a refueler, said that he would be willing to go five miles one way out of the way. One of the refueling commuters then said that two miles out of the way was something he was comfortable with. One of the researchers then clarified the scenario, asking participants to assume that the vehicle was their personal car. This prompted the first commenter to revise their response to two miles, about what he might do now. The first commenter on this question did point out that five miles in gridlock was different than five miles on a rural road. He stated that 10 minutes roundtrip would be the distance that he would tolerate. Three others followed up by saying that a 10-minute roundtrip would be fine, and a fourth stated she would be willing to travel 15 minutes roundtrip. The moderator then asked how long they would be willing to spend at the station. The responses included five minutes and five to 10 minutes, evenly split across the group.

The moderator asked whether an in-vehicle navigation system would be helpful. The response was "yes," but then the conversation quickly drifted to discussions about the cost. The moderator then clarified the question to say that this would be a full-service navigation system with station locations in it. One participant said that he would pay a $100 flat fee for such a service, while another suggested it should be standard and would pay nothing more. A fourth participant said that he had his own navigational system that he can take with him. He thought a system with refueling stations would be nice and useful, but he would not buy a separate unit. Another commuting participant agreed. The last participant to comment on this said it depended on whether or not she expected to do a lot of freeway driving with the car, if most of her driving was local, then she would not pay for such a product.

With respect to the stations, the moderator asked the group how valuable it would be if the station told you how much fuel it had. One participant said that he was comfortable planning ahead, and another said that it would be rather useful, if it could tell users what the estimated wait time was at the station. The moderator asked how much participants would you pay for it at a store, such as Best Buy. The participant comfortable planning ahead said that he would know in advance where the stations are located. The fellow respondent suggesting the advanced wait time notice said $15 a month. Another said $150 flat fee, plus $15 a month. A final comment suggested a $200 flat fee or $7.50 a month, but that it depends on what it was bundled with. He might pay more, if it came with additional features.

Nearing the end of the focus group, the moderator asked whether participants had heard of the environmental benefits and negative impacts of hydrogen vehicles. Among the negative issues raised included the fact that there was no way to produce hydrogen from a clean source, the fuel source was currently expensive, and the consequences of fuel cell disposal are unclear. One participant suggested that he thought that there could be a negative impact with hydrogen venting into the atmosphere. As hydrogen vents, it goes to the upper reaches of the atmosphere and eventually escapes because it cannot be retained by the Earth's gravity. The participant suggested that this results in a net loss of the Earth's original endowment of hydrogen. Another participant countered to say that he thought hydrogen was so abundant that this would not be a concern. The positive issues raised included that it had zero tail pipe emissions, there were no particulate emissions, and it was emitting less carbon dioxide.

The moderator then asked whether anyone knew what criteria pollutants are, and no one knew. The moderator asked about ozone and nitrous oxide, and there were nods of familiarity. The focus group came to a close with the moderator asking if there were any final comments; none were raised, and the session adjourned.