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ALTERNATIVE FUEL VEHICLES: THE CASE OF COMPRESSED NATURAL GAS (CNG) VEHICLES IN CALIFORNIA HOUSEHOLDS

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Alternative Fuel Vehicles: The Case of Compressed Natural Gas (CNG) Vehicles in California Households

Abstract

Compressed natural gas (CNG) vehicles have been used internationally by fleets and households for decades. The use of CNG vehicles results in less petroleum consumption, and fewer air pollutant and greenhouse gas emissions in most applications. In the United States, the adoption of CNG technology has been slowed by the availability of affordable gasoline and diesel fuel. This study addresses the potential market for CNG vehicles at the consumer level in California. Based on semi-structured personal interviews, this study reveals the nature of the CNG vehicle ownership experience, determines the effects of government incentives on the decision to own a CNG vehicle, and considers the California CNG refueling network in the context of future alternative fuel vehicles (AFVs), such as fuel cell vehicles. The effects of government financial incentives, such as tax deductions and buy-down rebates were not influential in the decision to purchase a CNG vehicle. Rather, recent owners of dedicated CNG vehicles in California purchased a CNG vehicle because they can drive in the high occupancy vehicle (HOV) lanes regardless of the number of occupants in the vehicle. This significantly reduces their commute time to and from work, improves commute time reliability, and relieves stress. However, CNG vehicle owners have expressed significant dissatisfaction with the CNG refueling network and the driving range of CNG vehicles. Despite these disadvantages, most California CNG vehicle owners would own another CNG vehicle in the future given the same circumstances.

ALTERNATIVE FUEL VEHICLES: THE CASE OF COMPRESSED NATURAL GAS (CNG) VEHICLES IN CALIFORNIA HOUSEHOLDS

FIGURES: PAGE:

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I. "THE SANDERS BUY A NEW CAR"

The following story represents a "typical" household owner of a dedicated CNG vehicle in Southern California. It is fictitious and describes the household ownership experience of a CNG vehicle based on the household interviews conducted for this study.

> Mike and Jane Sanders are a dual-income family of four living in Irvine, CA. Like their neighbors, they make a very comfortable living; they earn a combined household income of around $100,000. Their two children are enrolled in elementary school near their home. Jane works at a local business. Mike commutes from Irvine to Los Angeles.
>
> Mike commutes 50 miles each way five days a week on the I-405 Freeway. Due to congestion, his commute time varies from just over an hour to more than two-and-a-half hours. The length and uncertainty of his commute time has caused considerable stress for Mike and Jane. They are happy living in Irvine; the schools are good and they enjoy their lifestyle in Orange County. They are in a quandary. Mike enjoys his job in Los Angeles, but neither Mike nor Jane want to move away from Orange County.
>
> Mike was commuting home from work one day when he noticed all the vehicles in the carpool lane were moving at a smooth, quick pace. He was stuck in traffic. He thought to himself, "I wish I could drive in that carpool lane." Mike had previously looked into carpooling with colleagues from work. However, due to conflicting schedules and commitments, it did not work out. Further down the I-405 Freeway a road sign in the median explained the rules of the carpool lane. This time he noticed a message on the sign he had never seen before: It said, "Clean Air Vehicles OK." Mike immediately wondered what that meant and when he returned home began researching for information on the internet.
>
> As Mike researched the internet, he found battery electric vehicles (BEVs) and dedicated compressed natural gas (CNG) vehicles were eligible for access to the carpool lane regardless of the number of occupants. He thought, "This is great. If I can get into the carpool lane with one of these BEVs or CNG vehicles, my commuting problem can be solved." He mentioned this to Jane and she encouraged him to further investigate. From her perspective, if they could own a vehicle that would allow him access to the carpool lane, thus reducing their stress and allowing them to live in Irvine, then it was worth looking into.
>
> Mike heard a lot about BEVs on TV and in the newspaper. He liked the idea of driving a electric car. However, upon further research because of BEVs short driving range, he would need to recharge the vehicle at work. Unfortunately, his workplace did not have a charging

station installed. As a result, Mike redirected his research toward CNG vehicles. He found out CNG vehicles can drive about 170 miles on a tank of fuel. Since his commute was 50 miles each way, he could make three one-way trips before refueling. He thought to himself, "I'll be refueling twice as often as my gasoline car, but it may be worth it." Therefore, he wanted to find out where he could refuel a CNG vehicle. Mike noticed after looking in a CNG fueling stations directory obtained from a natural gas web site, a few stations existed along his commute route on the I-405 Freeway. Perhaps this could work out for him.

As Mike continued his internet research, it appeared there were many dedicated CNG vehicles from which to choose. He called local dealerships asking how to obtain one. He quickly became frustrated because none of the dealerships were knowledgeable about CNG vehicles and were unable to refer him to a dealer that was. After Mike contacted the manufacturers directly, he was able to locate a few dealerships authorized to sell CNG vehicles. However, he was unaware most of the CNG vehicles he was considering were only available to business fleets. The vehicles available to the private consumer were the Honda Civic GX, Ford Crown Victoria CNG, and the Ford F-150 CNG. Since he was not interested in commuting in a car as large as the Crown Victoria or a truck like the F-150, he decided to pursue the Honda Civic GX. Jane agreed, the other two vehicles were probably bigger than they needed. Mike owned a Honda in college and was aware they make reliable cars. Therefore, he and Jane were comforted that Honda was offering this vehicle.

With Jane's blessing, Mike located the closest dealership authorized to sell the Civic GX and spoke with the alternative fuels vehicle fleet manager for more information. The manager told him the Civic GX drives just like a regular Civic; he wouldn't know the difference. However, he was honest with Mike and explained how CNG fuel stations were limited compared with gasoline, but he would give him a pamphlet to find all the stations in California (the same pamphlet Mike had already obtained). Mike knew of the stations along his commute route but realized it would be handy to keep a pamphlet on hand in case he wanted to drive elsewhere. Excited at the prospect of driving in the carpool lane, Mike asked for a test drive in the Civic GX. Unfortunately, the Civic GX is manufactured in batches and none were available to test drive. However, he could drive a Civic LX, an equivalent gasoline vehicle, instead. If Mike liked it, he could place an order for the Civic GX based on that test drive. Mike agreed, and was impressed with the Civic LX, considering it would just be a commute car. He decided to place an order. Mike noticed the Civic GX had a sticker price over $20,000 which he considered pretty high since the LX he test drove had a sticker price around $16,000. The manager explained the Civic GX is about $4,000 more due to the cost of the CNG fuel cylinder and the low production of the vehicle. That seemed like a small premium to pay considering the time he would save on his commute that he would now be able to spend with

his wife and family. While filling out the order, the manager mentioned the Civic GX was also eligible for a $3,000 buy-down incentive offered by their local air quality management district. This would reduce the cost Civic GX to just over $1,000 compared with the Civic LX he test drove. Mike was not aware of this incentive and would have bought the vehicle regardless, but was nonetheless pleased to save money.

Mike took delivery of his Civic GX about two months after his order. It had a full tank of gas but after two days of commuting, he needed to refuel. Mike was aware of the shorter driving range but the need to refuel so soon caught him somewhat by surprise. So he drove to one of the CNG fuel stations along his commute route to refuel. Unfortunately, he had not established an account with that fuel provider and could not fuel his vehicle. Somewhat perturbed, he scrolled through his fuel stations directory to find a CNG fuel provider that accepted a credit card. Fortunately, there was a station in Anaheim that did. Though Anaheim was a detour from his commute route, Mike needed to refuel immediately to get home. He wished somebody would have mentioned the need to establish separate accounts for the independent fuel providers. The next day, after explaining the situation to Jane, Mike opened several fuel accounts and continued to refuel in Anaheim until his fuel cards arrived.

Over time, Mike realized his CNG vehicle was much like a regular gasoline vehicle. It had good performance for a subcompact car, it started every time, and was a good commute car. It seemed like a regular Civic to him. Even Jane liked to drive it occasionally, though she was apprehensive about fueling it. Their primary complaint with the vehicle is that fueling was inconvenient and the car could not travel as far as their gasoline cars on a tank of gas. This has prevented them from driving CNG vehicle places they would like to travel with the car. As a result, they are very apprehensive about taking it outside the LA area. However, for them, the CNG vehicle has served its intended purpose: it allowed Mike access to the carpool lane which reduced his travel time, improved his travel time reliability, and as a result eliminated the stress he was enduring due to his commute.

The story of Mike and Jane Sanders is fictional. But it is typical of the recent CNG vehicle ownership experience of California households. The story sets the framework for this report on the household ownership experience of CNG vehicles in California. I will begin by explaining why this study is useful (Section III), and provide an introduction (Section IV). I will then discuss the historical context of alternative fuel

vehicles (AFVs) and CNG vehicles (Section V), followed by a discussion of the current context of AFVs and CNG vehicles (Section VI), such as energy, tailpipe emissions, and greenhouse gas emissions benefits as well as incentives, the California refueling infrastructure, and current CNG vehicle use in California. I discuss relevant differences betweeen CNG vehicles and traditional gasoline vehicles (Section VII). CNG vehicles and AFVs have been studied extensively using both econometric models and national and international case studies. Therefore, I review these previous studies and research (Section VIII). Finally, the California household CNG vehicle ownership experience, as exemplified by the story of Mike and Jane Sanders, will be discussed, beginning with the methodology for the study (Section IX). This will be followed by the results/analysis of the household interviews and supplemental questionnaires (Section X). Section X will reveal the extent of owners' awareness of and motivation to buy a CNG vehicle prior to purchase (Section X, A), their experience with the CNG refueling network (Section X, B), their overall ownership experience and driving behavior (Section X, C), and a summary of the previous three sections (Section X, D). The following three sections will include policy recommendations to further stimulate the household CNG vehicle market (Section XI), areas for further household CNG vehicle research (Section XII), and conclusions (Section XIII).

Based upon the literature review, a review of government AFV policies, conversations with government agencies, and ownership experiences of California CNG vehicle households (as exemplified by the story of Mike and Jane Sanders) this research was designed to examine the following hypotheses:

II. HYPOTHESES OF POTENTIAL DEMAND FOR CNG VEHICLES IN CALIFORNIA

Hypothesis #1: Currently in California, CNG vehicles are primarily purchased for HOV lane access.

Hypothesis #2: Government buy-down and tax incentives were influential in the decision to buy a CNG vehicle.

Hypothesis #3: Refueling infrastructure is pervasive enough to support more CNG vehicles and is accessible by a large percentage of the population.

Hypothesis #4: CNG vehicles are owned by "hybrid-households" where they complement other vehicles in the household fleet.

Hypothesis #5: Household CNG vehicle market penetration is low due to unfamiliarity with the vehicles and a lack of information.

III. PURPOSE OF THE STUDY

California is expecting a 46 percent increase in petroleum consumption over the next twenty years (CEC, 2000). In the absence of fuel conservation policies such as higher corporate average fuel economy (CAFE) requirements, higher fuel taxes, or increased prices for gasoline, AFVs will need to enter the California vehicle fleet to reduce or stabilize such growth. Currently, two dedicated AFV options exist: battery-electric vehicles and compressed natural gas vehicles. Since BEVs are expensive to produce and have significant limitations, they are not a realistic option for large-scale deployment unless battery technology advances. Fuel cell electric vehicles are another option, but they will not be widely available in the near future. Currently, CNG vehicles

are the only type of dedicated AFV available to the general public in potentially high production numbers and can be sold by manufacturers for a profit. CNG vehicles offer substantial air quality and energy security benefits (compared to most gasoline vehicles) which are of value to the State of California. Previous econometric stated-preference surveys have been conducted on the general population to understand their preferences for AFVs, including CNG vehicles. Several reasons justify a study of household CNG vehicle use.

Various levels of government have introduced incentives for AFVs to make ownership more appealing. Recent legislation allowing CNG vehicles access to high-occupancy vehicle (HOV) lanes has introduced a new incentive for CNG vehicle ownership not previously explored. Additionally, the South Coast Air Quality Management District (SCAQMD) offered $3,000 buy-down incentives to the public for CNG vehicles to reduce the incremental cost of initial ownership. The effect of this incentive has also not been explored elsewhere. Combined, these two incentives make the market for CNG vehicles in California substantially different from the assumed market conditions in previous studies.

This study of current household CNG vehicle owners will offer insight with regards to the types of policies/incentives influencing CNG vehicle ownership; both policies that currently apply and policies which could further stimulate the market.

Understanding the household CNG vehicle ownership experience is valuable to determine the potential growth and subsequent viability of a CNG vehicle market while helping government agencies tailor their programs to meet the needs of current and future owners.

Studying current CNG vehicle owners is useful to compare against previous studies. Case studies in British Columbia and New Zealand were conducted in the 1980s with retrofitted dual-fuel gasoline vehicles. However, considerable differences exist between these early vehicles compared with CNG vehicles offered today. As a result, there may also be significant differences between the motivations of those in that study to own a CNG vehicle and today's California car-buying households. Because the ownership experience of those in New Zealand and Canada may not reflect that of Californians, new research into the California ownership experience is justified.

Due to the potential energy security benefits of large-scale CNG vehicle deployment in the California vehicle fleet, the ownership experience from these initial owners can provide considerable insight into the market barriers which currently restrict more consumers from considering a CNG vehicle.

Finally, many believe natural gas may be the initial fuel source from which on-board reformers would extract hydrogen for fuel cell vehicles. Since this will likely require use of the existing CNG fueling infrastructure, information from current CNG vehicle owners regarding their experience with CNG refueling is useful. Additionally, fuel cell vehicles may be deployed in a similar manner to CNG vehicles: fleets first, then households. The dynamic between fleet and household use of the same limited refueling infrastructure is worth exploring if fuel cell vehicles are expected to enter the market place.

IV. INTRODUCTION

As stated, California will need substantial penetration of AFVs to the vehicle fleet to reduce the potential adverse impacts of an increasing rate of gasoline consumption.

Some of these impacts include fuel price volatility, disruptions in gasoline supply, and price gaming by the fuel providers (Levin and Monahan, 2001). In the interest of energy security, the State of California has been complying with the Energy Policy Act (EPACT) of 1992 and integrating AFVs into their government and private vehicle fleets throughout the 1990s. However, if progress to reduce the State's petroleum consumption is desired, AFVs will need to enter the consumer marketplace; especially in light of California's population growth, rising VMT, and a stagnant federal corporate average fuel economy (CAFE).

To date, the only dedicated AFVs to reach the consumer market have been battery electric vehicles (BEVs) and compressed natural gas (CNG) vehicles. While BEVs were received with mixed results (as a result of lack of vehicle availability and charging as well as extremely high production, and subsequent consumer costs), they were promoted based upon their potential air quality as opposed to energy security benefits. CNG vehicles, in contrast, have existed for decades but only used in limited applications such as government and private fleets in California until recently. CNG vehicles are better suited to displace petroleum than are EVs, while generally offering superior tailpipe emissions to gasoline vehicles (though still not as good EVs).

Only now, due to slowed progress in battery-electric vehicles as well as legislation allowing CNG vehicles access to high occupancy vehicle (HOV) lanes, are CNG vehicles considered by consumers and automobile manufacturers as a viable AFV option in the light-duty consumer vehicle market. As a result, some compelling topics to research are whether light-duty CNG vehicles are a viable substitute for gasoline vehicles, how they can be used, what is their potential consumer market, and what

similarities might exist between the CNG vehicle ownership experience and that of future alternative fuel vehicles, such as fuel cell vehicles.

I will first describe the historical context of CNG vehicles and their emergence in the marketplace. While this topic occasionally extends beyond the scope of California, it frames the role of CNG vehicle use by citing international case studies which, despite their differences, provide an appropriate context and foundation from which to study the California household market potential.

CNG vehicles (as well as other AFVs) provide distinct societal advantages making their use in households desirable. These advantages include improved energy security, improvements in tailpipe emissions, and a favorable effect on global climate change compared with equivalent gasoline vehicles in most applications. However, growth of the CNG vehicle market is unlikely unless tangible advantages exist for the owners. Thus I will also describe current incentive programs, refueling infrastructure, and ownership costs. As part of this background, I will diagnose historical and current levels of CNG vehicle use and sales, primarily in business applications.

The characteristics of light-duty CNG vehicles, including how they differ from a traditional gasoline vehicle, are also integral to a market potential analysis. CNG vehicles offer a distinct set of advantages and disadvantages compared to a traditional gasoline vehicle. Since dedicated CNG vehicles are an alternative fuel by the EPACT definition vehicle (i.e. fuel not originating from petroleum), it is worthwhile to consider their relative strengths and weaknesses to other alternative fuel vehicles such as battery-electric vehicles. The scope of comparison, however, will be limited to CNG vehicles and BEVs since these are the only dedicated AFVs available to the California consumer market in substantial quantities.

The preceding topics discussed why CNG vehicles are desirable for emergence into the household vehicle market. However, they do not address consumer motivations, opinions, and purchasing decisions. Since the California (and US) household market for CNG vehicles is in its infancy, a review of previous literature and international studies to assess the potential market for CNG vehicles in California households is justified. Historically, two approaches have been used: stated-preference economic demand models and revealed-preference studies. While neither provide a definitive prediction of the potential market, they offer considerable insight with respect to their methodological strengths and weaknesses. Both approaches research the priorities of consumers, how the vehicles may be used, and under what circumstances a CNG vehicle meets their needs.

While international case studies provide the framework to study the CNG vehicle market, several issues distinguish the California market from those cases. As a result, semi-structured personal interviews and supplemental written surveys with current owners of CNG vehicles were conducted in California. The personal interviews and written surveys are the foundation of this study and from which many of the conclusions, policy recommendations for further development, and areas for future research will be drawn.

V. HISTORICAL CONTEXT OF AFVs/CNG VEHICLES

A. EPACT and the Alternative Motor Fuels Act of 1988

EPACT required the federal government to begin purchasing alternative fuel vehicles in 1993 and required state fleets and alternate fuel providers to begin purchasing AFVs in 1997 model year (NGVC, 2001). In summary, the Act affects all "persons" operating at least 50 vehicles in the US in cities with a population over 250,000 as of

1980 (CEC, 1999). As a result, EPACT has been an influential variable in the deployment and use of alternative fuel vehicles in the United States as well as California

While EPACT was the "stick" by which AFV use began, legislation such as the Transportation Equity Act for the 21st century (TEA-21) was the "carrot" by which funding became available to government fleets to make procurement and use of AFVs more affordable. Additionally, tax deductions which made AFV purchases less expensive and tax credits for AFV purchases exceeding EPACT requirements were also part of the original legislation package to make AFV use more appealing. Fleet vehicles were originally targeted because it was believed most large fleets can be centrally fueled. While many assumptions about AFVs and fleet use have since been proven incorrect (Nesbitt, 1996; Nesbitt and Sperling, 1998), EPACT was a primary stimulus for AFV fleet penetration in the United States.

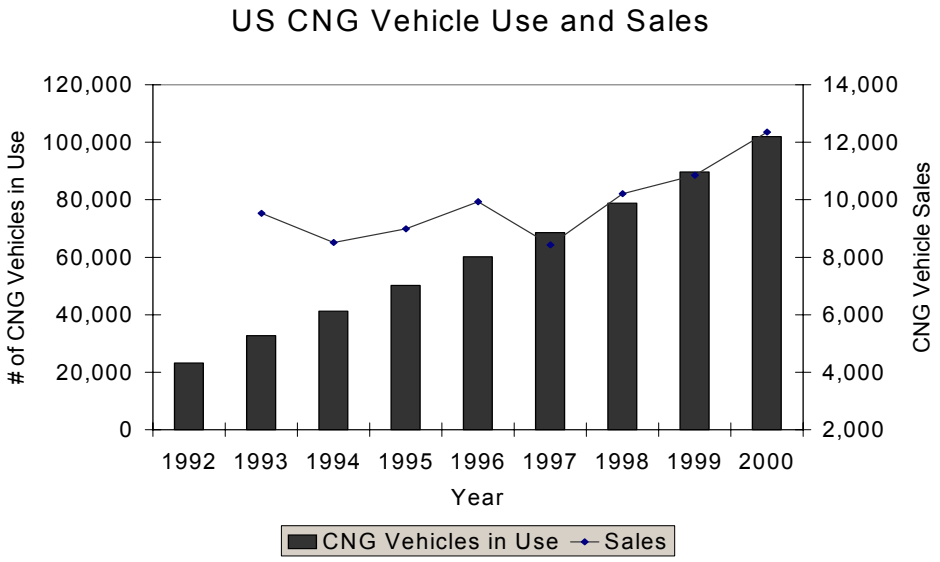
Another "carrot" influencing AFV fleet penetration was the favorable treatment flex-fuel vehicles (FFVs) received from CAFE as a result of the Alternative Motor Fuels Act (AMFA) of 1988. Flex-fuel vehicles are capable of operating on either gasoline or an alternative fuel, in most cases ethanol (E85) or methanol (M85). The Alternative Motor Fuels Act of 1988 assumed flex-fuel vehicles would operate on the alternative 50 percent of the time and credited them a fuel efficiency of 100 mpg at 50 percent and the other 50 percent at the vehicle's gasoline mpg (McCormack, 2000). Therefore, a flex-fuel vehicle earning 25 mpg on gasoline would earn a CAFE rating of 40 mpg. As a result, there was a direct incentive for auto manufacturers to produce flex-fuel vehicles and hundreds of thousands of flex-fuel vehicles have been sold nationally since 1993 (McCormack, 2000). However, they are rarely run on the alternative fuel since there are

neither consumer incentives to use the alternative fuel (due to the low price of gasoline), nor ubiquitous fuel availability.

B. EVOLUTION OF US CNG VEHICLE MARKET

EPACT targeted fleet vehicle use and placed auto manufacturers in the position of producing AFVs as OEM vehicles, some of which were CNG. The first offerings from the auto manufacturers appropriately reflected the market to whom they were selling, government and private fleet vehicles. The OEM CNG vehicles included vehicle classes ranging from full-size vans and trucks to minivans to large and small cars. These were frequently bi-fuel vehicles (a vehicle designed to run on either CNG or gasoline, but with separate fuel tanks) as opposed to dedicated CNG. Such vehicles allowed government fleets to meet the EPACT requirement. However, in most cases, they were rarely fueled with CNG because most fleets do not centrally refuel and those that do, have high travel demands which precludes the use of CNG fuel (Nesbitt and Sperling, 1998). As a result of this loophole, sales of CNG and CNG/bi-fuel vehicles have increased since 1992 as has their use in the national fleet.

Figure 1:



Source: US Department of Energy, 1999.

In absolute numbers, CNG vehicle use appears impressive. However, despite mandates and incentives for the fleet market, AFV and CNG vehicle use has not met expectations (Anderson and King, 1999). Some of the reasons include higher initial cost of CNG vehicles, a limited refueling infrastructure; limited availability of original equipment manufacturer (OEM) models; and concerns with operation characteristics of CNG vehicles such as range, efficiency, power, trunk space, weight, safety, and maintenance (Anderson and King, 1999).

By 1999, eleven vehicle models existed that were either bi-fuel or dedicated CNG vehicles (CEC, 1999). However, most of these were not made available to private consumers. As of today, only three vehicles (a subcompact sedan, full-size sedan, and full-size regular cab pickup) are available to households today.

VI. CURRENT CONTEXT OF AFVs/CNG VEHICLES

A. ENERGY SECURITY

California's expected increased demand for gasoline can be explained by a projected annual population increase of 1.4 percent (UCLA, 1999 as cited by CEC, 2000) and a decrease in the light duty vehicle fleet average fuel economy of 6 percent (CEC, 2000). California oil refineries have been operating at full capacity while our demand for gasoline continues to climb (Levin and Monahan, 2001). As result, gasoline supply, which is controlled by a few companies, leaves California subject to price volatility, supply disruption, distribution problems, and price increases which may lead to weaker public health protections and new refinery construction (Levin and Monahan, 2001). While many options exist to reverse this trend, one of the more plausible and least intrusive to citizens' lives is to make ownership of fuel efficient cars and alternative fuel vehicles more appealing to consumers. While fuel efficient cars *reduce* gasoline consumption, AFVs *displace* gasoline which offers a more significant per capita energy security benefit to the State. Penetration of light-duty CNG vehicles in the California fleet may be the most likely of alternative fuel vehicles to play an immediate role in reducing the rate of consumption mentioned.

B. TAILPIPE EMISSIONS AND AIR QUALITY

Most alternative fuel vehicles tend to emit fewer tailpipe emissions when compared with an equivalent gasoline vehicle. When direct emissions testing was conducted (Battelle Memorial Institute, 1995 as cited by CEC, 1999), CNG earned the lowest ozone forming potential and carbon monoxide emissions of the four fuels tested: CNG, LPG (propane), M85, and reformulated gasoline (the base fuel). The exhaust

system of CNG vehicles requires few modifications to produce low emission levels in comparison with a gasoline engine. While tailpipe emissions of gasoline vehicles have improved substantially over the past few years (and some have reached super ultra-low emissions (SULEV) certification), they require complex emissions control systems or a hybrid-electric drivetrain to achieve this in comparison with a natural gas vehicle. It must be noted, however, that auto manufacturers are capable of improving emissions of their gasoline vehicles. However, they typically only design their vehicles to meet emissions requirements, not to exceed them. Therefore, the fact that CNG vehicles have superior tailpipe emissions to most equivalent gasoline vehicles is more a cost-saving measure in the design of gasoline vehicles than an inability to improve their emissions. However, CNG vehicles appear to be a more cost-effective means of producing very low emissions vehicles.

Several studies have analyzed the cost of improving air quality by comparing a number of alternative fuel vehicles. These studies generally consider the cost of the fueling system and CNG technology versus the amount of reduction in tailpipe emissions. One study (Harrington, Walls and McConnell as cited by Walls, 1996) revealed natural gas vehicles meet the EPA's cutoff point for cost-effectiveness of under $10,000 per ton of hydrocarbons (HC) reduced. In comparison, the cost per ton of HC reduction in methanol vehicles was estimated at $33,000 to $60,000 (Krupnick and Walls, 1992 as cited by Walls, 1996). With regard to electric vehicles, it was concluded that due to the high production cost and disadvantages of ownership, battery-electric vehicles (which are currently the only vehicles capable of meeting California's zero-emission vehicle [ZEV] mandate) are an excessively expensive method of achieving tailpipe emissions goals, and can be met more cheaply with other low-emission fuels and vehicles (Rubin, 1994).

Due to the nature of their fueling system, dedicated natural gas vehicles produce little or no evaporative emissions during fueling and use as opposed to a gasoline vehicle which requires special modifications to achieve this goal. Dedicated CNG vehicles present substantial tailpipe emissions benefits over other alternative fuel and gasoline vehicles and from a cost-effectiveness perspective, are a viable solution to reducing emissions from the light-duty vehicle segment, assuming auto manufacturers are unwilling to invest more money in further reducing gasoline vehicle emissions.

C. GLOBAL CLIMATE CHANGE

A growing concern with the American transportation sector is the potential impact carbon dioxide (CO_2) emissions can have on global climate change. Carbon dioxide is a greenhouse gas (GHG) and the rising concentration of GHGs is expected to increase the average surface temperature of the earth and affect global climate, sea levels, water resources, agriculture, and ecosystems (CEC, 2000). Regional changes in climate can create favorable conditions for pathogens, and expand the life cycle of pests and enhance the spread of disease (CEC, 2000).

The Intergovernmental Panel on Climate Change (IPCC) in 1997 stated "the balance of evidence…suggests a discernible human influence on global climate (as cited by Laird, 2001)." The United States transportation sector emits large amounts of carbon dioxide into the atmosphere. In 1999, total US carbon dioxide emissions equaled 5,598.7 million metric tons and the transportation sector accounted for one-third of those emissions (DOE, 1999). Of that one-third, 98 percent were a result of petroleum products for transportation (DOE, 1999). California's vehicle fleet represents roughly 15 percent of the nation's total. It is understandable why the State of California, though officially not

as concerned with global climate change as air quality, would nevertheless have interest in reducing the amount of carbon dioxide it produces. As a secondary benefit, vehicles which provide CO_2 reductions may also provide energy security benefits.

Alternative fuel vehicles are considered to have carbon dioxide emissions advantages over gasoline vehicles because they generally contain less carbon than gasoline. Natural gas vehicles produce roughly 20 percent fewer carbon dioxide emissions than an equivalent gasoline vehicle (CEC, 1998) even after accounting for the input energy to compress natural gas (CEC, 1998). However, natural gas has a higher methane content (another greenhouse gas) so this could affect CNG fuel's advantage somewhat. Therefore, while CNG vehicles are not likely to offer the sole solution to reducing carbon dioxide emissions and subsequent potential effect on climate change, they do have significant advantages over traditional gasoline fueled vehicles, all other factors equal.

D. GOVERNMENT INCENTIVE PROGRAMS

As a result of energy security and improved emissions from AFVs, government at all levels has implemented incentive programs to make ownership of AFVs more appealing and less expensive. The federal government currently offers a $2,000 tax deduction for the purchase of an AFV and many states have implemented AFV programs for business fleets. The success of those state programs, however, has been limited due to minimal funding (Howell and Chelius, 1999) and most did not extend to the household consumer.

In California, several air quality management districts (AQMDs) offer buy-down incentives for alternative fuel vehicles. South Coast AQMD offers a $3,000 incentive for

purchases of new CNG vehicles. Incentives of $1,000 and $200-$800 are available in the San Diego Air Pollution Control District and Sacramento AQMD, respectively. The Bay Area AQMD currently does not offer financial incentives for household purchases of a CNG vehicle. In all these programs, incentives will be disbursed until the funding is exhausted.

Perhaps a more compelling incentive for CNG vehicle ownership is the recent legislation (July, 2000) allowing "clean air vehicles" (defined as CNG vehicles and battery-electric vehicles) access to the high-occupancy vehicle (HOV) lanes when they are driven as single-occupant vehicles (SOV). Research studies in the past have not considered this incentive on the market potential of CNG vehicles which could be influential if consumers value their savings in travel time more than the incremental cost of a CNG vehicle. When included with a local buy-down incentive and federal tax deduction, the market potential for CNG vehicles could be higher than predicted by stated-preference research studies.

E. CALIFORNIA REFUELING INFRASTRUCTURE

Another variable in the market potential of CNG vehicles in California is the development of a refueling infrastructure. Currently over 105 public CNG refueling stations exist in California (CNGVC, 1999). Most of these stations are located in major metropolitan areas (San Francisco Bay area, Los Angeles basin, Sacramento, and San Diego). It is plausible large numbers of consumers could adapt to using a CNG vehicle based upon the spatial distribution of refueling stations.

CNG fuel stations operate differently than gasoline stations. They are usually operated by independent fuel providers catering to public CNG vehicle fleets, not

necessarily to private consumers. In contrast to gasoline stations, CNG stations are frequently unattended and located in industrial areas. In most cases, CNG fuel stations are open 24 hours. However, it is not uncommon for them to only operate Monday through Friday during "normal" business hours (in some cases 7:00 AM to 5:00 PM). To access fuel at a CNG station it is usually necessary to open an account with that provider and use a card to dispense fuel. Once or twice a month, account holders receive an invoice in the mail to pay their bill. Each fuel provider requires an account, so a single CNG vehicle owner may have several accounts and fuel cards. Additionally, at least one CNG fuel provider requires training before they will allow a customer to establish an account.

The historically low price of natural gas has been considered an advantage. To the consumer, it is usually two-thirds that of gasoline per equivalent gallon. In late 2000 and early 2001, prices have been volatile, sometimes approaching that of gasoline. It is unknown what impact there has been on the household market for CNG vehicles due to the increased price of CNG fuel. However, while CNG prices at the pump are currently higher than usual, they are still lower than gasoline.

F. CURRENT CALIFORNIA CNG VEHICLE USE

There are currently over 13,000 CNG vehicles in California's public and private business vehicle fleets (CEC, 1999). However, penetration into the household market has been virtually nonexistent to date. Financial incentive programs alone have had little influence on the household market. Many hypotheses exist explaining why the market has stagnated, some of which are attributable to the unique characteristics of CNG vehicles:

- Higher first cost of CNG vehicles
- Limited fueling infrastructure
- Limited Availability of original equipment manufacturer (OEM) models
- Concerns with operation characteristics of CNG vehicles (e.g. range, efficiency, power, trunk space, weight , safety, and maintenance)

  (Anderson and King, 1999)

VII. CHARACTERISTICS OF CNG VEHICLES

Alternative fuels are defined by the Energy Policy Act (EPACT) of 1992 as "any alternative fuel that is substantially non-petroleum and yields energy security and environmental benefits (CEC, 1997)." These fuels include compressed natural gas (CNG), electricity, hydrogen, liquefied natural gas (LNG), liquefied petroleum gas (LPG), alcohol fuels such as methanol and ethanol, coal-derived liquid fuels, and fuels derived from biological materials.

Compressed natural gas (CNG) vehicles are similar to traditional gasoline vehicles though there are clear distinctions. Like a gasoline vehicle, a CNG vehicle is an internal-combustion engine vehicle. However, the fueling system is different since the natural gas is stored under high pressure, typically 3000 to 3600 psi. High storage compression of CNG fuel is necessary because it is a gas as opposed to a liquid and natural gas contains approximately one-fourth the volumetric energy content compared with gasoline (CEC, 1999). Therefore, a fuel tank of twice the volume is required to provide roughly half the driving range of a gasoline vehicle. Due to the size of the fuel storage cylinders, light-duty CNG vehicles sacrifice a significant amount of trunk space. Additionally, because production of the fuel tanks is expensive and the vehicles and tanks

are produced in low volume, the incremental cost of a CNG vehicle compared with a gasoline-equivalent vehicle is around $2,500 to $5,000 (Gushee, 1995), though this cost would decline if vehicles were produced in higher volume.

Since a high pressure tank and compressor are used, the refueling procedure for a CNG vehicle is also somewhat different from a gasoline vehicle. Other than the refueling system and reduced trunk space, a CNG vehicle operates and handles the same as an equivalent gasoline vehicle. However, driving range is reduced. Typically, CNG vehicles travel around 170 miles per "tankful" compared with 300 for a gasoline vehicle. This requires the drivers to refuel more frequently. Additionally, the weight of a CNG vehicle is approximately 300 pounds more than a gasoline-equivalent vehicle.

Dedicated CNG vehicles have the potential for increased power or better fuel efficiency compared with equivalent gasoline vehicles due to the high octane of CNG fuel. Models currently available to the public are designed to produce slightly less, or slightly more power than their gasoline equivalents so the potential power advantage of CNG vehicles is not fully realized by OEM vehicles in the market.

VIII. REVIEWS OF PREVIOUS STUDIES/RESEARCH

A. STATED PREFERENCE (SP) ECONOMETRIC MODELS

Stated-preference studies researching the market potential of AFVs usually select a representative sample of the population and ask their opinions of vehicles directly or their opinions of preferred "bundles" of vehicle attributes. Both are usually based on hypothetical scenarios. Accuracy of SP economic demand models of AFVs have been questioned because of a "belief that consumers react differently to hypothetical experiments than they would facing the same alternatives in a real market (Brownstone et

al, 1999)." Nevertheless, since the household market for AFVs, and CNG vehicles in particular, has a short history, SP studies have been used to gain insight into the market for CNG vehicles.

Stated-preference studies and AFV market projections are typically framed with a set of assumptions that may or may not adequately reflect those of consumers considering a CNG vehicle. These range from consumers owning only one vehicle in their household (Walls, 1996) to the assumption that an AFV/CNG vehicle purchase would replace a vehicle in the household fleet (Walls, 1996 and Kavalec, 1996). While these assumptions for analysis are valuable, it is unknown whether those considering CNG vehicles will be purchasing with these criteria in mind, so market projections under this context must be carefully considered.

Discrete-choice models are the favored methodology for evaluating the market potential of AFV/CNG vehicles in stated-preference surveys. While the assumptions in the purchasing scenario model were previously articulated, the criteria by which consumers will consider a CNG vehicle are also subject to assumptions that must be explained. In one of the more well-known models (Kavalec, 1996 based on Bunch et al, 1993) the following vehicle attributes were assumed important to consumers:

1. Acceleration
2. Top speed
3. Tailpipe emissions
4. Dual fuel capability
5. Service station and fuel availability (relative to gasoline)
6. Home refueling or recharging ability
7. Luggage space (relative to a similar car or truck)
8. Fuel operating costs
9. Price
10. Range on a full tank or charge in miles
11. Time required to refuel at home (if capability is available)
12. Time required to refuel or recharge at a service station
13. Body style/size

Based on the stated-preference survey data and the aforementioned assumptions (among others), the California Conventional and Alternative Fuel Response Simulator (CALCARS) model projects California in-use CNG vehicle fleet penetration will vary from 150,000 to 388,000 by year 2015 (Kavalec, 1996). Despite this low market projection of CNG vehicles into the household fleet (for reference, annual new car sales in California are about 1.8 million), the results suggest a large absolute number of CNG vehicles entering the California fleet by 2015. These estimates represent an increase of at least ten times the current California CNG vehicle fleet penetration rate.

CNG vehicles perform poorly in three of the above variables important to consumers when considering an alternative fuel vehicle: Driving range, fuel availability, and trunk space (Bunch et al, 1993). The CALCARS model indicates trunk space is an important attribute, but not to the extent of driving range and fuel availability. Combined, the three vehicle attributes help explain why the projected market penetration of CNG vehicles by the model is low compared with gasoline vehicles. Since many of the ownership benefits assumed in the model are societal rather than direct to the consumer, this may explain the relatively small projected market penetration relative to gasoline vehicles. Additionally, there are much fewer CNG vehicle models for consumers to choose (three), which limits consumers' selection and subsequent projected market for CNG vehicles.

The results of the CALCARS model can be critiqued, however, based upon its embedded assumptions. A closer look at the assumptions reveals the model may be inaccurate in determining the potential household market for CNG vehicles.

CALCARS assumes a CNG vehicle purchase will replace a preexisting vehicle in a household fleet. This may or may not represent how the car-buying population will respond when considering CNG vehicles. If the vehicle is purchased as a supplement to a

household vehicle fleet, their disadvantages previously mentioned (fuel range, availability, trunk space) may be less of a factor than is assumed by the model.

Additionally, federal incentives are factored into the forecast assumptions and then phased out by 2005. If federal incentives continue beyond 2005, the model would likely project higher market penetration. The model also does not consider local AQMD buy down incentives and their potential to influence consumer purchasing decisions of CNG vehicles. As stated, in some areas the incentive is $3,000. If those programs continue, it may result in higher penetration of CNG vehicles in the California fleet due to a reduction in the incremental cost of the vehicle. Finally, the model does not factor the role of the legislation in the year 2000 allowing CNG vehicles access to HOV lanes through the year 2007. Potential exists for this to have a significant impact on consumer response to CNG vehicles as well as other non-financial incentives which may be offered in the future to make CNG vehicle ownership more appealing. However, this itself assumes a large number of drivers place a high value on their travel time and.

While the absolute cost of fuel was factored into the model, the price of natural gas relative to gasoline was not explored. Natural gas has historically enjoyed a price advantage over gasoline. Should this continue (or grow) there could be an advantage for CNG vehicle ownership.

Finally, the stated preference CALCARS model is based upon data collected in 1992. It is plausible opinions regarding alternative fuel vehicles and preferences for vehicle attributes have changed over the last nine years. An update of this model is in progress and may reveal new findings on consumer preferences and/or awareness of AFVs/CNG vehicles. It is unknown whether the changes will favor or reduce AFV/CNG vehicle projections from the model.

Despite debatable assumptions in the econometric models (some of which are inherent in any SP survey) the results indicate while market penetration of household CNG vehicles is low compared with gasoline vehicles, there is substantial room for growth. And while this rate of CNG market penetration will not satisfy the State of California's desire to stabilize the growing rate of petroleum consumption in the transportation sector, it is one of many variables and/or policies which can lead the State in the right direction.

B. REVEALED PREFERENCE (RP) STUDIES OF AFVs/CNG VEHICLES

Stated-preference surveys can predict the potential market for CNG vehicles. However, revealed-preference (RP) studies provide better insight with respect to the long-term viability of the market because they can determine the level of satisfaction and commitment to CNG vehicle ownership. Additionally, they have the capability of revealing why people choose to own a CNG vehicle, the nature of their ownership experience, and whether they would own another in the future. These variables are useful as analysis tools for a growing CNG market. RP studies can be used to better understand the decision-making process about vehicles, consumer motivations, and types of promotional programs most effective at stimulating a market response to CNG vehicles. However, RP studies of AFV ownership are usually based upon a small group of early adopters who may not be representative of the car-buying public. As a result, conclusions drawn from RP AFV studies should be carefully considered.

Extensive RP research has been conducted with alternative fuel vehicles (Kurani, 1992; Kurani and Turrentine, 1994; Greene, 1989; Turrentine and Sperling, 1989 and 1991). This research is generally based on the premise that AFV market potential cannot

be adequately predicted due to a few inherent flaws in the methodology of SP studies. It is believed that much can be learned by studying real behavior. Some fundamental arguments are: drivers tend to overestimate their need for driving range, vehicle preferences toward or against AFVs are not well formed without knowledge and/or experience, and economic theory of the AFV market only captures the market potential at a "snapshot" in time. In other words, it ignores the impact changing cultural norms, values, and preferences may have on the potential for AFVs to penetrate the market. Finally, in contrast to SP studies, RP case studies of CNG vehicles in New Zealand; British Columbia, Canada; and the California EV Drivers Survey indicate a generally positive experience with AFVs/CNG vehicles. However, this does not imply they can or should be considered as substitutes for gasoline vehicles under all circumstances because, as mentioned, these were early adopters whose motivations for ownership may not reflect the general car-buying public.

A frequently criticized attribute of AFVs and CNG vehicles is their reduced driving range compared with gasoline vehicles. Consumers in the United States generally expect a 300 mile or more driving range between fueling their vehicle. Most likely, they indicate this preference because it is the standard for current gasoline vehicles and they have not had experience with anything else. In reality, travel behavior studies indicate with 95% probability, half of all vehicles travel less than 105 miles per day on 95% of all days (Greene, 1985 as cited by Kurani et al, 1994). This clearly illustrates that despite the cultural mindset of a 300 mile expected range, it is not necessary. A vehicle with a driving range as low as 105 miles per day would impose little or no adverse impact on the mobility of half the households in the United States. CNG vehicles easily exceed a 105 mile driving range, so conceivably they could supplement a preexisting vehicle in the

household vehicle fleet for an even higher percentage of households based on this criterion. The idea of an AFV (or CNG vehicle) supplementing a gasoline vehicle in a household fleet has been coined a "hybrid-household" (Kurani et al, 1994). While econometric SP studies show consumers emphasizing the need for a 300 mile driving range, when asked to closely consider their daily driving habits, they become more receptive to the concept of a vehicle with reduced driving range. In fact, when closely scrutinized in focus groups, it was found "… stated preferences for range were extremely volatile and changed dramatically under the influences of new information (Kurani et al, 1994)."

Another factor possibly influencing consumer response to CNG vehicles is the assumption consumers are capable of forming preferences for or against CNG vehicles without adequate knowledge of, or experience with, a CNG vehicle. A 1992 comparative study of AFVs with non-owners revealed CNG vehicles were the least understood of the three following AFVs: electric vehicles, methanol vehicles, and CNG vehicles (Turrentine et al, 1992). In fact, some had confused CNG vehicles with propane. However, once participants in the study learned about them and were able to drive the vehicles themselves, 54 percent of opinions of CNG vehicles were either better or much better after the drive as opposed to only 10 percent whose opinions were either worse or much worse (Turrentine et al, 1992). While these findings do not indicate a market potential in California for CNG vehicles, it is apparent consumer motivations and opinions of vehicles are highly flexible. Consumer opinions of CNG vehicles without information and experience tend to result in "guesses" rather than choices (Kurani, 1992). This should be kept in mind when quantitative market projections based on SP surveys are conducted.

Market projection for CNG vehicles based on economic theory is also based on several other assumptions that are better addressed by RP studies. For example, economic demand models project market potential at a "snapshot" in time and do not consider changing social norms and attitudes towards vehicles over time. Additionally, the projections do not address the impact of an increasingly knowledgeable public as CNG vehicles are deployed, but instead assume a static level of knowledge. As consumers become more informed about CNG vehicles and exposure to them increases, it is reasonable to expect opinions of them to change. The aforementioned study (Turrentine et al, 1992) reveals opinions of CNG vehicles tend to improve with more exposure.

The refueling network is expected to improve over time. However, economic demand modeling does not accurately reflect the impact this may have on consumers' opinions of CNG vehicle ownership. It is reasonable to expect opinions to improve as the CNG refueling infrastructure expands as this was a strongly valued ownership attribute, even by those in the economic studies. It is plausible that the disadvantage of shorter driving range currently inherent with CNG vehicles would be partially negated by an expanding refueling infrastructure.

Finally, economic models place little value on societal benefits of CNG vehicle ownership. While most studies, including RP studies, indicate little current consumer interest in owning a CNG vehicle or AFV based on societal benefits, this value can change depending on future environmental/public health circumstances, however unlikely that may be. Again, since economic models are taken at a "snapshot" in time, these changing cultural norms are not captured and can only be accurately tracked by frequently surveying the population. When these collective arguments are considered, it becomes apparent the market potential for CNG vehicles is complex and not accurately

predicted by an economic demand model. Understanding in detail how and why consumers form opinions about vehicles and how they make purchase decisions is valuable because it reveals their personal value system, the factors influencing their decisions, and how they prioritize those factors. This knowledge can then be utilized to determine how cultural norms change over time, which is not captured with a market prediction using hypothetical situations, debatable assumptions, and perishable data. This is an area where RP studies improve upon economic SP studies.

While the 1992 test drive study (Turrentine, 1992) provided short-term insights of consumer opinions, four additional studies better address the long-term ownership experience of AFVs/CNG vehicles and hence the potential stability of the CNG vehicle market in California. Two CNG vehicle studies (Greene, 1989; Kurani, 1992) researched household ownership of dual-fuel CNG and gasoline vehicles. Though a dual-fuel CNG vehicle differs from a dedicated CNG vehicle, there was enough commitment to CNG fuel by users of dual-fuel vehicles to draw connections with regards to viability of CNG vehicles in the California fleet. The third study of consumer ownership of electric vehicles in California (CEC, 2000) offers additional insight of AFV use with similarities CNG vehicles. The fourth study, conducted in the late 1980s (Kurani and Sperling, 1988; Sperling and Kurani, 1988) considered the experience of owning and refueling diesel passenger vehicles. While diesels are not defined by EPACT as alternative fuel vehicles (non-petroleum based), the study explores the ownership experience of refueling a vehicle with limited fuel availability compared with gasoline. Connections can be made with CNG fuel and the extent to which it must be available for the car-buying public to seriously consider it for their next vehicle purchase.

i. British Columbia, Canada Case Study

The first studies of Canadian CNG vehicle conversion owners in British Columbia were based on focus groups and a survey questionnaire (Canadian Facts, 1986; Greene, 1989, respectively). They showed owners generally converted their vehicles to dual-fuel/CNG based on the fuel cost advantage of CNG fuel over gasoline. In fact, were it not for the lower fuel cost, (which was typically perceived to be 40 to 50 percent) many of them would not have converted their vehicle to dual-fuel (Canadian Facts, 1986; Greene, 1989). This study also indicated societal benefits and government rebates/financial plans were secondary influences. Environmental concerns had strong appeal but ultimately did not influence the decision to convert. From a drivability/performance perspective, those who converted their vehicle to CNG were "solidly satisfied" with that decision and were very likely to do the same with their next vehicle (Canadian Facts, 1986). Additionally, the concern of vehicle safety as a result of the high pressure fuel cylinder did not adversely impact the decision to convert to dual-fuel. Apparently, dissemination of accurate safety information was able to alleviate fears of CNG safety. Californians appear to be somewhat behind this issue as they frequently mentioned concerns of CNG "bombs" in the trunk when referring to the high pressure fuel cylinder (Turrentine et al, 1992).

CNG vehicle use in Canada is unique from the current situation in California because the vehicles were dual-fuel. This offered a safety net - consumers could switch to gasoline if the CNG tank became empty. Californians interested in a CNG vehicle do not have this luxury if they wish to take advantage of incentives being offered. However, Canadians who converted a vehicle to CNG indicated one significant disadvantage of CNG vehicle ownership that could be reflected in California: an apprehension to rely

totally on natural gas as a fuel because the distribution of CNG refueling stations was less than adequate (Greene, 1986). A follow-up study revealed their concern was the availability of CNG fuel, not as much with the range of CNG vehicles (Turrentine and Sperling, 1989). While the Canadian case study provides valuable information, it will become clear the California CNG vehicle ownership experience differs in many respects.

ii. New Zealand Case Study

From 1980 to 1988, the New Zealand government implemented a dual-fuel CNG vehicle conversion program which influenced the conversion of over 120,000 light-duty vehicles to run on dual-fuel gasoline/CNG (Kurani, 1992). An integral part of the program was the government's commitment to provide a price advantage for CNG fuel over gasoline. They also progressively increased incentives to remove market barriers to CNG conversion until 1985 at which point they rapidly removed their financial backing (Kurani, 1992).

Conclusions based on a few central themes provide similarities between the New Zealand and British Columbia, examples. In New Zealand as in British Columbia, the fuel price advantage of CNG over gasoline was the most compelling incentive for owners to convert their vehicles to dual-fuel CNG. However, since dual-fuel vehicles cannot be fully optimized to run on either gasoline or CNG, one would expect power loss under CNG would be a significant issue to owners. This did not occur because the vehicles in New Zealand were tuned to run better on CNG than gasoline. Rather, owners were more concerned with reduced driving range than power loss (Kurani, 1992). Additionally, those who converted their vehicle experienced little problem acquainting themselves with the refueling network whereas those who did not convert perceived this as a significant

obstacle. They frequently assumed fuel availability was worse than it was in reality (Kurani, 1992). For those who converted, the fuel cost advantage was the motivating factor. Yet for those who did not convert, the cost of conversion was the main factor for not having done so (Kurani, 1992). Finally, when the government eliminated its support for CNG, interest in CNG vehicle ownership declined rapidly and so did the CNG vehicle conversion market. As with the Canadian case study, the New Zealand case study is similar to the California ownership experience in some respects, but it will be illustrated there are significant differences as well.

iii. California Electric Vehicle Drivers Survey

The 2000 California Electric Vehicle Driver's Survey (CEC, 2000) does not offer insight on the ownership experience of CNG vehicles. However, EVs and CNG vehicles are subject to similar limitations such as reduced driving range and fueling infrastructure, which justifies a review of the survey. Additionally, since EVs were surveyed in the same market (California) as this CNG vehicle study, demographic comparisons can be made between EV owners and CNG vehicle owners. A point of distinction between the two should be made: the EV Drivers Survey included fleet use as well as household use, whereas this California CNG vehicle study focuses solely on household ownership.

a.) Vehicle Use

Results of the EV Drivers Survey indicate on average, owners drive their EVs over 7,700 miles a years. Since the VMT of a typical gasoline vehicle is around 12,000 to 15,000 miles per year, this suggests EVs are either not completely displacing gasoline vehicle use or the drivers are atypical of the general population. This point is further

illustrated by the fact that 70 percent of owners use the EV as their primary vehicle (CEC, 2000).

b.) Fueling/Public Charging

While similarities exist between CNG and EV vehicles with respect to fueling, a significant difference also exists: EV owners generally have access to home fueling and are not entirely dependent on the public charging infrastructure. However, those who do not use the public charging facilities essentially reduce their driving range in half, in part because of the length of time required to fully recharge a depleted EV: four to six hours. Despite access to home charging, 49 percent of respondents use public charging facilities one-to-four times a week and 69 percent drive their EV more because of the public charging infrastructure (CEC, 2000). As evidenced by the annual VMT of EVs, the reduced range and limited refueling infrastructure (despite having a positive effect on EV use), has imposed restrictions on the vehicles' use which is not apparent in gasoline vehicles. In contrast to EVs, the impact of the CNG refueling infrastructure and driving range of the vehicles with respect to how they are used, will be revealed in forthcoming sections of this paper.

c.) Ownership Experience

EV owners are quite happy with their vehicles. Eighty percent are more satisfied with their EV than their gasoline car and were overall extremely satisfied with their EV (CEC, 2000). Seventy-seven percent also indicated they would lease another EV under their current circumstances (CEC, 2000). They were very pleased with vehicle performance, while partially satisfied with driving range. Sixty-three percent of

respondents reported incentives were a somewhat or very important factor in their decision to lease an EV (CEC, 2000). When asked why the number of EV leases have not been greater, "drivers list limited range, lack of public awareness, and ineffective marketing" as the most important reason. Drivers commented the public is unaware of its actual mileage needs and therefore is unaware EVs may actually exceed their daily driving needs (CEC, 2000)." Also noted were a lack of vehicle availability and manufacturer support. These are all themes expressed by CNG vehicle owners that will be addressed in future sections of this study.

d.) Owner Characteristics

It can be argued drivers self-select themselves as owners/lessees of AFVs due to their socio-demographic and travel behavior characteristics. That is, they may represent working households with high incomes, commutes of a certain distance, and who highly value their travel time (the latter two to be discussed in forthcoming sections). Therefore, a market for AFVs cannot be determined with RP surveys of these initial buyers. It is possible similar arguments apply to lessees of EVs. For example, 72 percent of EV lessees were male and 47 percent of EV drivers are 35-50 years old (CEC, 2000). Additionally, the annual income of the respondents was $150,000 and 54 percent were employed as business or technical professionals (CEC, 2000), though no clarification was made how this information was collected with fleet users. The results of the demographic characteristics suggest middle-aged males with high incomes are more likely to lease an EV than the general car buying population.

iv. Diesel Car Case Study

In the late 1970s and early 1980s, sales of diesel fueled vehicles experienced a dramatic rise and fall in the United States market. By 1981, diesel vehicle sales peaked at 6 percent nationally and 9 percent in California (Kurani and Sperling, 1988). Consistent with the British Columbia and New Zealand case studies, the conclusions in the California diesel car study found were consumers purchased the vehicles primarily because of its relative fuel price advantage in the late 1970s and early 1980s as well as the improved fuel efficiency of diesel compared with gasoline. However, like CNG fuel, diesel fuel availability was limited compared with gasoline.

Two conclusions can be drawn from the diesel car case study making it particularly relevant to CNG vehicle market acceptance. First, the authors determined if 10 percent or more of fuel stations supply an alternative fuel (in this case diesel, though not "alternative" by the EPACT definition), then fuel availability will not be a major concern for buyers of alternative fuel vehicles (Kurani and Sperling, 1988). Second, for alternative fuel vehicles to gain market acceptance, the fuel must provide some significant performance advantage. For example, it must be priced lower than gasoline, and its future price advantage must be guaranteed by government and/or industry (Kurani and Sperling, 1988). These findings are consistent with the British Columbia and New Zealand case studies as the success of those programs was directly related to the fuel price advantage of CNG and can be applied to the market potential of household CNG vehicle use in California.

STUDY OF HOUSEHOLD CNG VEHICLE OWNERSHIP EXPERIENCE IN CALIFORNIA

IX. METHODOLOGY

This study of household CNG vehicle ownership in California was conducted via semi-structured personal interviews. A sample of 18 households was selected from a list provided by the South Coast AQMD of people who received the $3,000 buy-down incentive and from two San Francisco Bay area Honda dealers who were willing to provide names of CNG vehicle customers. The interviews were conducted in people's homes and workplaces in the San Francisco bay area and Los Angeles area during the Spring of 2001. Of the eighteen interviews, four took place in the S.F. Bay area and fourteen in the L.A. area. The interviews covered topics such as environmental values and opinions, knowledge of CNG vehicles and AFVs, CNG vehicle purchase decisions, effects of government incentives, CNG vehicle use, opinions of refueling and the refueling infrastructure, and general questions about their ownership experience. At the conclusion of the interview, the respondents were asked to complete a supplemental written survey which focused on many of the topics covered in the interview, at which time they had the option of completing the survey or returning it via business reply mail. Of the eighteen supplemental surveys distributed, seventeen were returned. Copies of the interview outline and supplemental questionnaire can be found in the Appendix.

Personal household interviews were conducted and supplemental questionnaires were provided because they can provide depth and detail of the CNG vehicle ownership experience better than a survey questionnaire. An interview with open-ended questions and a conversational style also allows topics to enter the interview which may not have been previously considered by the interviewer. A study based solely upon a written

survey implies the researcher understands well the subject he/she is attempting to study. I determined household interviews would be the most effective method of completely understanding the CNG vehicle ownership experience. The interviews lasted anywhere from forty-five minutes to one-and-a-half hours.

Telephone interviews were also considered. However, a few problems exist with this method. Respondents usually become fatigued more quickly when answering questions than in personal interviews (Richardson et al, 1995). Telephone interviews are typically limited to twenty minutes (Richardson et al, 1995), and after conducting trial personal interviews, I determined the interviews would take considerably longer to obtain the depth of information desired. Additionally, I hoped CNG vehicle owners would be more revealing and provide explanations for their answers person than on the telephone (as [Richardson et al, 1995] argue in comparing interview methods). Also, a personal interview allows the interviewer the luxury of noting facial expressions and body gestures in their responses, interaction between spouses (where applicable), the validity of their answers (Richardson et al, 1995), and take that into account when interpreting their responses. This cannot be done with a telephone interview. Taking all research methods into consideration, it was determined household personal interviews would be most effective at capturing the ownership experience of a CNG vehicle.

It is not known exactly how many household CNG vehicle owners exist in the State of California. Not all owners responded to the initial solicitation letters and other metropolitan areas such as Sacramento and San Diego are not represented. Two owners in Sacramento were contacted, but neither replied. There were no dedicated CNG vehicle owners in San Diego at the time of the study. Without knowing exactly how many household CNG vehicle owners exist in California, it is difficult to speculate what

percentage of them were interviewed. There may have been 100 to 150 household dedicated CNG vehicle owners in California at the time the original contact list was obtained.

Due to the relatively small eligible sample population and the time required to conduct household personal interviews, the small sample of eighteen households was considered appropriate for this study. It was believed patterns would develop among the respondents based upon their ownership experience and that interviewing more owners would not significantly change the conclusions made based upon the experience of those interviewed in this study.

In the results/analysis section, some of the findings presented are a result of questions asked in the interviews, some from the written survey, and some from both. However, the results from which the charts and tables are generated are identified by an "I" or "S" for interviews and surveys, respectively. For questions asked on the survey, comments from the respondents are frequently included to provide a better feel for their opinions on the subject.

CNG vehicles owned by those interviewed consisted primarily of the Honda Civic GX. In fact, sixteen of the eighteen respondents owned a Civic GX, which ranged from model years 1998 to 2001. One respondent owned a CNG Dodge Ram van while the other owned a CNG Ford Crown Victoria.

Owner Characteristics:

It can be concluded that current owners of CNG vehicles are probably not representative of the car-buying population as a whole. These owners are highly educated and have high annual household incomes (10 of 15 over $125,000; 13 of 15 over

$100,000; 3 non-responses). Leasing the vehicle through their dealership was not available for the Honda Civic GX and while some would have preferred this option to minimize their financial risk, their income allows them to concede a substantial loss on their CNG vehicles if they choose to resell it. Interviews confirmed owners were persistent in accumulating information especially in the absence of a central information source and misleading and/or inaccurate information. They also carefully considered the costs and benefits of ownership and whether a CNG vehicle was an appropriate purchase decision. Most generally consider their household and CNG vehicles as simply a means of transportation. In general, these owners were emotionally detached from the purchase, which may also not be representative of the general car-buying population.

Current CNG vehicle owners are the first to take the risk of CNG vehicle ownership and likely have a higher level of tolerance for the inconvenience of refueling, reduced driving range, and reduced trunk space. Future CNG vehicle owners may not be as willing to accept these deficiencies when a gasoline vehicle is used as their vehicle of comparison.

Finally, CNG owners in this group were all between 31and 60 years of age and employed, which (will be revealed) is consistent with their desire to reduce travel time and improve travel time reliability via HOV lane access. Younger consumers were not represented in this sample perhaps because of a lower income-earning potential to absorb the losses involved with resale should that arise. The older demographic was absent perhaps because they are of retirement age and access to HOV lanes may not be a compelling incentive for ownership.

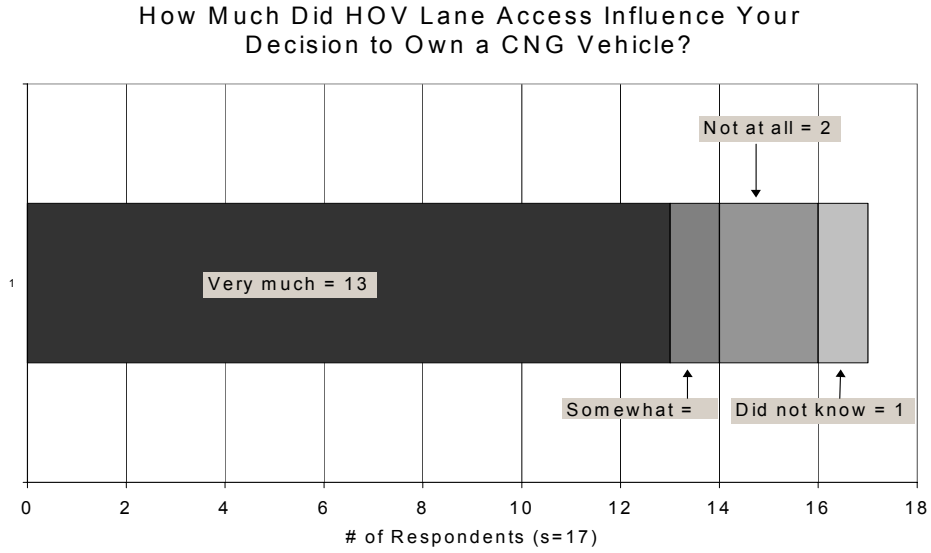
X. RESULTS/ANALYSIS OF INTERVIEWS AND SUPPLEMENTAL SURVEYS

A. PRE-OWNERSHIP/EFFECTS OF INCENTIVES

In this section, owners were asked a line of questions related to the period leading up to their decision to buy a CNG vehicle.

The primary motivation for the households I interviewed to buy a CNG vehicle is illustrated by the introductory story of Mike Sanders sitting in traffic, wishing he too could be driving in that fast moving carpool lane. Like Mike, access to HOV lanes was the single most influential of all incentives in the decisions of the interviewed households to purchase a CNG vehicle. Thirteen of 17 households stated that access to the HOV lane was "very" influential in their decision to purchase a CNG vehicle. One interviewee stated, "My entire reason for buying the car was to use the carpool lane." This comment was representative of a large number of CNG vehicle owners. When asked why they chose to own a CNG vehicle when they did, most began researching CNG vehicles as soon as they learned of the eligibility for CNG vehicles to access the HOV lane. One respondent said her reason to buy a CNG vehicle was, "Desperation. I drive 100 miles a day. That [carpool lane] was really the driving force behind the purchase. My commute was driving me crazy."

Figure 2 (S):



For those who did not purchase a CNG vehicle based on HOV lane access, two purchased their CNG vehicle before legislation for HOV lane access was implemented. Overall, the owners' response to this question confirms Hypothesis #1: This group chose to own a CNG vehicle primarily for the carpool lane privileges..

Just as the character of Mike Sanders did not test drive his CNG vehicle prior to purchasing, the majority of households interviewed (10 of 17) did not test drive or rent a CNG vehicle prior to their ownership, either. A few reasons explain this: Since most of the CNG vehicle models in this sample are produced in "batches" they are not always available in a dealer's inventory. This required several owners to place an order for the vehicle without driving it. Although placing an order is not the same as a purchase, interviews confirmed this was how respondents interpreted the question, since several stated they ordered the vehicle without a test drive.

Another reason for purchasing without test driving first is these owners were familiar with the gasoline version of the vehicle. They trusted the company offering the vehicle, and did not feel it required a test drive prior to purchase.

Those who did test drive a CNG vehicle can be categorized into two groups: Those who test drove the vehicle on the day of purchase and those who rented a CNG vehicle before buying to determine how it would integrate into their lifestyle. Of the second group, some rented a CNG vehicle for a day, while one respondent rented one for an entire month.

Table 1 (S):

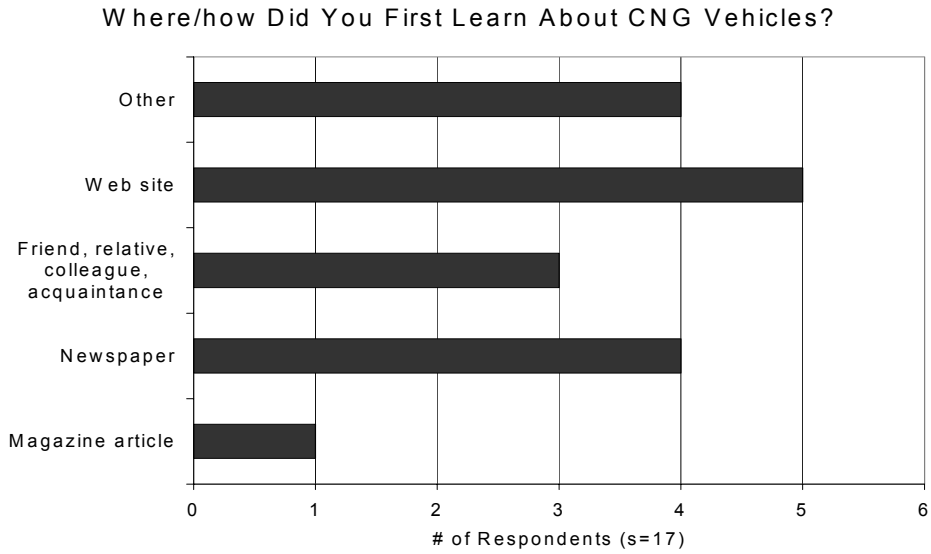
	Yes	No
Drive or Rent Before Owning?	7	10
Refuel Before Owning?	2	15

Like the character of Mike Sanders, most respondents (15 of 17) indicated they had not refueled a CNG vehicle prior to their purchase. In conversations with them, it appeared they were unaware the refueling process would be different from gasoline vehicles. This suggests those interested in CNG vehicles expected them to fuel much like gasoline vehicles.

When asked where they had first learned about CNG vehicles, owners offered a variety of sources. The most common was one of several internet web sites. If you recall, the character of Mike Sanders decided to investigate CNG vehicles when he saw a "Clean Air Vehicles OK" by a sign on the freeway. Respondents confirm this. Like Mike, their visit to CNG vehicle internet web sites was prompted by a highway sign or by a pamphlet

in their utility bill. Not only was the internet their initial source of information, but other sites on the internet were the overwhelming choice for follow-up and in-depth research.

Figure 3 (S):

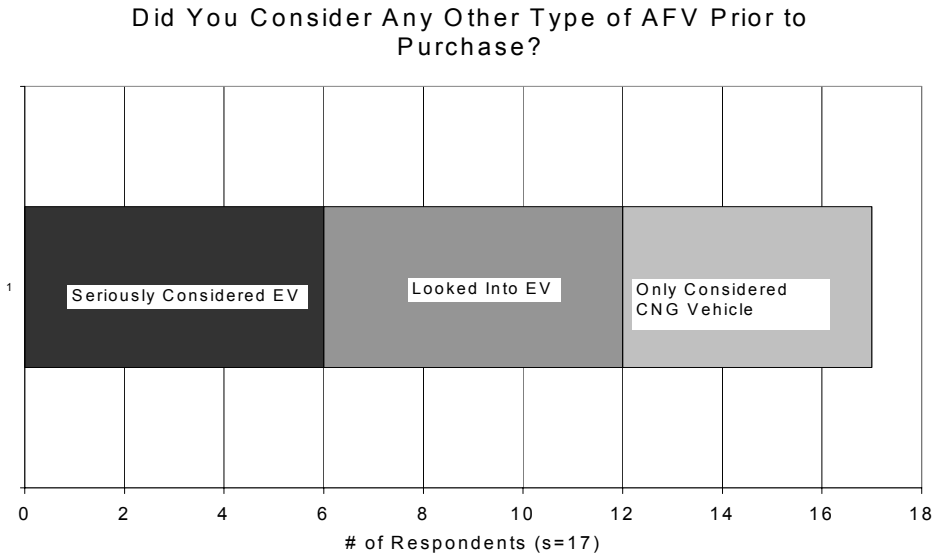


A frequent complaint of the respondents was the difficulty finding appropriate consumer CNG vehicle internet sites and obtaining accurate, reliable information once the correct web sites were found. This can be partially explained by the fact that internet sources for CNG vehicle information are also directed at fleets. Fleet operators have different information requirements than households. For example, all CNG vehicles are available to fleets, yet only a select few are available to consumers. Respondents complained this was not clarified on the web sites and that the models indicated available for consumer purchase was misleading.

Respondents were asked if they considered any other type of alternative fuel vehicle prior to CNG vehicle ownership. Just as the character of Mike Sanders looked into an electric vehicle before a CNG vehicle, so too did the households I interviewed.

Twelve of 17 households stated they had “looked into” or “seriously considered” an electric vehicle before they considered a CNG vehicle.

Figure 4 (I):

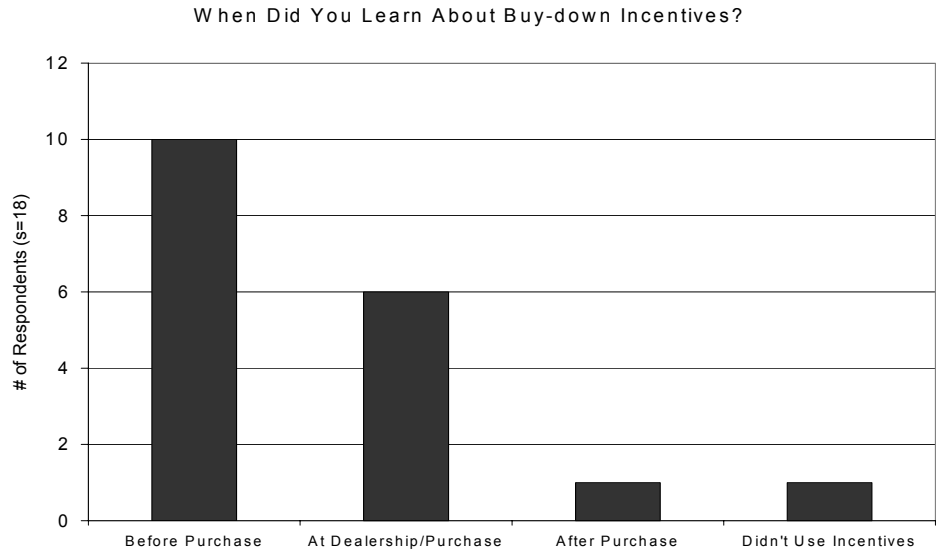


Many of the respondents would have preferred an EV over a CNG vehicle. However, they did not lease an EV because EVs did not meet the driving range demand for their commute, were too difficult to obtain, expensive, or were only available for lease. Those who looked into an EV but did not seriously consider one, did so briefly and quickly concluded an EV would not meet their needs for the same reasons. Five of 12 respondents only considered owning a CNG vehicle, they investigated no other AFVs.

An important factor in understanding the effects of government incentives on the decision making process of CNG vehicles is when the owners learned about the incentives. It appears this group of owners self-selected themselves for CNG ownership based upon knowledge of the incentive that influenced them the most: HOV lane access. However, it is plausible government incentives can play a more significant role if the

public was more aware of the incentives. In my opening story, the character of Mike Sanders did not learn of his local buy-down incentive until he had already decided to buy his CNG vehicle. However, while the majority of current CNG vehicle owners (10 of 18) learned about the incentives prior to their purchase, many of them were unaware of government buy-down and tax incentives for CNG vehicles prior to their purchase.

Figure 5 (I):

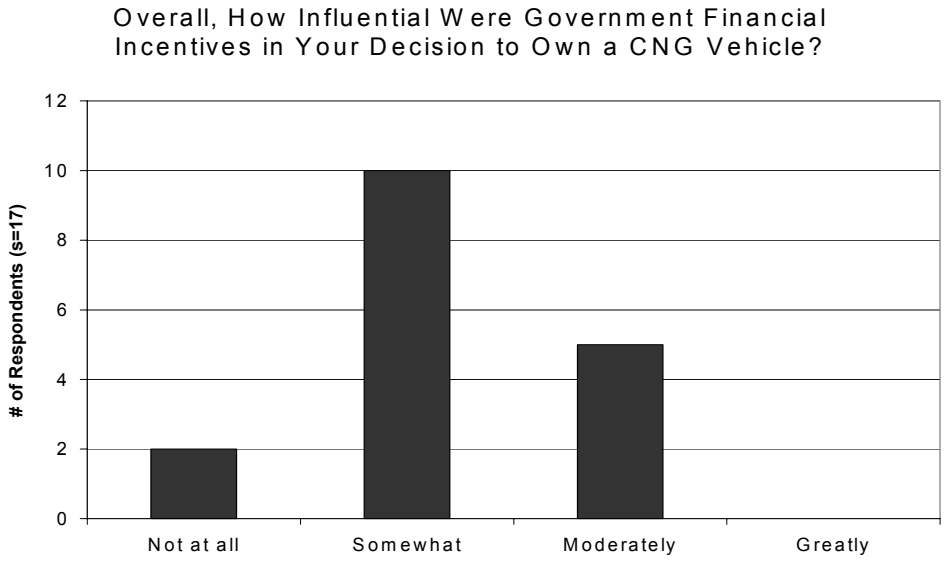


Since many current CNG vehicle owners were unaware of the local buy-down incentives for CNG vehicles this implies financial incentives were not influential in the decision to buy a CNG vehicle. It also implies that a segment of the population for whom the combined incentives of the HOV lane access and buy-down incentives may have an influence are not being reached.

When respondents were asked whether the government financial incentives (local buy-down or federal tax-deduction) influenced their decision to own a CNG vehicle, they

generally indicated they were "somewhat" influenced. Recall that four of the respondents were from the San Francisco Bay area and only the federal tax deduction would apply for them. Since incentives did not "greatly" influence any respondents' decision to own a CNG vehicle and since HOV lane access was the motivating factor for the purchase decision, government financial incentives played a secondary influential role for this group of owners. One respondent stated the incentives were "definitely a factor, but not a major factor." Another respondent commented the incentives "didn't drive my decision but they certainly helped."

Figure 6 (S):



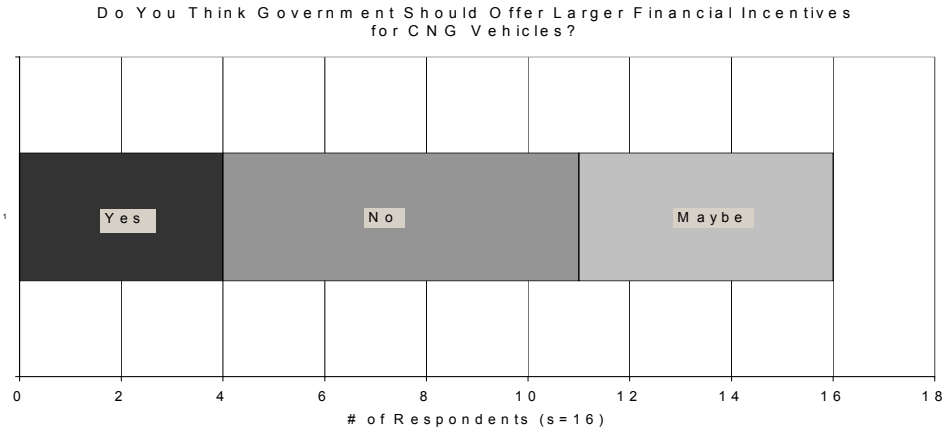
In summary, while financial incentives did not have much of an impact on the purchasing decision of this group, they were helpful. They eased the initial cost penalty of a CNG vehicle versus an equivalent gasoline vehicle.

Respondents were asked whether they would own a CNG vehicle had no financial incentives been offered. Sixteen said yes, the other two said maybe. This suggests access to the HOV lane was reason enough for them to purchase the CNG vehicle. This also confirms financial incentives played a minor role in the decision to own a CNG vehicle. Additionally, for those who did not buy a vehicle for HOV lane access, there were other reasons compelling enough for them to own a CNG that were stronger than the influence of financial incentives. These other reasons include environmental concerns and their self-perception as innovators. Thus, responses from current owners appear to reject Hypothesis #2: Contrary to that hypothesis, government buy-down and tax incentives did not play an integral role in the decision to own a CNG vehicle.

Another question posed in the interviews is whether respondents believe government should be offering greater incentives for CNG vehicles. Many answered "no" (7 of 16), indicating the current incentive package was reasonable or sufficient. However, some believed even though the financial incentives did not influence their decision, they did value the incentives and believe government should be offering additional incentives considering significant drawbacks in ownership exist which are not fully compensated by HOV lane access. Those who answered "maybe" tended to believe if government is serious about increased market growth of CNG vehicles, it may be necessary to offer greater incentives. One respondent commented,

> "If they want to increase the number of these cars on the road, then they need to make it sweeter. At least make it cheaper. The cost of ownership is probably a push (when compared with a gasoline vehicle)."

Figure 7 (I):



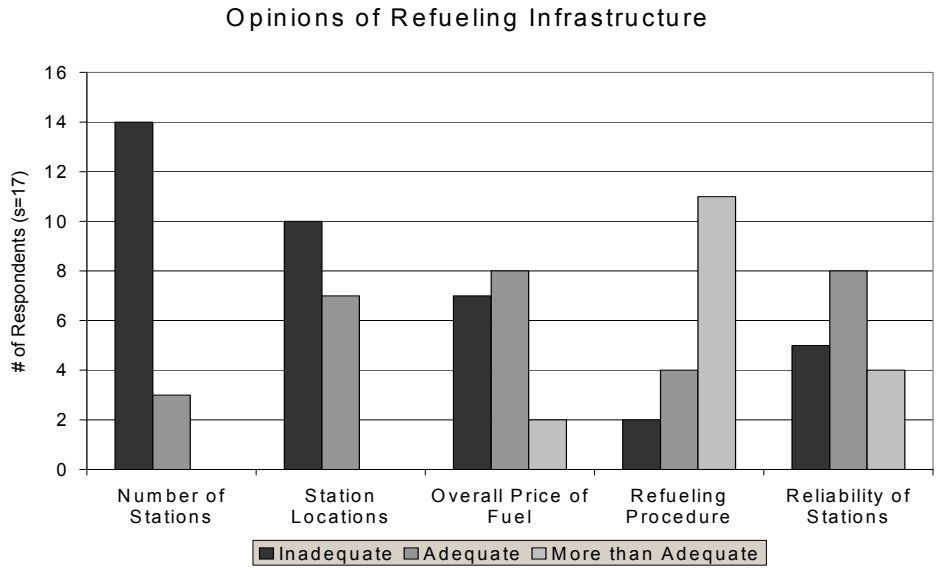
In some cases, respondents answered in a manner which reflected their personal opinions whether *they* should have received more incentives (those answering "yes"), while others answered on grounds of what would be necessary for further market growth of CNG vehicles (those answering "maybe").

B. REFUELING

The topic of refueling evoked very strong opinions from this group of CNG vehicle owners. Some owners feel the refueling infrastructure is meeting their basic needs. However, almost all agree much improvement is necessary if CNG vehicle ownership is to become a viable option for many people.

In my opening story of Mike and Jane Sanders, a primary complaint was their CNG vehicle was very inconvenient to refuel and they could not drive as far on a tank of fuel as they could a gasoline vehicle. This describes the experience of most current CNG vehicle owners. They were asked to provide their opinions on the adequacy of the current refueling infrastructure. Their responses are summarized in Figure 8.

Figure 8 (S):



Number of Stations:

Most CNG vehicles owners were dissatisfied with the number of CNG refueling stations. The limited refueling infrastructure has had a major impact on how they use their vehicle. When they were asked if the lack of refueling infrastructure prevented them from driving places they would otherwise like to drive, nearly all owners answered affirmatively. A representative comment was, "If there were more fueling stations, this vehicle would be viable for more than just commuting." Another respondent replied, "Yes, definitely. I would drive the car all around…I would like to take it out to Corona (about 50 miles from this respondent's house) but I have to plan my trip and am nervous about going out there and if they will accept my card."

When respondents want to take their CNG vehicle somewhere they are uncertain about CNG fuel availability, they will usually take their gasoline vehicle instead. Since finding a gasoline station is comparatively easy, they eliminate the risk of not finding fuel

they would otherwise be taking if they drive their CNG vehicle to an area with which they are unfamiliar.

CNG vehicle owners will sometimes experiment with new stations which allows them to increase the geographic area they feel comfortable driving their CNG vehicle. This usually involves a "trial" trip, where the owner would experiment with a new station. However, they only do this when they have enough fuel to return to a more familiar station.

Station Locations:

Respondents did not express the same level of dissatisfaction with station locations as they did with the number of stations. However, they believe improvements can be made. In the interviews, most CNG vehicle owners indicated that while the number of stations is inadequate, the actual location placement was adequate. Like the character of Mike Sanders, they stated refueling stations were often located close to the freeways along their commute route. Of those displeased with station locations, most expressed a dissatisfaction with gaps in the refueling system which reduced the confidence under which they could travel beyond their "comfort zone."

Unlike gasoline stations, CNG fueling stations are usually unattended and located in industrial areas. As a result, a minor complaint among CNG vehicle owners is that some refueling stations are located in neighborhoods they consider unsafe. Some owners are unwilling to fuel at these locations even though they may be more convenient than their preferred station. Additionally, because of these reasons a number of respondents (usually females) indicated an unwillingness to refuel their CNG vehicle after dark at some locations.

Most CNG fueling stations are located close to the freeways on which the CNG vehicle owners drive. Interviews confirmed they are generally satisfied with the placement of the stations since they make refueling convenient along their commute route. Their response on the survey to this question is more likely a result of the geographic distribution and inadequate number of stations than the placement of current stations.

Overall Price of Fuel:

Respondents' opinions of the overall price of fuel were mixed. Opinions differ according to when they purchased the vehicle. Those who purchased a vehicle before the recent rise in CNG fuel prices expressed more dissatisfaction than newer owners who never experienced the lower fuel prices.

Respondents were generally displeased with the instability of CNG fuel prices primarily because these vehicles are promoted as enjoying a tangible advantage in fuel costs over gasoline. Interviews confirmed the price of CNG fuel has fluctuated substantially in the past year and owners feel they are at the mercy of the fuel providers since few alternatives exists for them within their daily driving patterns. One respondent noted, "Fuel price as been pretty random," implying CNG fuel prices vary considerably even among stations within close proximity to each other. Their dissatisfaction with stability of CNG fuel prices, however, can also be partially explained by the volatile energy market the past year (if you recall, most have owned their vehicles a year or less) and may not represent the long-term price stability of CNG fuel.

Refueling Procedure:

The majority (15 of 17) of owners did not have any complaints with the process of refueling their vehicle. When interviewed they stated a learning curve is involved with

refueling the vehicle and two types of refueling procedures must be learned. They stated refueling a CNG vehicle was no more difficult than a gasoline vehicle. However, one fuel provider does require account applicants to be trained by their staff prior to accessing their CNG refueling facility. Finally, one owner who suffered from arthritis complained about the difficulty of the refueling procedure. She did not indicate if refueling a gasoline vehicle was more or less difficult than refueling a CNG vehicle.

Reliability of Stations:

Opinions of CNG refueling station reliability were mixed. Their overall opinions were highly influenced by the stations at which they most frequently fueled. Most (12 of 17) indicated the reliability of stations was either "adequate" or "more than adequate." However, two reasons were given for rating the reliability of refueling stations as "inadequate" (5 of 17). One, occasionally a pump does not operate. Thus the driver must use another pump at the station or drive to a different station location. Two, due to the increased demand for CNG fuel by fleets at a few station locations, the pressure to which they can refuel their tank is variable at certain times of the day (usually late morning at those stations where this is a problem). Several CNG vehicle owners told stories of waiting in line to fuel behind a fleet of CNG taxi cars or buses. This not only imposed a considerable delay but more importantly depleted the compressor of its charge. When it was the respondents' turn to refuel, occasionally they could only fill to 2,000 psi; considerably less than the rated 3,000 to 3,600 psi to which they were accustomed. When this happens, the tank is not filled entirely and the vehicle's driving range is further reduced. In summary, anecdotal evidence from respondents suggests the increased overall demand for CNG fuel due to public fleets has had an adverse impact on the reliability of some refueling stations. This criticism, however, appears to be limited to the stations

which experience heavy fleet usage. The majority of CNG fueling stations do not appear to have problems with overuse at this time.

To understand the extent of owners' knowledge of natural gas vehicles prior to their purchase of such a vehicle, respondents were asked where in their decision-making process they researched CNG fueling locations. Prior to their purchase, most owners (15 of 18) conducted varying amounts of research with regards to where they would fuel their vehicle. Like Mike Sanders in my opening story, much of the respondents' research was conducted on the internet. In contrast, some only considered where they would refuel their vehicle when they reached the dealership. At this point, the salesman showed them a booklet of fueling station locations. A small number of owners did not research the refueling network until after they purchased their vehicle. All respondents had a copy of the station location booklet and it was the source of subsequent searches for CNG refueling stations beyond those they could retain by memory.

The large number of respondents who researched the refueling network prior to purchase indicates this group of owners was aware of the limitations in the refueling structure and carefully considered whether it would meet their basic fueling needs to justify ownership of the vehicle. If you recall, the character of Mike Sanders had conducted some preliminary research to determine if there were refueling sites along his commute route. This was representative of most current CNG vehicle owners. In one interview a respondent said, "I needed to find out in advance where the stations were located relative to my commute." Another respondent said, "We did research before we bought and found the stations near us…we wanted to know how limited we were going to be on this vehicle." This group of owners appeared to take the limited refueling into

consideration in determining whether their driving patterns were compatible with the refueling network.

When owners were asked in the interviews whether they purchased their CNG vehicle based on the current refueling infrastructure or future expansion, 13 of 17 respondents indicated they bought based on the current refueling network. They commonly expressed they were hoping for future expansion, just not *expecting* it. One respondent said, "We were hoping that it was going to expand. We didn't know if there was a plan to increase the number of stations. Hoping but not expecting." A small group of respondents (3 of 17) indicated an expectation of further growth in the refueling network as a factor in their purchase decision. Of those respondents, one said, "Absolutely expecting it to expand. In a year nothing has happened." While most CNG vehicle owners are committed to long-term ownership based on the current refueling infrastructure, this is the area they believe improvement is most necessary.

Question 1 (I): ***WHAT IS THE FARTHEST DISTANCE YOU WOULD HAVE BEEN WILLING TO DRIVE TO REGULARLY REFUEL YOUR VEHICLE?***

Some CNG vehicle owners expressed their response to this question in distance and others in travel time. Those who answered in distance frequently said "less than x miles" off the freeway or from home/work. Another typical response was, "if more than my current situation, I would have to reconsider." Therefore, quantification was difficult. However, analysis of the interviews confirmed they seem to have an outer bound which they were willing to regularly drive off the freeway or from home/work to refuel their vehicle. A few indicated 10 miles while most were clustered around the 5 mile range.

Others measured their tolerance for fueling in travel time. These owners generally stated a tolerance of 5-10 minutes.

It was frequently mentioned if they had to travel too far out of their way in one direction, this would adversely affect the overall driving range of the vehicle (which is already reduced compared to a gasoline vehicle). While their tolerances were mentioned above, most do not currently have to drive this far out of their way to refuel. Most mentioned the station locations were conveniently located off the freeways they drive, though some changed their commute route to access the stations with whom they have a refueling account.

The following two figures illustrate five and ten-mile concentric circles around current refueling stations in the San Francisco bay area and Los Angeles area, respectively. While it cannot be assumed the general car-buying public is willing to drive either of these distances from their homes to regularly refuel their vehicles, the figures illustrate the outer bounds of current owners' tolerance for driving to refuel their vehicle. Since current CNG vehicle owners highly value their travel time as much, if not more, than the general car-buying public, are willing to drive these distances to refuel, and most fueling stations are not overused, this supports Hypothesis #3: the current CNG refueling infrastructure is capable of supporting more growth in the household CNG vehicle market.

Figure 9:

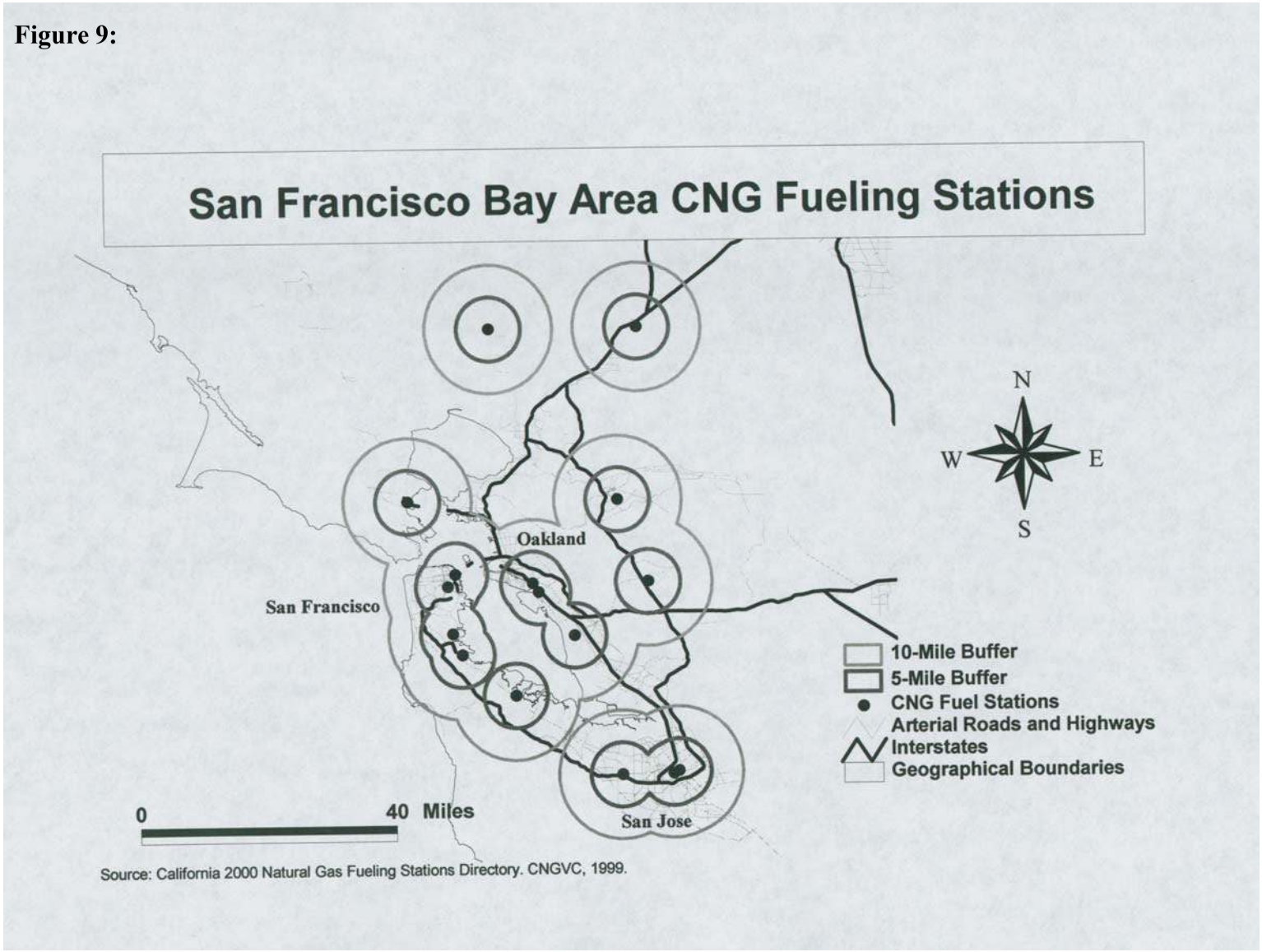
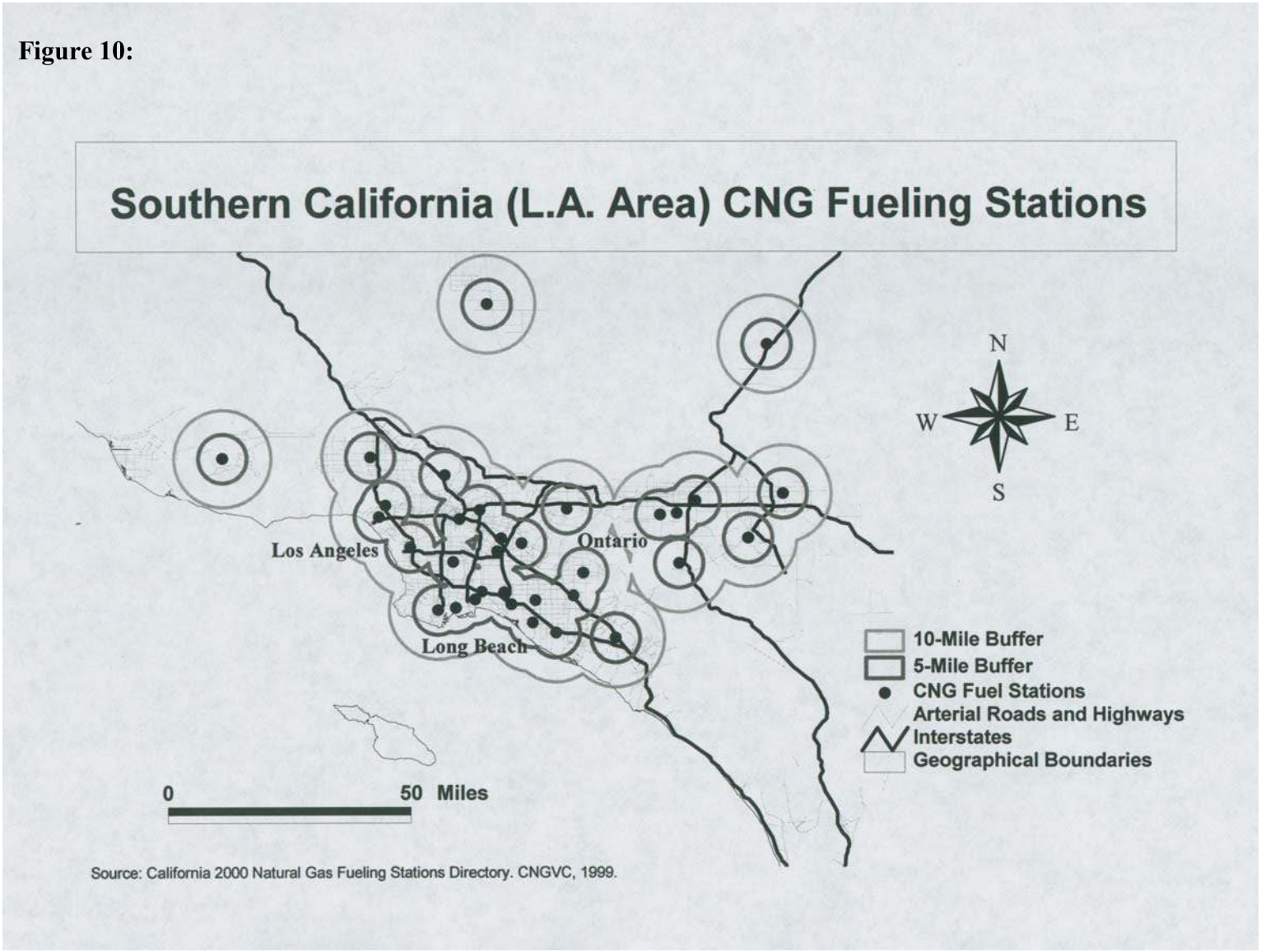

San Francisco Bay Area CNG Fueling Stations
N
W
E
S
Oakland
San Francisco
San Jose
10-Mile Buffer
5-Mile Buffer
CNG Fuel Stations
Arterial Roads and Highways
Interstates
Geographical Boundaries
0
40 Miles
Source: California 2000 Natural Gas Fueling Stations Directory. CNGVC, 1999.

Figure 10:

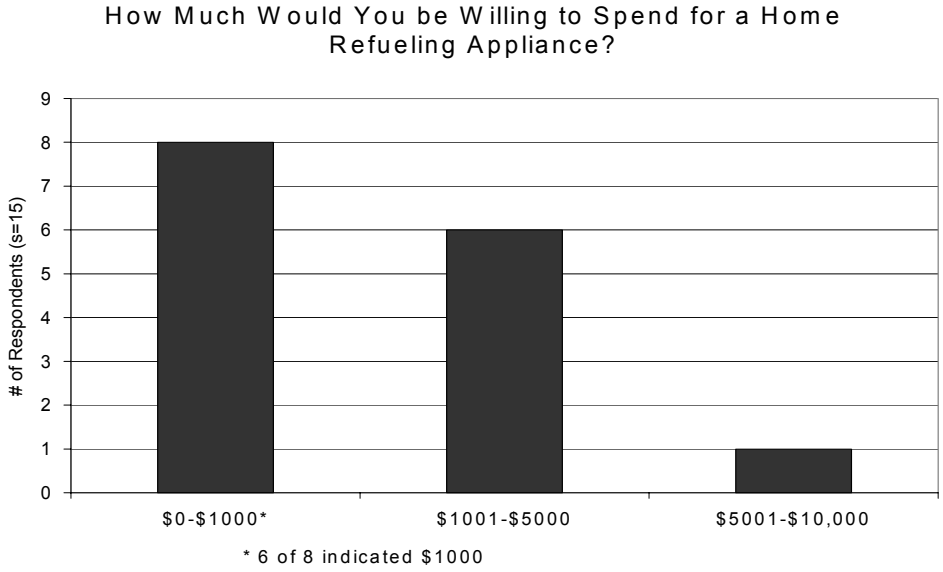

Southern California (L.A. Area) CNG Fueling Stations
N
W
E
S
Los Angeles
Ontario
Long Beach
10-Mile Buffer
5-Mile Buffer
CNG Fuel Stations
Arterial Roads and Highways
Interstates
Geographical Boundaries
0
50 Miles
Source: California 2000 Natural Gas Fueling Stations Directory. CNGVC, 1999.

Respondents were asked their extent of interest in owning a home refueling appliance. They are very interested in home refueling. This likely is due to the inconvenience of using the public refueling stations. They frequently claimed more travel time could be saved along their commute if they could fill their vehicle overnight at home.

A few respondents researched home refueling appliances extensively. However, due to obstacles such as cost, building code regulations, or reliability and maintenance uncertainties, it was not feasible for them to pursue it further. Additionally, while most expressed an interest in owning a home refueling appliance, a few respondents expressed apprehension about the safety of the device and would only consider owning one if safety was ensured.

As a follow-up to that question, respondents were also asked how much they would be willing to spend for a home refueling appliance. The most frequent response (6) was they were willing to spend $1,000 or less. In all, 8 of 15 respondents would spend somewhere between $0-$1,000 with the lower bound expressed by one owner as “a couple hundred bucks”.

Figure 11 (I):



A home refueling device currently costs about $6,000 for plus installation costs according to FuelMaker, the leading manufacturer of CNG home refueling devices. Others, however were willing to spend much more for this convenience as evidenced by 6 of 15 respondents willing to spend between $1,001-$5000. Only one respondent stated a willingness to spend as much as $10,000 for this convenience. While nearly all respondents would like to fuel at home, their willingness to pay for the home refueling appliance varied considerably.

C. OWNERSHIP EXPERIENCE

At the time of the interviews, most respondents (15 of 17) had owned their CNG vehicle for less than a year. As mentioned previously, CNG vehicles are produced in batches. The lengths of ownership tended to cluster around what appeared to be the two delivery periods for the vehicles. Two respondents were very early adopters of CNG

vehicle technology and owned the first generation Honda Civic GX for over two years. The gap between one year and two years of ownership can be partially explained by legislation which allowed CNG vehicles access to the HOV lane in July, 2000. Since this was the primary factor in the CNG vehicle purchase decision, there was little incentive for this first group of owners to purchase before then.

Table 2 (S):

	Length of Ownership (s=17)
<6 months	7
6-12 months	8
1-2 years	0
> 2 years	2

How long CNG vehicle owners planned to own their vehicles was asked in both the interviews and the supplemental surveys. However, for presentation the responses from the interviews were considered most valuable.

Table 3 (I/S):

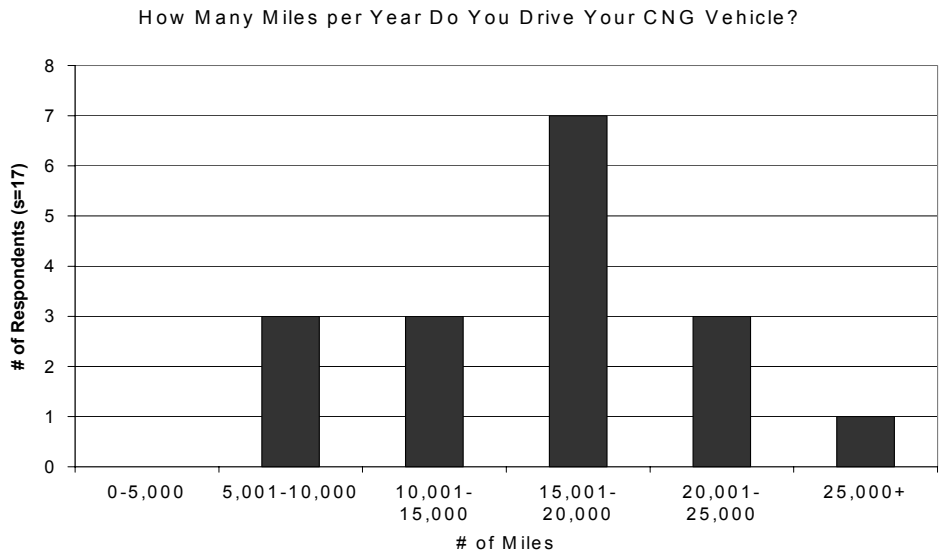
	How Long Do You Plan to Own Your CNG Vehicle? (s=14)
0-5 years	3
6-10 years*	8
11-15 years	1
>15 years	2

*6 of 8 indicated 10 years

Responses indicate household CNG vehicle owners are probably not typical of the average driver. Nine of 14 respondents indicate they plan to own their CNG vehicle for at least ten years. While this seems somewhat unusual, a few factors help explain why this group of CNG owners may differ from typical gasoline vehicle owners: Some CNG vehicle owners keep all their vehicles for a very long time and view them simply as transportation from point A to point B, so the long ownership expectancy is not unique to the CNG vehicle. However, some only view their CNG car in this manner since several acknowledged ownership of a CNG vehicle is a risk and from a cost-effectiveness perspective, a long ownership period is necessary.

Respondents put many miles on their CNG vehicles. Eleven of 17 owners claim to drive their vehicle more than 15,000 miles per year while 6 of 17 drive less than 15,000 miles annually. The high annual mileage of these vehicles is consistent with the claimed use of these vehicles as commuter cars. Three factors help explain this: the owners tend to have longer commute (35-50 miles each way), more moderate commutes (15-35 miles each way), and/or they use their vehicle for purposes in addition to commuting. In contrast, interviews revealed those with lower annual mileage were likely to only use the CNG vehicle as a commute car and had moderate one-way commutes.

Figure 12 (S):



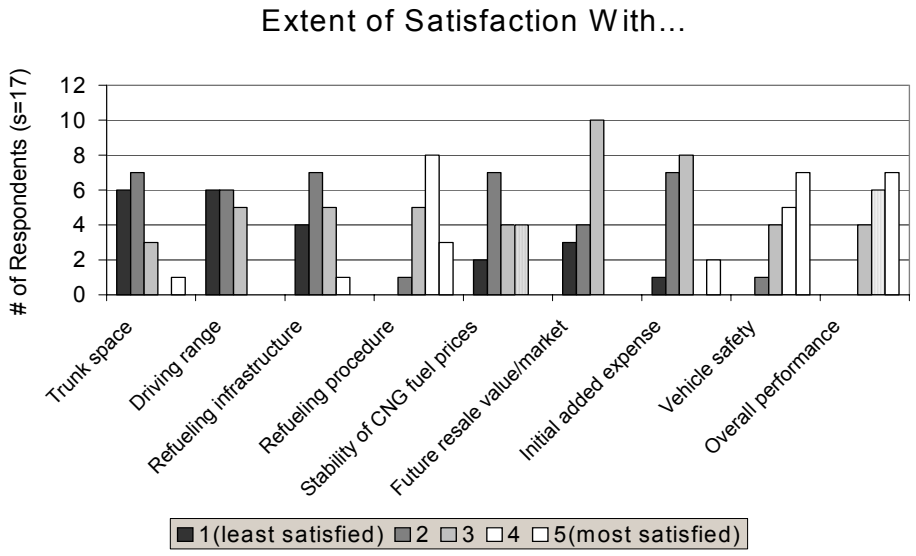
Interviews also revealed those who purchased the CNG vehicle for carpool lane access drove a long enough commute to justify the travel time savings/reliability of CNG vehicle ownership. However, none of them commuted more than 50 miles one-way. This suggests that perhaps current CNG vehicle owners are representative of a niche: one where HOV lane access does not justify CNG vehicle ownership for those with short commutes because travel time savings is insignificant, and also where CNG vehicle ownership is not justified for very long commutes (perhaps over 50 miles one-way) because the travel time benefit is partially lost as a result of the need to refuel the vehicle much more frequently (and usually along the commute).

In contrast, annual mileage of CNG vehicles differ significantly from vehicles in the Electric Drivers Survey (CEC, 2000). Lessees of electric vehicles were driving those vehicles an average of 7,000 to 8,000 miles annually (CEC, 2000). This suggests perhaps CNG vehicles are better suited for displacing petroleum than EVs while generally offering superior tailpipe emissions to gasoline vehicles (though still not as good EVs).

In a previous section of this report (Section VIII, A), I challenged an assumption in the CALCARS econometric model that a CNG vehicle would replace a vehicle in the household fleet. The character of Mike Sanders in my opening story did not replace one of his gasoline vehicles, but most CNG vehicle owners (9 of 14) did. This does not imply, however, the CNG vehicle is the respondents' only vehicle (an assumption not clarified in the econometric model). Rather, all respondents owned more than one vehicle. Five of 14 respondents purchased their CNG vehicle as a supplement to their household fleet without replacing any previous vehicles they owned. This supports the idea that CNG vehicles function very well in a "hybrid-household," where there is at least one gasoline vehicle in the fleet. Interviews from owners revealed CNG vehicles are not only useful for commuting but are an adequate replacement for one of the gasoline vehicles in the household.

Respondents were asked the extent of their satisfaction with various aspects of CNG vehicle ownership. The column graph above illustrates the relative level of satisfaction, ranked on a scale of 1 (least satisfied) to 5 (most satisfied) for each topic. Responses are averaged and displayed adjacent to each topic heading in the following sections.

Figure 13 (S):



Trunk Space:

CNG vehicle owners are generally dissatisfied with the volume of trunk space occupied by the CNG fuel cylinder. However, these opinions are tempered by the stated purpose of their CNG vehicle (primarily a commute vehicle). Therefore, respondents state they rarely need to carry anything in the trunk. Several respondents indicated the reduced trunk space prevents them from taking trips in the CNG vehicle which they would otherwise like to go. Interviews with the respondents revealed this is an important area for improvement.

Driving Range:

In the story of Mike and Jane Sanders, one of their criticisms of the CNG vehicle was the reduced driving range. Current CNG owners share the opinion that driving range is one of their main concerns. This is closely related to the limited refueling infrastructure. Since none of the people in this group have previously owned a CNG vehicle or AFV, they have no previous experience with the reduced driving range

imposed by the vehicle. The reduced driving range has imposed more inconvenience than they expected. However, the issue is slightly more complex than it seems on the surface. Owners do not generally criticize the range because they cannot drive where they need to on a daily basis (which is sometimes imposed by an EV), but rather the inconvenience it imposes on the necessity to refuel so frequently (especially without access to home fueling). CNG vehicle owners indicate that as a result of the reduced driving range, they must refuel every two or three days which as previously mentioned, negates some of the advantage of travel time savings due to HOV lane eligibility. The reduced driving range and limited refueling infrastructure also prevents drivers from taking the vehicle on trips outside their normal "activity space." This is evidenced by one respondent who said, "…there's also the fear of running out of gas. You know you have limited range and the penalty for running out of CNG is much worse than running out of gasoline." The fear of running out of fuel is also a deterrent for taking trips in the CNG vehicle they would otherwise like to take. However, when asked if they would be willing to concede even more of their trunk space for more range, most stated they would not be willing to make that sacrifice.

Refueling Infrastructure:

CNG owners are dissatisfied with the CNG refueling infrastructure. Most mentioned if the driving range of the vehicles was greater the infrastructure would be more tolerable, yet if the refueling infrastructure were more ubiquitous they would not be as dissatisfied with the driving range of their vehicles. The results of this question essentially summarizes findings previously mentioned.

While not specifically asked in the survey, interviews with CNG vehicle owners revealed there is a general dissatisfaction with the payment system for refueling their

vehicles. In both the San Francisco Bay area and Los Angeles area there are several different CNG fuel suppliers, each requiring separate accounts and most require separate cards to dispense fuel. CNG vehicle owners would like to see a standardized payment system or the ability to purchase fuel with a credit card or ATM instead. In Southern California, a standardized payment system is in development, but not yet implemented (CNGVC, 1999).

Refueling Procedure:

As mentioned previously (Section X, B) respondents were content overall with the process of refueling their CNG vehicle.

Stability of CNG Fuel Prices:

As mentioned previously (Section X, B) respondents expressed disappointment with the overall stability of CNG fuel prices even though they purchased their vehicle after prices rose considerably. They were also dissatisfied with the price variability of CNG fuel among stations in close proximity to each other.

Future Resale Value/Market::

Respondents are aware of the risk in CNG vehicle ownership. Some respondents expressed concern over the resale value of their vehicle. However, since the majority intend to own their vehicle for ten years or more, they speculate the car would not have any value at that time. This could explain why 10 of 17 responded they were neither satisfied nor dissatisfied to this question.

Initial Added Expense:

As mentioned previously, a new CNG vehicle imposes costs of about $2,500 to $5,000 more than a gasoline equivalent vehicle (Gushee, 1995). The vast majority of owners in this study own a Honda Civic GX, which costs $4,000 more than a gasoline

Honda Civic LX. A $3,000 buy-down incentive is offered in the South Coast Air Quality Management District to help reduce the cost and make CNG vehicle ownership more appealing. In the Bay Area Air Quality Management District, buy-down incentives are not offered for consumer CNG vehicle purchases. Therefore, the incremental expense was greater for some than others. CNG owners in Southern California (14 of 18 interviewed) felt the $3,000 rebate was adequate, though a few complaints were made of dealerships' unwillingness to "deal" on these cars and had a "take it or leave it" position towards the sale of the vehicle. This suggests perhaps a misunderstanding exists by the owners of the true incremental cost of the vehicle for the dealer. However, according to invoice pricing on the Honda Civic GX, there appears to be negotiation room available as a $1,200 discrepancy currently exists between dealer invoice and Manufacturers Suggested Retail Price (MSRP) on 2001 models.

Vehicle Safety:

A previous study (Turrentine, 1992) indicated those with little experience or knowledge of CNG vehicles are concerned they are rolling "bombs" due to the high-pressure cylinder tank, despite a commendable safety record in all vehicle applications. In contrast, CNG vehicle owners interviewed for this study are confident in the safety of their CNG vehicle as evidenced by their response to this question. While overall safety of the vehicle was considered rather than just the fuel system, interviews confirmed CNG vehicle owners researched the issue of vehicle safety on various internet sites and believed their CNG vehicle was at least as safe as a gasoline-equivalent vehicle. It is hypothesized some owners may have compared the safety of their CNG vehicle (in most cases a subcompact vehicle) to others on the road, which may explain a "2" or "3" response to this question.

Overall Performance:

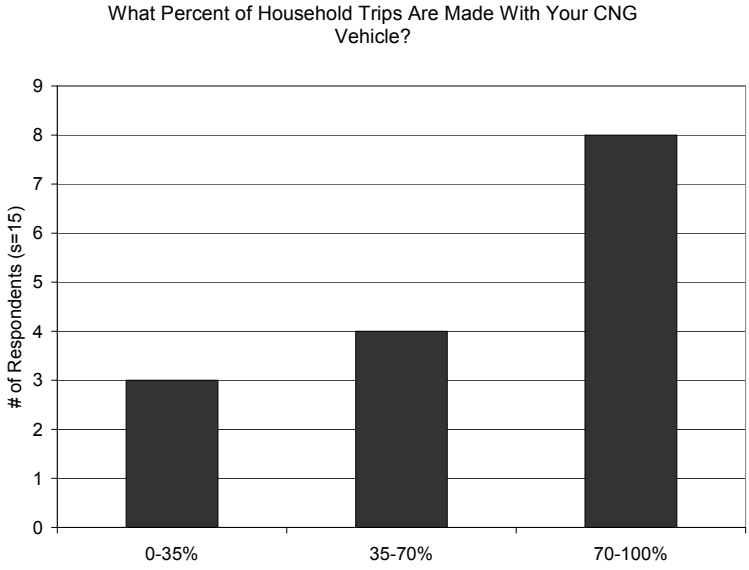
Respondents were generally pleased with the overall performance of their CNG vehicle. This question was duplicated in the household interviews and included any definition of "performance" the respondent felt applied (such as handling, acceleration, braking, ignition/starting, etc.). The character of Mike Sanders was pleased with the performance of his vehicle, noting it drove like the Honda Civic LX he test drove. This was representative of most current CNG vehicle owners' impressions as they were extremely pleased with the operation/performance of the vehicle or at least compared to their expectations. With regards to performance, one respondent said, "I love it." Another said, "Certainly fine for me," while a third said, "Great, excellent." The most common sentiment expressed was representative of one respondent who said, "The vehicle is just like a regular Honda Civic as far as I can tell. I think performance is great." There was only one complaint in the interviews with cold-starting the vehicle, (which had been an issue of dual-fuel CNG vehicle conversions in a previous study [Greene, 1989]). This was probably because the respondent was accustomed to a gasoline vehicle. However all owners stated they were always able to start their vehicle.

A few respondents were less enamored with the vehicles' performance claiming it was "adequate," or "I wouldn't say it's great. Fine compared to what I expected." These comments suggest any disappointment with the performance of the vehicle was not inherently related to the CNG technology, but rather the nature of a 4-cylinder subcompact vehicle combined with an automatic transmission.

In the interviews respondents were asked to estimate what percentage of their total household trips were made with their CNG vehicle. This included all trips of all eligible drivers in their household. While their responses are not scientifically derived, it

does provide an indication how CNG vehicles are used in a household. While most owners purchased their CNG vehicle as a commute car and for access to the HOV lane, substantial anecdotal information suggests the owners use their vehicle for more than purely commuting. This is loosely confirmed by the fact most owners replaced a gasoline vehicle with a CNG and the high annual mileage of their CNG vehicle (though this could also be explained by long commutes). It appears CNG vehicle owners use their vehicle for more than just commuting and displace a large number of trips and mileage from the gasoline vehicle(s) in their household fleet.

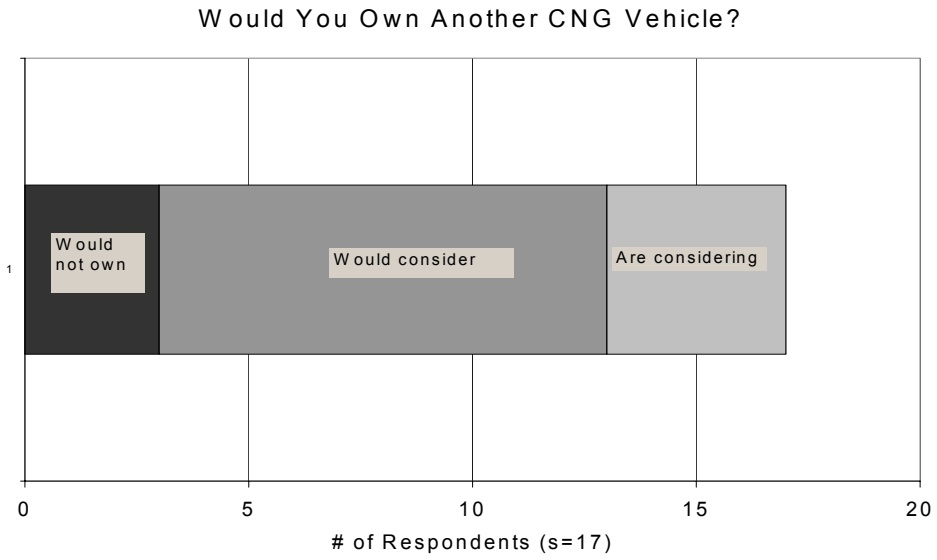
Figure 14 (I):



Eight of 15 indicate they use their CNG vehicle for 70-100% of their trips and prefer driving it to other vehicles in their fleet. Others, however, do not use the vehicle beyond commuting and tend to be households owning more than two vehicles, including the CNG vehicle.

Based on their current ownership experience and incentives (HOV lane access, buy-down incentives, etc.), most owners (14 of 17) stated they would buy or are considering buying another CNG vehicle in the future. One respondent said, "Depending on my situation and incentives…perhaps. It makes a fine second car. I wouldn't want to have all CNG cars." Another respondent said, "Yes, if the benefits were the same."

Figure 15 (I/S):



Most owners are pleased with their ownership experience and would consider another CNG vehicle in their household fleet. Most owners replaced a gasoline vehicle with the CNG vehicle, they have high annual mileage on their CNG vehicles, they claim to make a large number of trips with their CNG vehicles, and most would buy another one. These points all support Hypothesis #4: CNG vehicles function very well when integrated into a "hybrid-household" where the CNG vehicle complements one or more gasoline vehicles in the household fleet.

QUESTION 2 (I): ***WHAT DO YOU THINK WOULD BE EFFECTIVE AT FURTHER STIMULATING THE HOUSEHOLD MARKET FOR CNG VEHICLES?***

While current owners of CNG vehicles are not experts on marketing strategy and/or government policy towards promoting CNG vehicles, they can provide insight with regard to the types of incentives which were effective at influencing their decision and which may make ownership appealing to more people.

The following list provides some of the most common ideas presented by this group of owners for further stimulation of the household CNG vehicle market:

- More media exposure, advertising, publicity, marketing, and awareness (nobody knows about CNG vehicles)
- More refueling stations
- Home refueling should become viable. This could be accomplished with a lower cost out of pocket cost, with financial incentives, or as part of the package as was done with electric vehicles.
- More models available and more options. Many would have preferred a CNG Honda Accord. Others would like the CNG Toyota Camry available to the public. Respondents stated a preference for these vehicles because they were larger and more comfortable than the Civic GX.
- Preferred parking at desirable locations such as malls, downtown locations, etc. Another idea was to waive fees on parking meters for CNG vehicles.
- Reduced/exempt registration fees, taxes, etc.
- Subsidized fuel to ensure the price advantage of CNG over gasoline.
- Trade fairs to increase public exposure to CNG vehicles.

- Education of the next generation, children in particular, to instill the benefits of alternative fuel vehicles and make them aware of environmental at an early age.
- More driving range on the vehicle. Respondents would like a driving range comparable to a gasoline vehicle, around 300 miles
- Tax breaks. Even though tax and financial incentives for current owners were not influential in their decision to purchase a CNG vehicle, they believe more financial incentives, such as an annual tax deduction, may be necessary to influence more car-buyers to consider purchasing a CNG vehicle.

The most frequent comment expressed by this group of owners was they believe the general public is simply not aware of CNG vehicles. More media exposure, advertising, publicity/marketing, and consumer awareness of CNG vehicles should be the first step if substantial growth is desired in the household CNG vehicle market. Econometric models of AFV/CNG vehicle markets were previously criticized because they assume a perfect level of knowledge from the general public. In this case, the general public appears completely unaware of CNG vehicles, therefore they do not have a foundation from which to make an informed opinion. The CNG vehicle market will likely see little growth until the general public becomes aware of them, both their advantages and disadvantages. In contrast, the general car-buying public seems aware of hybrid-electric vehicles (HEVs) largely due to marketing efforts of automobile manufacturers and media exposure, despite their recent introduction compared with CNG vehicles. CNG vehicles have not received the same level of exposure from media, automobile manufacturers, and government at the consumer level despite similar or better tailpipe emissions certification and the advantage of gasoline displacement (as opposed to

reduced gasoline consumption), and access to the HOV lanes when compared with HEVs.

The recurring theme of the general public's unfamiliarity with CNG vehicles combined with the favorable ownership experience of this group of CNG vehicle owners, supports Hypothesis #5: household CNG vehicle market growth has been slow due to an absence of public awareness not a lack of public acceptance of CNG vehicles per se. Therefore, the conclusion can be made there is considerable market potential for CNG vehicles if public awareness increases.

D. SUMMARY:

Based on the results from semi-structured household interviews and supplemental questionnaires, a few conclusions can be drawn from the effects of government incentives, vehicle refueling, ownership experience, and the demographics of CNG vehicle owners:

i. Government Incentives:

The story of Mike and Jane Sanders in the opening story, as representative of interviews with CNG vehicle owners, clearly indicates government financial incentives, both local buy-down incentives and federal tax deductions may have had an insignificant impact on the decision to purchase a CNG vehicle at this point in time. This may be especially true in the San Francisco Bay area where no local buy-down incentives were offered. For natural gas vehicle owners there, the $2,000 federal tax deduction was the only applicable financial incentive and had virtually no impact on the purchase decision of the four households interviewed. Even in the Los Angeles area, nearly all respondents revealed they would have purchased the CNG vehicle even if the $3,000 local-buy down

incentive were unavailable. The questionable impact of government incentives to influence a purchase decision suggests, in the absence of a public information campaign advocating CNG vehicles, perhaps buy-down incentives were not a cost-effective use of government funding. However, future populations may be more influenced by financial incentives.

In contrast, CNG vehicle access to the HOV lane was the single most motivating factor to purchase a CNG vehicle for nearly all respondents. Current owners clearly value the reduced travel time and improved travel time reliability. According to respondents, this benefit exceeds the refueling inconvenience and incremental cost of ownership compared with a gasoline-equivalent vehicle. This policy has been more effective at stimulating a consumer response to CNG vehicles than buy-down incentives and suggests future policies/incentives for CNG vehicles should perhaps focus on these types of incentives for CNG vehicle owners rather than simply reducing the cost to that of a gasoline-equivalent vehicle.

ii. Refueling:

The primary complaint among CNG vehicle owners is the limited infrastructure available to refuel their vehicle. If this improved significantly, so too would the overall ownership experience of a CNG vehicle. While the driving range of CNG vehicles has been criticized by owners it appears to be secondary to the limited refueling infrastructure. This inconvenience prevents owners from driving their CNG vehicles places they would otherwise like to, and forces them to plan trips outside of their normal "activity space" in advance. Other complaints included the requirement by fuel providers to have separate accounts, an absence of a standardized card to fuel at all CNG locations,

questionable fuel station reliability at some locations, inconsistent operation hours at some stations, and inconsistent fill pressures at certain stations. So while the refueling infrastructure is large enough to accommodate more growth, it imposes a considerable inconvenience upon current owners. The one aspect of CNG vehicle ownership experience most in need of improvement according to them is expansion of the refueling infrastructure.

iii. Ownership:

Most respondents indicated they were very pleased with the performance of their CNG vehicle, either by an absolute definition or at least compared to their expectations. According to them, CNG vehicles operate like a gasoline vehicle and the main complaint is the lack of trunk space due to the CNG fuel cylinder.

Another primary complaint of ownership is the reduced driving range per fuel fill. Owners would prefer a driving range typical of gasoline vehicles (around 300 miles). However, as mentioned, owners are realistic. They would accept either more driving range from their vehicle or more CNG fuel stations, but would not expect both. They would also prefer home fueling become a viable option and most are willing to spend around $1,000 for this convenience.

Several respondents stated they would prefer more CNG vehicle models become available to the public. The vast majority were owners of the Honda Civic GX, and while this model serves its primary purpose as a commute car, many expressed a preference for a CNG Honda Accord or Toyota Camry. The Accord or Camry are mid-size vehicles that are more comfortable and are more practical as a family car than the Civic. The fact they would prefer a less fuel efficient car confirms current owners are not purchasing CNG

vehicles for energy security or environmental concerns. However, owners felt this vehicle was their only option since the only other dedicated CNG vehicles available were a regular cab full-size pickup and a large sedan. Some also wanted more options available on their vehicle such as a manual transmission, leather seats, moonroof, keyless entry, etc.

Despite some disadvantages, most owners have expressed a long-term commitment to their CNG vehicle and would purchase another if all current benefits were the same. This suggests experience with and knowledge of CNG vehicles is more likely to result in informed opinions than a stated-preference survey. It also suggests a stable, if small, long-term market potential. Many respondents believed CNG was a viable energy source and think it should be more heavily promoted.

The response to the California CNG refueling network can have future implications for future AFV technologies such as fuel cell vehicles. Since it is possible the initial generation of fuel cell vehicles may be fueled by hydrogen extracted from CNG, early adopters of that technology may be subject to a similar refueling experience as current CNG vehicle owners, assuming little or no further expansion of the infrastructure. Current CNG vehicle ownership experience with refueling provides considerable insight and lessons for improvement in refueling which can have implications on the development of a fuel cell vehicle market/refueling infrastructure.

XI. POLICY RECOMMENDATIONS

If the State of California is interested in reducing the rate of petroleum consumption and improving energy security it will be necessary to stimulate the consumer market for alternative fuel vehicles, assuming no other transportation policies

specifically targeted at this issue are implemented, and perhaps even if some are. CNG vehicles are the only currently commercially viable/available technology capable of large production volumes with minimal resistance from auto manufacturers and with a large enough refueling network to accommodate greater volumes than currently in use. Based on research of econometric models, local and international revealed preference case studies, and interviews/surveys with current owners of CNG vehicles, the following policies are recommended to stimulate the consumer response to CNG vehicles:

A. Public Awareness/Information:

The general public is simply not aware of CNG vehicles. According to the respondents, most people with whom they speak have never heard of them or confuse them with other AFVs. As a result, they are unaware of their advantages/disadvantages, incentives offered, or other benefits of CNG vehicle ownership. In contrast, there appears to be more public awareness of hybrid-electric vehicles, which have not been available for as long as dedicated CNG vehicles. This is likely a result of marketing efforts from automobile companies and media exposure promoting the advantages of their use. CNG vehicles have not received the same level of support. Rather than marketing CNG vehicles at consumers, all advertisements are focused at fleets who are bound by EPACT to purchase alternative fuel vehicles.

It is recommended the State or local air quality management districts (AQMDs) initiate a public awareness/information to increase public exposure to CNG vehicles and their benefits. Automobile manufacturers as well should promote CNG vehicles, focusing on personal and societal benefits of ownership to consumers and not only at business fleets. This can be accomplished either through television, radio, newspaper/magazine

advertisements, web site ads, etc. Regardless of the method, it is believed the most effect way of generating a consumer response to CNG vehicles is to improve public awareness.

B. Refueling:

It is recommended the State of California continue its support in the expansion of the CNG fueling network. Public fleets are obligated under EPACT to continue purchasing alternative fuel vehicles and even more fleets are converting their heavy-duty vehicles and transit buses to CNG. Additionally, while the consumer CNG vehicle market is currently small compared with the fleet market, State and local agencies should monitor the development of the market if public information/awareness campaign mentioned above stimulates growth, where market growth is occurring, and use that to determine where future stations should be located.

Expansion of the CNG fueling network is also recommended to help establish an infrastructure for future alternative fuel vehicles. Fuel cells, specifically, may be fueled by CNG initially and the establishment of a viable CNG fueling network may be critical to facilitate consumer acceptance of fuel cell vehicles. If advancements in hydrogen storage do not materialize to the extent anticipated, CNG could be a viable permanent fuel from which hydrogen can be extracted for those vehicles. A well-established, existing CNG infrastructure should be ready for a smooth transition to fuel cell vehicles.

As expressed by the respondents in this study, home refueling should become a viable option. If CNG is used as a fuel for fuel cell vehicles, the home refueling option would be valuable for those who may want to transition from a CNG vehicle to a fuel cell vehicle as several respondents mentioned they would keep their CNG vehicle until the "next best" technology came along. Interviewees expressed a willingness to spend $1,000

for this convenience and have suggested a refueling appliance (paid via a tax credit, deduction, or rebate) along with the buy-down incentive would make a very attractive incentive package. While this may be a costly incentive to provide over the long term, it could be used as a short-term incentive to stimulate market growth initially.

Finally, government should consider subsidizing a price advantage for CNG fuel relative to gasoline if/when the need arises. This would stabilize the price volatility of CNG fuel and ensure a consumer fuel cost savings over gasoline. Additionally, a significant fuel price advantage for CNG over gasoline may influence those who are sensitive to fuel price (and other benefits) to purchase a CNG vehicle. The international case studies previously mentioned (Canadian Facts, 1986; Greene, 1989; Kurani, 1992) illustrate the success of those programs was directly related to the government's commitment to ensuring low CNG fuel costs for the consumer. They also influenced dual-fuel CNG vehicle conversions from demographic segments which differ substantially from current California CNG vehicle owners. While recent spikes in CNG fuel price appear to have subsided and have historically enjoyed a cost advantage per gasoline gallon equivalent, a policy in place to ensure stable, low CNG fuel price relative to gasoline would ensure a positive ownership experience.

C. Government Incentives:

Government financial incentives (both the federal tax deduction and local buy-down incentives) did not play a significant role in the purchase decision of current CNG vehicle owners. The type of financial incentives offered to CNG vehicle buyers were not cost-effective considering many respondents would have bought one without the incentives. However, it is recommended buy-down incentives such as that in the South

Coast Air District and tax deductions continue and additional AQMDs offer similar incentives for the following reasons:

1. Buy-down incentives indicate government support for CNG vehicles which helps minimize the perception of risk to CNG vehicle owners.
2. While financial incentives were relatively insignificant in their purchase decision, they reduced the "sting" (i.e. incremental cost) of CNG vehicle ownership and owners were nonetheless appreciative of the incentive.
3. A public marketing campaign, fuel infrastructure expansion, or fuel subsidization programs, if implemented, may stimulate response from socioeconomic segments who are more sensitive to a buy-down incentive and who would otherwise be unwilling to absorb the $4,000 incremental cost of a CNG vehicle.
4. If a public marketing campaign, fuel infrastructure expansion, or fuel subsidization are not implemented, greater buy-down incentives may be necessary to stimulate the same demographic who are unwilling to absorb the incremental cost of a CNG vehicle.

Current legislation allowing CNG vehicles HOV lane access will expire at the end of 2007. For this group of respondents, it was highly influential in their decision to own a CNG vehicle. The effectiveness of this policy to influence CNG vehicle ownership should continued to be studied. If it is determined to have a continued significant effect on CNG vehicle ownership, consideration should be made to renew the legislation beyond 2007. Current owners anticipate an ownership period extending beyond that time period and have stated they would purchase another CNG vehicle in the future. It is plausible new CNG vehicle owners before then will have similar purchasing motivations (if policy recommendations are not considered) and expect HOV lane access to continue.

Local governments, AQMDs, or the State should consider non-financial incentives such as preferred parking, parking meter exemption, or reduced registration to make CNG vehicle ownership more appealing to the car-buying public. This study shows for this group of owners, these types of incentives are more effective at stimulating the CNG vehicle market than financial incentives.

XII. AREAS FOR FURTHER RESEARCH

While this study provided useful insight of the CNG vehicle ownership experience, the sample chosen cannot be considered representative of the entire car-buying population. The goal of this study was to make an initial attempt at understanding the household ownership experience of dedicated CNG vehicles in California. There is considerable room for additional research which may offer equally valuable information. Some recommendations for further research include:

1. Interviewing this same group of respondents (panel survey) in three to five years. Most respondents have only owned their CNG vehicle for a year or less and are still acclimating themselves to ownership. A study three to five years from now would determine if their opinions of CNG vehicles and their ownership experience have changed.
2. Conduct a study based on a larger sample size (when the consumer market is large enough). A larger sample would allow for more definitive conclusions on the CNG vehicle ownership experience and effects of financial incentives.
3. Conduct interviews with those who seriously considered purchasing a CNG vehicle but did not. This information is not currently collected but would provide a useful contrast between those who purchased a CNG vehicle and those would actively chose against it.
4. Conduct a CNG vehicle-specific panel study of the general population to determine the extent of awareness of CNG vehicles and how it has changed over the course of time.
5. Conduct a study measuring consumer response to the policy recommendations in Section XI, if any are implemented.

XIII. CONCLUSION:

This study illustrates that despite comparatively limited California vehicle fleet penetration projections (compared with gasoline vehicles) from econometric models regarding the household market for CNG vehicles, once owners are aware of and have experience with CNG vehicles, their attitudes and opinions toward them change. With this group of owners, the CNG vehicle ownership experience has been generally positive and most would consider purchasing another one in the future if given the same circumstances. Most owners purchased their CNG vehicle due to the HOV lane access and were not heavily influenced by government buy-down and tax incentives. It should be acknowledged, however, that if HOV lane access were not available, most respondents would not have purchased one. While CNG vehicles were purchased as commuter vehicles, owners find themselves using them for more than simply commuting to and from work. As a result, CNG vehicles function well in "hybrid-households" where the CNG vehicle is a supplement to one or more gasoline vehicles in the household. Since household CNG vehicles experience high annual mileage and many owners considered electric vehicles prior to their purchase, they appear to integrate into hybrid-households better than electric vehicles and are displacing more gasoline than an electric vehicle on a per vehicle basis. Additionally, while the refueling infrastructure imposes inconveniences for current CNG owners, it has capacity to accommodate further growth in the household consumer market. Refueling infrastructure warrants further support for continued expansion to help stimulate the market for a first generation of fuel cell vehicles using natural gas.

CNG vehicles are currently serving a very narrow niche market who highly value their travel time over the refueling inconvenience imposed by CNG vehicle ownership.

However, household CNG vehicle market penetration appears to be low due to unfamiliarity with the vehicles due to lack of marketing and media support. If public awareness improves and policy recommendations are implemented, considerable room exists for CNG market growth at the household level. This is a benefit to California's transportation energy security as well as air quality concerns.

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XV. APPENDIX

A. INTERVIEW OUTLINE

Environmental Values and Opinions

* I would like to start by discussing your views, philosophies, and values on the environment.

  -How would you characterize your level of concern for the environment in general?
  -How serious do you think are the environmental and health issues that are caused automobiles? What specifically?
  -How much did your concern for the environment affect your decision to buy a CNG vehicle?

General CNG vehicle and AFV knowledge:

* Now I would like to ***discuss in depth your opinions of CNG vehicles before your purchase*** (compare and relate to stated-preference surveys).

  -What did you personally think about them?
  -What did you think were their advantages?
  -What did you think were their disadvantages?
  -What did you think about refueling? (difficult to learn locations, refueling procedure, etc.)

* Discuss any previous exposure to CNG vehicles prior to your purchase.

  -How did you learn about them?
  -Had you driven one personally? If so, when? where? How much? Did this influence your decision to purchase one?

CNG vehicle purchase and effects of incentives

* I would like for you to provide me with a start-to-finish explanation of your decision-making process of purchasing your CNG vehicle.

  -When did you buy a CNG vehicle when you did and how did you arrive at that decision?

-Why, specifically, did you buy a CNG vehicle?
    -What impact did fuel price have on your decision to purchase your CNG vehicle?

-When in your decision process did you learn about incentives? (Also, how many months/years before purchase?)
    -Were you going to buy a CNG vehicle before you found out about the incentives?
-How did you learn about incentives? (use as prompt if not answered from above question)
-*As a whole, how influential were the incentives in your decision to own a CNG vehicle?*
    -*Which incentives (Federal, State, Local) were most influential in your decision to own a CNG vehicle? (State incentive N/A in California).*

* Now I would like to discuss incentives in a deeper context, including what decisions you *would* have made under different scenarios (such as those indicated in the survey instrument).

-Would you have owned a CNG vehicle if NO incentives were offered? Why or why not?
-Would you have owned one SOONER if the incentives were greater?

Use as prompts, if necessary

NO:
-Why not?
-Were you not in the market for a car sooner?
-Were there a lack of vehicles availabe?
-Or did you not have the information necessary for the incentive to influence your decision towards a CNG vehicle?

YES:
-What, incentive amount would have realistically persuaded you to have purchased one sooner? The current incentive amount?
-Why did you choose to own a CNG vehicle at the current incentive amount?

* Why did you choose a CNG vehicle over another AFV.

Use as prompts, if necessary

-Did you simply have more information on CNG vehicles?
-Did you feel it complemented your driving needs better than other AFVs?
-Did you choose a CNG vehicle because it was more affordable than other AFVs, such as BEVs?
-Did they know about incentives for other AFVs and EVs?

*Philosophically, who do you think should be responsible for creating the market for natural gas vehicles? More specifically,

-Do you think consumers should be willing to pay more for a CNG vehicle than an equivalent gasoline vehicle?
-Do you think the government should be offering larger incentives for natural gas vehicles?
-Do you think the automobile manufacturers should be offering CNG vehicles at the same price as their gasoline equivalent vehicles?

* What do you think would be most effective at further stimulating the CNG household vehicle market? (e.g. improved infrastructure, greater monetary incentives, free/preferred parking in high demand locations , HOV lane access, education/information, tax incentives for alt fuel use).

* What was your dealership experience like?
-What was the extent of their knowledge of CNG vehicles?
-How supportive of the technology were they?
-Who did you primarily work with (salesperson, sales manager, fleet manager?) when purchasing your vehicle?

<u>CNG vehicle use and its role in travel</u>:

* What percentage of your household trips would you estimate are made with your CNG vehicle?

* In your best estimate, who drives what percentage of the CNG vehicle trips? Why?

* Does anyone in your household refuse to drive the CNG vehicle? If so, why?

* Now I would like to discuss the role of your CNG vehicle relative to other vehicles in your household (hybrid household, single-vehicle household).

-Are your daily driving habits different as a result of the CNG vehicle?
-Have you found your household driving more, less, or the same amount as a result of owning a CNG vehicle? How much? Is this what you expected?

* Did you experience any necessary or unexpected adjustments to become accustomed to your CNG vehicle (maintenance, drivability, etc.). What were the extent of these adjustments?

Use as prompts, if necessary

-Have you found the driving range of your CNG vehicle compared to a gasoline vehicle to be sufficient?

-Has reduced cargo capacity had an impact on your opinion of CNG vehicles?
-How would you characterize the vehicle's performance? (Less than acceptable, acceptable, more than acceptable)

CNG vehicle and Refueling:

*Now I would like to discuss the topic of refueling your CNG vehicle:

-Do you own a home refueling appliance?
*What % of your refueling is done at home?
*Would you own a CNG vehicle if you did not have the appliance?
-Would you like to own a home refueling appliance?
-How much would you be willing to spend for such an appliance?
-How do you think home refueling appliances would affect the development/expansion of the CNG refueling infrastructure?

-What did you know about the refueling network before buying? --How did you find this information?
-Where in your purchase decision process did you research this? Before, after?
-How difficult has it been for you to find CNG refueling stations? Is this what you expected?
-In regards to fueling, did you buy a CNG based on the current infrastructure or on its future expansion?

-Does your refueling pattern for your CNG vehicle differ much from your gasoline vehicle(s)? (In other words, do you primarily fuel your gasoline vehicles at one station or do you fuel them at a variety of different stations within your activity space?)

* Discuss the nature of fueling and fueling infrastructure (i.e. are the pumps reliable, convenient locations, fuel costs, etc.).

-Where do you primarily refuel your vehicle?
*How far is this from your work/home? (whichever is applicable)
-Is this in close proximity to your primary gasoline station?
-Do you know where other stations are located within your area?

No:
*Has that prevented you from driving some places you'd like to drive?

-What is the farthest distance you would have been willing to drive to regularly refuel your vehicle? (Get time and distance)

<u>CNG vehicle ownership</u>:

*Based on your CNG ownership experience, how have your opinions of CNG vehicles changed since you've owned one?

-How do your ownership costs compare with what you expected (maintenance, fuel, etc)?

*How long do you intend to keep your CNG vehicle? (years, miles)

-What do you intend to do with it at that time?

*Do you plan to buy another CNG vehicle in the future? (why, why not?)

-Will this be your next vehicle purchase? (why, why not?)

*Have you influenced anybody else to purchase a CNG vehicle?

*Do you know anybody that has considered purchasing a CNG vehicle but did not?

-Do you know if they would be willing to talk with me?

*Are there any other topics you would like to discuss regarding your CNG vehicle that I may have overlooked?

B. SUPPLEMENTAL QUESTIONNAIRE (See following page)

UCDAVIS
INSTITUTE OF TRANSPORTATION STUDIES

Dear CNG vehicle owner,

Thank you again for your valuable information during the interview. This supplemental questionnaire is designed to help solidify your opinions and thoughts that were discussed during the interview. Please take time now to fill this out and return it to the UC Davis researcher as soon as you have finished. Please note that the information you provide in this questionnaire will be kept confidential. Feel free to contact your local air quality management district representative in a few months if you wish to follow up on the results of this study.

Sincerely,

Brian Abbanat, Graduate Researcher
Institute of Transportation Studies
University of California, Davis

UCDAVIS
INSTITUTE OF TRANSPORTATION STUDIES

ID # _____

PART 1

ENVIRONMENTAL OPINIONS AND PREOWNERSHIP AWARENESS OF CNG VEHICLES

In this first section, we ask a few background questions regarding your opinions of the environment as well as a few pre-CNG ownership questions.

1. Please indicate your overall level of concern for the environment:
   - ☐ Not at all concerned
   - ☐ Slightly concerned
   - ☐ Moderately concerned
   - ☐ Very concerned

2. What adverse impact do you think the automobile has had on air pollution?
   - ☐ No effect at all
   - ☐ Slight effect
   - ☐ Moderate effect
   - ☐ Major effect

3. Do you consider yourself an environmentalist?
   - ☐ Yes
   - ☐ No

4. Where/how did you first learn about compressed natural gas (CNG) vehicles?
   - ☐ Magazine article
   - ☐ Newspaper
   - ☐ Friend, relative colleague, acquaintance
   - ☐ Lease offer at work
   - ☐ Web site (manufacturer, special interest)
   - ☐ Television, radio (news special, ad?)
   - ☐ Mechanic/Dealership
   - ☐ Other: _____

5. Are high-occupancy vehicle (HOV) lanes available on the freeways that you drive?

   ☐ Yes
   ☐ No
   ☐ Not Sure

6. How much did being able to use HOV lanes influence your decision to own a CNG vehicle?

   ☐ Not at all
   ☐ Somewhat
   ☐ Very much
   ☐ Did not know this was allowed

7. Prior to owning one, had you ever driven or rented a CNG vehicle?

   ☐ Yes ☐ No

   -If Yes, how much did you drive a CNG vehicle prior to ownership?

   ☐ I took a single "test drive" in a CNG vehicle
   ☐ I had driven a CNG vehicle on a few occasions
   ☐ I had driven a CNG vehicle quite often

8. Prior to ownership, had you ever refueled a CNG vehicle?

   ☐ Yes ☐ No

PART 2

CNG OWNERSHIP

In this section, we ask some questions about your CNG vehicle ownership experience.

1. Please provide the following information of your CNG vehicle:

Make (Ford, Toyota, etc.): _____

Model (Taurus, Camry, etc): _____

Model year: _____

Price paid (pre-sales tax): _____

2. Do you currently own or lease your CNG vehicle?

- ☐ Own
- ☐ Lease

3. For how long have you owned/leased your CNG vehicle?

- ☐ Less than 6 months
- ☐ 6–12 months
- ☐ 1-2 years
- ☐ Over 2 years

4. Did you own/lease any other CNG vehicles prior to this vehicle?

- ☐ Yes
- ☐ No

5. How many years (total) do you plan to keep your CNG vehicle?

- ☐ Less than 1 year
- ☐ 1 year
- ☐ 2 years
- ☐ 3 years
- ☐ 4 years
- ☐ 5 years or more

6. How many miles per year do you drive your CNG vehicle?

- ☐ 0 – 5,000 miles
- ☐ 5,001 – 10,000 miles
- ☐ 10,001 – 15,000 miles
- ☐ 15,001 – 20,000 miles
- ☐ 20,001 – 25,000 miles
- ☐ 25,0001 + miles

7. How would you characterize your overall ownership experience with your CNG vehicle compared to your initial expectations?

- ☐ Very Satisfied
- ☐ Satisfied
- ☐ Not satisfied

8. Where do you typically refuel your CNG vehicle?

- ☐ At a public refueling station
- ☐ At a private refueling station
- ☐ At both private and public refueling stations

*Please indicate approximate percentage of both: _____% private
_____% public

9. Approximately how far is it from your home/work to the CNG station at which you most often refuel?

Home: _____ miles

Work: _____miles

10. How would you describe the public fueling infrastructure?

	Inadequate	Adequate	More than Adequate
a.) Number of stations	☐	☐	☐
b.) Station locations	☐	☐	☐
c.) Overall price of fuel	☐	☐	☐
d.) Ease of refueling procedure	☐	☐	☐
e.) Reliability of stations	☐	☐	☐

11. Based on your experience, please indicate your level of satisfaction with the following categories regarding your CNG vehicle:

	least satisfied				*most satisfied*
	1	2	3	4	5
a. Trunk space/cargo carrying capacity…….	☐	☐	☐	☐	☐
b. Driving range…….	☐	☐	☐	☐	☐
c. Refueling infrastructure…….	☐	☐	☐	☐	☐
d. Refueling procedure…….	☐	☐	☐	☐	☐
e. Stability of natural gas fuel prices……..	☐	☐	☐	☐	☐
f. Future resale value/market…….	☐	☐	☐	☐	☐
g. Initial added expense……..….	☐	☐	☐	☐	☐
h. Vehicle safety…….	☐	☐	☐	☐	☐
i. Overall performance……	☐	☐	☐	☐	☐
j. Other: _____……	☐	☐	☐	☐	☐

12. How has your household experience with a CNG vehicle affected your decision to own another CNG vehicle in the future?

☐ I would not own a CNG vehicle for a future personal vehicle

☐ I would consider owning another CNG vehicle for a future personal vehicle

☐ I am considering owning a CNG vehicle for my next personal vehicle

PART 3

VEHICLE INCENTIVES

In this section, we ask some questions about incentives that applied to your CNG vehicle purchase, the influence they may have had, and some hypothetical purchasing situations.

1. Please indicate which of the following incentives were received for your CNG vehicle:

   a.) My total federal income tax deduction for this vehicle was: _____

   This incentive affected my purchase decision:

   - ☐ Not at all
   - ☐ Slightly
   - ☐ Moderately
   - ☐ Greatly
   - ☐ Was not aware of federal income tax deduction

   b.) My local cash incentive for this vehicle was: _____

   This incentive affected my purchase decision:

   - ☐ Not at all
   - ☐ Slightly
   - ☐ Moderately
   - ☐ Greatly
   - ☐ Was not aware of local cash incentive

2. Would you have purchased a CNG vehicle **sooner** if the incentives offered were greater?

   - ☐ Yes
   - ☐ No
   - ☐

Maybe

a.) If you answered "yes" or "maybe" please indicate the total amount of **additional** incentive you would have required, beyond what you received:

_____

b.) If you have a preference, how would you prefer that incentive be distributed (should add up to total in "2a.")?

No preference ☐

Federal tax deduction: $ _____ more

Local cash incentive: $ _____ more

Other: _____ $ _____ more

3. In your opinion, total incentives for CNG vehicles **should** be:

☐ Less than the additional cost of the CNG vehicle over the equivalent gasoline vehicle.

☐ Equal to the additional cost of the CNG vehicle over the equivalent gasoline vehicle.

☐ More than the additional cost of the natural gas vehicle over the equivalent gasoline vehicle.

4. Would you have purchased a CNG vehicle if any of the incentives offered were **less** than what you received?

☐ Yes
☐ No
☐ Maybe

a.) If you answered "yes" or "maybe" please indicate how much **less** you would have been willing to accept: _____

b.) If you have a preference, how would you prefer that incentive be distributed (should add up to total in "4a.")?

No preference	☐
Federal tax deduction:	$ _____ more
State tax incentive:	$ _____ more
Local cash incentive:	$ _____ more

5. Please rank which incentives were most influential in your purchase decision:

Incentive	Rank
Federal tax deduction	____
Local cash incentive	____

6. Overall, how influential were the government incentives in your decision to purchase a CNG vehicle?

- ☐ Not at all
- ☐ Somewhat
- ☐ Moderately
- ☐ Greatly

PART 4

GENERAL INFORMATION

Now I would like to ask you a few questions regarding your household background. Answers to these questions will help us generalize findings from this small sample to the population as a whole.

1. Please indicate the total number of vehicles owned in your household, *including your CNG vehicle*:

_____ vehicles

*Please indicate the number of vehicles you own next to each class:

Sedan:	**Wagon:**	**Hatchback:**
Small ____	Small ____	Small ____
Medium ____	Medium ____	Medium ____
Large ____	Large ____	

SUV:	**Van:**	**Truck:**
Small ____	Minivan ____	Compact ____
Medium ____	Full-size ____	Full-size ____
Large ____		

Sports Car: ____

Other: ____

2. Including yourself, how many people are living full time in your household (write in number of people in each category)?

Category	# of people
Children under 6	____
Children 7-12	____
Children 13-17	____
Females 18 and older	____
Males 18 and older	____

3. Are you:

☐ Male
☐ Female

4. What is your age?

☐ 20 or younger ☐ 31 – 40 ☐ 51 - 60
☐ 21 – 30 ☐ 41 – 50 ☐ over 60

5. What is your educational background (check highest level)?

- ☐ High school diploma
- ☐ Some college or technical school
- ☐ 4-year college/technical school degree
- ☐ Some graduate school
- ☐ Completed graduate school

6. What is your occupation?

- ☐ Business professional
- ☐ Medical/health professional
- ☐ Service professional
- ☐ Retired
- ☐ Technical professional
- ☐ Teacher/educator
- ☐ Business support
- ☐ Other: _____
- ☐ Upper mgt
- ☐ Homemaker
- ☐ Skilled labor

7. The combined annual income of my household is:

- ☐ Under $50,000
- ☐ $50,001 - $75,000
- ☐ $75,001 - $100,000
- ☐ $100,001 - $125,000
- ☐ $125,001 - $150,000
- ☐ over $150,000

8. Please provide your home address (if interview was held at work):
   This information will be kept strictly confidential and will only be used to compare relative residential locations of CNG vehicle owners with each other.

   Address: _____

   City: _____

   e-mail: _____

Thank you for your time and patience, the information you have provided is extremely valuable. In the area below, please take the opportunity to express any additional thoughts or opinions regarding your CNG vehicle or this study (Please continue on back of paper if needed).