The Household Market for Electric Vehicles:

Testing the Hybrid Household Hypothesis--
A Reflexively Designed Survey of New-car-buying, Multi-vehicle California Households

by

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Prepared for The California Air Resources Board and The California Environmental Protection Agency

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ABSTRACT

We report the results of a survey of the potential demand for electric vehicles (EVs) among a subset of California households. We limit our analysis to one group of *potential hybrid households*. These households own two or more light duty vehicles and buy new vehicles of the body styles we expect will be offered as electric vehicles. These characteristics identify households who may be able to incorporate at least one limited range vehicle into their household vehicle holdings with no, or minimal, affect on household lifestyle choices. We define *hybrid households* to be those households that choose an electric vehicle in the choice exercises in the survey. We formulate our central research question as the *hybrid household hypothesis*. It states that potential hybrid households will choose to include at least one EV in their household fleet of vehicles, thus becoming hybrid households.

We believe that this subset of potential hybrid households buys between 35 and 45 percent of all new, light-duty vehicles sold in California every year. The survey instrument was administered to households who belong to this subset of households in 6 metropolitan areas of California. Four hundred and fifty-four households completed and returned the questionnaire.

The hybrid household hypothesis is supported by our respondents' choices. In two different choice scenarios, nearly half our sample indicates they would choose an electric vehicle as their next new vehicle. Even among those who indicate their next new vehicle would be either a gasoline or natural gas vehicle, some indicate they would choose an EV at some point in the future.

Based on the responses to the vehicle choice exercises and on the share of the market that our sample represents, we find the market potential for EVs to be 13 to 15 percent of the annual, new light-duty vehicle market in California. Based on past annual sales of 1.4 million new, light-duty vehicles in California (a typical market during the past few years), the EV market share represents between 186,000 and 213,000 vehicles annually. This is subject to several assumptions, most importantly that, besides smaller EVs, consumers will be able to choose from midsize EVs that have driving ranges between 60 and 150 miles and that EVs will be priced comparably to gasoline vehicles. Even if the former is not true, and only sub-compact and compact body styles are available, the potential market for EVs among hybrid households will be no less than 7 percent of the new light-duty vehicle market.

We believe therefore, there is sufficient household consumer interest in EVs to satisfy the mandated 2 percent level of sales of zero emission vehicles (ZEVs) in the year 1998 as well as the 5 percent level in 2001 given current EV technologies. To meet the mandated level of 10 percent of light-duty vehicle sales in the year 2003, will require either that advances in electrical storage technology allow for mid-size electric vehicles with driving ranges of 60 to 150 miles or the sale of sufficient smaller EVs to the market segments not surveyed for this study—commercial and government fleets and households that do not meet the *potential hybrid household* definition used in this study.

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EXECUTIVE SUMMARY

Introduction

The California Air Resources Board will soon require that auto-makers offer for sale "zero emission vehicles" (ZEVs) in California. Starting in 1998, the auto-makers subject to this mandate will be those who sell more than 35,000 vehicles in California whose laden weight is less than 3,750 lb. They must offer for sale ZEVs in sufficient numbers that at least 2 percent of all the vehicles (under the weight limit) that they offer for sale, are ZEVs. This mandate is flexible in two ways: sales of ZEVs weighing between 3,750 lb. and 5,750 lb. are not required, but any such ZEVs will count toward the mandate and auto manufacturers can obtain credits from other manufacturers who exceed their quotas. This 2 percent level increases to 5 percent in the year 2001. In the year 2003, the mandate changes in two ways. First, any auto maker who sells more than 3,000 vehicles that are under the 3,750 lb. weight limit will be subject to the mandate. Second, the proportion of ZEVs offered for sale rises to 10 percent. Currently, the only type of vehicle to meet the ZEV definition is electric-powered vehicles (EVs) that store their energy in batteries. The idea behind the mandate is to kick start a competitive industry for clean cars that need no emissions systems testing, suffer no long term degradation of emissions control equipment, and will help to eliminate emissions from urban centers in California.

Market research for ZEVs is difficult because, besides having no tailpipe emissions, electric vehicles are different from gasoline vehicles in ways which are unfamiliar to consumers, most notably the way in which energy to drive the wheels is stored, used and replenished. Compared to the fuel tanks of gasoline vehicles, which store at least 300 miles of fuel, current EV battery technologies store a very limited amount of energy. Current EVs must be recharged after 60-120 miles of use depending on the type of batteries and vehicles. Compared to refueling gasoline vehicles, recharging electric vehicles can take hours, depending on the voltage and sophistication of recharging equipment. However, there are potential advantages to electric vehicles which mitigate these limits, primarily that recharging can take place at many locations where cars are parked, including home, work and public parking, thus eliminating special trips to refueling stations. EVs can also be pre-cooled, heated or defrosted while they are being recharged. Electric vehicles will have new driving, braking and sound characteristics which may appeal to some drivers. Additionally, electric vehicle costs and maintenance schedules will be different, offering advantages to some users. Finally, some drivers who dislike gasoline for its smell, toxicity or combustion dangers as well as prefer a vehicle with no tailpipe emissions may prefer electric propulsion.

The limited range and long recharge times of EVs have been seen by market analysts as either a fatal flaw or a minimal limitation. Econometric models of stated preferences purport to show almost no market for EVs. Travel behavior studies which study travel patterns, purport to show sizable markets. We report here the results of a survey for the electric vehicle market designed to resolve this conflict. In the absence of established purchase preferences or habits for EVs which could be measured in conventional surveys, we investigate here a central research question we call the *hybrid household hypothesis*:

> *A driving range limit on one household vehicle will not be an important barrier to the purchase of an EV by a potential hybrid household.*

Underlying this hypothesis, is the assumption that electric vehicles could be compliments to gasoline vehicles in many multi-vehicle households given some of the advantages listed above. A hybrid household is one which combines electric vehicles and gasoline vehicles into its household fleet. We limit our analysis to one group of *potential hybrid households*. These households own two or more light duty vehicles and buy new vehicles of the body styles we expect will be offered as electric vehicles. These characteristics identify households who may be able to incorporate at least one limited range vehicle into their household vehicle holdings with no, or minimal, affect on household lifestyle choices. We believe that our subset of potential hybrid households buys between 35 and 45 percent of all new, light-duty vehicles sold in California every year.

Based on the hybrid household hypothesis, and on the share of the market that our sample represents, we predict the market potential for EVs to be 13 to 15 percent of the total, new light-duty vehicle market in California. Based on a projected sale of 1.4 million new, light-duty vehicles in California (a typical sales number from the past few years), the EV market share represents between 186,000 and 213,000 vehicles. This is subject to several assumptions, most importantly that, besides smaller EVs, consumers will be able to choose from midsize EVs that have driving ranges between 60 and 150 miles and that EVs will be priced comparably to gasoline vehicles. Even if the former is not true, and only sub-compact and compact body styles are available, the potential market for EVs will be no less than 7 percent of the new light-duty vehicle market, still above the 5 percent level. Additionally, this analysis has not included potential commercial fleet sales.

The hybrid household hypothesis is supported by our respondents' choices in the survey. In two different choice scenarios, nearly half our sample indicates they would choose an electric vehicle as their next new vehicle. We believe therefore, there is sufficient consumer interest in EVs to satisfy the mandated level of sales of 2 percent zero emission vehicles (ZEVs) in the year 1998 as well as the 5 percent level in 2001, even if EV technologies are limited to currently available technologies. To meet the mandated level of 10 percent EVs in the year 2003, will require either that advances in electrical storage technology allow for mid-size electric vehicles with driving ranges of 60 to 150 miles or the sale of sufficient smaller EVs to the market segments not surveyed for this study—commercial and government fleets and households that do not meet the *potential hybrid household* definition used in this study.

Survey Design

Our survey was designed to overcome some of the limitations of previous EV market research; primarily we strove to inform participants about EV technology and to help participants assess the effects of electric vehicle technology on their lifestyle. The survey was developed to test what we call the *hybrid household hypothesis*. This hypothesis is implicit in much previous work, but has not been explicitly tested.

The survey was administered through the mail. It consisted of 4 parts.

Part One: A preliminary questionnaire of household vehicle holdings, previous vehicle purchase patterns, demographics and environmental attitudes.

Part Two: A three day travel diary, a map for recording household activity locations, and questionnaire based on these two for the two primary drivers in the household.

Part Three: A 15 minute informational video on electric and natural gas vehicles and CARB's ZEV mandate, as well as a set of magazine and newspaper articles on electric vehicles, the electric vehicle industry and the mandate. The information packet was designed to present a balance and variety of information. References for the articles are in Appendix B.

Part Four: A set of new car purchase experiments that included two different new vehicle purchase situations. The first, ***Choice Situation One***, included electric and conventional gasoline fueled vehicles. It was designed to test the hybrid household hypothesis. ***Choice Situation Two*** was a more complex market scenario with a number of alternative fueled vehicles including reformulated gasoline, natural gas vehicles and hybrid electric vehicles, in addition to three types of electric vehicles.

It is important to understand that the choice experiments are not intended as forecasts or predictions of future vehicle market scenarios. They are intended to maximize the information we gain about household response to driving range limits and home recharging. As such, the differences and similarities between vehicle types expressed in the choice experiments are a blend of existing, expected, and experimental design features. For example, it is both an existing and expected feature of electric and natural gas vehicles that they will have shorter driving ranges than gasoline vehicles. It is part of our experimental design that we have limited natural gas vehicles to ranges that are shorter than those already demonstrated for some natural gas vehicles.

Another intentional design feature of the choice experiments in Part Four was that we do not use purchase prices to differentiate vehicles that use different fuels and propulsion systems. Prices are used to distinguish between body styles, trim levels, and optional equipment, just as they do in today's car market. Prices of alternatively fueled vehicles are kept roughly comparable to gasoline to keep the focus of the study on consumer response to limited range and home recharging. These are the two fundamentally new attributes of electric and, to a lesser degree, natural gas vehicles.

Thus, one potential criticism of this study may be that we have priced EVs too low. The price of EVs is a central issue in the ZEV debate, but it is a highly uncertain and politicized variable. Some auto companies claim that electric vehicles will be priced at much more than gasoline vehicles. Most of this concern comes from the currently high price of batteries.

We counter this argument thus. It is true that the price for an EV with a certain driving range and the cost of building that EV are related through the cost of the battery. But the performance levels we offer in EVs are in many cases very modest, and well within the technical feasibility of existing EV and battery technology. For example, we define a range class of "community EVs" that are modest in terms of their range and performance; several examples of such vehicles are already on the road. We see little reason for such vehicles to persistently cost any more than gasoline vehicles of comparable body styles. Our price assumption is far more speculative when we consider longer range, mid-size electric vehicles and we address this issue in our analysis and conclusions.

Sample design

The survey was aimed at a specific portion of the light duty vehicle market—households with two or more cars, who buy new cars, who have at least one vehicle they purchased new that is not a full size van, sedan, truck or sport utility, and who have a logical location to recharge a vehicle while it is parked at home. Seven hundred forty such households were recruited from 6 metropolitan areas of California. They were offered $50 to complete the survey. 454 households completed all four parts of the survey, a total response rate of 61%. We compared this sample to other, larger samples from studies of the new car buyer market. We conclude our sample is representative of households that buy new cars.

Testing the Hybrid Household Hypothesis

To state the *hybrid household hypothesis* in a form we can test, we must make the following assumptions. Our sample selection criteria define what we believe to be the largest and most likely group of *potential hybrid households*. We assume that over a long period of time, hybrid households will choose to buy an EV about one in every N times they buy a new vehicle, where N is the number of vehicles they own. Given that we have found in previous work that about 8% of households who meet our selection criteria are unable to adapt to limited ranges because of their travel needs, and that our sample in this survey owns on average 2.43 cars per household, then the hybrid household hypothesis becomes:

H_0: at least 38% of our sample will choose an EV for their next new vehicle.

The hybrid household hypothesis is supported by our respondents. In fact, more households chose an EV than the hypothesis predicts. In the most robust test of our hypothesis, Choice Situation One, participants were offered a conventional gasoline vehicle in all vehicle body styles or a moderate range electric vehicle (80-100 miles) in all but full sized vehicle categories.

46% of our sample chose an EV over a gasoline vehicle for their next household vehicle.

Explanations other than the hybrid household hypothesis, such as environmental attitudes, income, age, sex or education, do not explain the distribution of choices as well as does the hybrid household hypothesis. These other household characteristics do contribute in less significant ways to explaining to the size and development of the market.

Travel patterns of participants

Among the reasons the hybrid household hypothesis is that most households' travel patterns are not a serious barrier to use of an electric vehicle. We note the following:

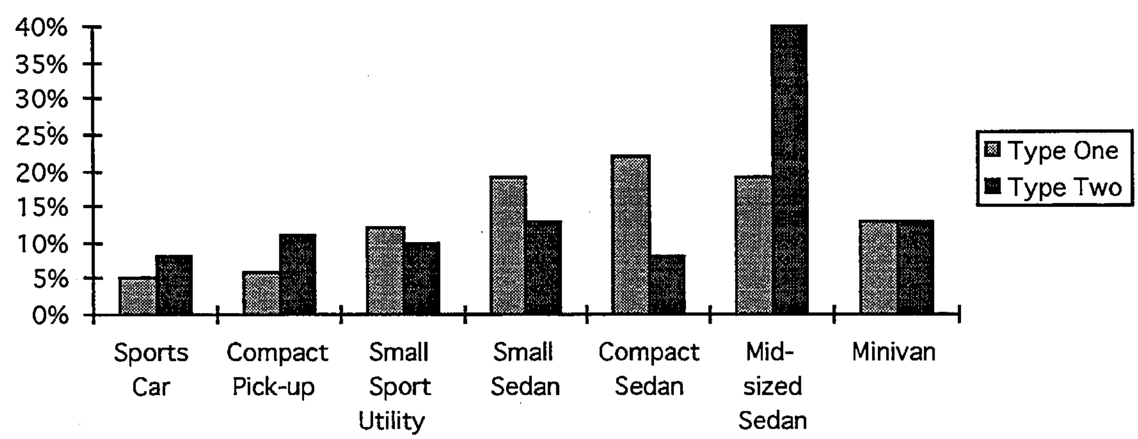
- The median one way commute distance of participants in this study is 10 miles;
- 90% of all one way commute distances in this study are under 35 miles;
- 90% of critical destination distances are under 50 miles, where the critical destination distance is the distance to an important destination a person needs to reach even if an "unlimited" range vehicle is not available.

Range , recharging , battery and vehicle body choices

In ***Choice Situation One,*** EVs were offered in seven body styles. EVs were offered with two different battery packs that had different ranges and costs:

- Type 1 was standard equipment and offered 80 or 100 miles driving range (depending on body style)—37% of those who chose an EV chose this battery;
- Type 2 cost $1,200 more and offered 100 or 120 miles driving range (depending on body style)—63% of those who chose an EV chose this battery

The graph below illustrates the distribution of Type 1 and Type 2 battery choices, showing the concentration of Type 2 choices in mid-sized vehicles categories.



In ***Choice Situation Two***, range and recharging choices were far more complex. In this more detailed scenario, households were offered a wider range of vehicles, including natural gas fueled vehicles (NGVs) with 80 or 120 miles of range, and hybrid electric vehicles with 140 and 180 miles of extended range (40 and 80 miles of battery only range). Replacement battery prices (minus core refunds) in this groups ranged from $800 for a small conventional lead acid battery pack in the neighborhood electric vehicle (NEV) to a $4,000 advanced battery pack in the Regional Electric Vehicle.

Types of vehicles offered in Choice Situation Two

1. Neighborhood electric, range 40 miles, top speed 40 mph (small sedan only)
2. Community electric, range 60 or 80 miles, top speed 75 mph (no full size styles)
3. Regional electric, ranges 120 to 150 miles, top speed 85 mph (no full size styles)
4. Hybrid electric, ranges 140 or 180 (40 or 80 on batteries), top speed 85 (no full size styles)
5. Compressed natural gas, ranges 80 or 120, all body styles
6. Reformulated gasoline, range same as current gasoline vehicles, all body styles

Distribution of vehicle choices in Situation Two

1. Neighborhood electric: 19 households, 4%
2. Community electric: 28 households, 6%
3. Regional electric: 119 households, 26%
4. Hybrid electric: 44 households, 10%
5. Compressed natural gas: 88 households, 19%
6. Reformulated gasoline: 154 households, 34%

Range groupings of vehicle choices in Situation Two (includes NGVs)

- 75 households chose vehicles with 40-80 miles of range
- 112 households chose vehicles with 120-130 miles of range
- 106 households chose vehicles with 140-180 miles of range
- 154 households chose vehicles with ranges similar to existing gasoline vehicles.

Home refueling/recharging capability.

- 246 households chose vehicles which refuel or recharge both at home and away-from- home (EVs and NGVs plus home refueling appliance).
- 206 households chose vehicles that refuel away-from-home only (NGVs without a home refueling appliance and gasoline vehicles).

Interpretations of range and recharging choices and vehicle refueling habits

As noted in several of our previous studies, understanding consumer response to driving range requires careful attention to household fleet composition, consumer learning processes (especially as consumers have previously not considered the impact of reduced range on lifestyle choices), changes in vehicle range instrumentation, and the recharging infrastructure (home and away-from-home).

We find in this study that consumer travel patterns are less of an obstacle to limited range vehicles than is lack of experience and knowledge with electric vehicle technology. Additionally, previous market research has failed to consider consumer response to the whole package of likely EV features, including precise range instrumentation and new recharging infrastructure. Further, they did not present new vehicle choices in the context of the household's fleet of vehicles. The findings we report in the body of the report on consumer travel patterns, use of existing range instrumentation in gasoline vehicles, and refueling behavior give evidence that gasoline vehicles currently do not meet consumer wants for much of their local driving tasks, a job that electric vehicles may do better.

Finally, it has been argued by others that to make it in the market, electric vehicles must have equivalent ranges and refueling times as gasoline vehicles. We believe this is an extreme and unwarranted position. We argue instead there is a viable niche market for "short" range electric vehicles in multi-vehicle households, just as there are niche markets for pick-up trucks and minivans.

We believe from the results of this study and previous studies we have done, that it is more important to provide a less expensive battery capable of providing 60 to 100 miles of range than to develop an expensive battery for vehicles with 200-250 miles of range. The marginal utility for electric vehicles with ranges above approximately 150 miles will rapidly approach zero so long as there are gasoline vehicles on the road which have 300-400 miles of range and can be refueled in less than 5 minutes. The utility of EVs with short ranges and home recharging lies primarily in their complementary relation to gasoline vehicles in a hybrid household to provide diversified, personal transportation services.

Choices of body styles

The most commonly chosen body style for any vehicle type was mid-sized sedan (114 households), with minivan (64 households) a distant second, followed by compact sedan (41 households), and small sedan (39 households). The single most frequently selected vehicle in our study was a mid-size regional electric sedan (41 households). At present we have not seen any mid-size regional electric vehicles demonstrated, although expected advances in batteries combined with light weight materials could fulfill this expectation by the year 2003.

If electric storage technology does not advance to allow mid-size electric vehicles with ranges up to 140 miles by the year 2003, then given the results of this survey, the EV market potential for smaller and shorter range vehicles represented by our sample is about 7% of annual, new light duty vehicle sales. Additional EV sales to commercial and government fleets and to other household market segments would be required to meet the 10% mandate level.

Vehicle choice and intended trip use

The body style a household chooses is shaped by a *defining purpose* for that vehicle. While a household may use a vehicle for all types of travel, the choice of a particular body style is often determined by the desire to access one particular type of activity. Thus, while one household member might commute to work everyday in a sport-utility vehicle (SUV), the reason the household bought a SUV, rather than any other body style, may have been to access recreation activities on weekends. In this case, the *defining purpose* is weekend recreation travel, not commuting. We recognize that not all vehicles are purchased for purely utilitarian reasons. We allow households to choose vehicles simply for styling and appearance. Below are the *defining purposes* for the body styles of the vehicles chosen in Situation Two by all participants.

- Commuting to work or school: 188 households, 47%
- Vacation or weekend travel: 91 households, 23%
- Chauffeur children: 44 households, 11%
- Looks and styling: 36 households, 9%
- Hauling loads: 19 households, 5%
- Business errands: 16 households, 4%
- Chauffeuring clients: 8 households, 2%

These defining purposes affect what types and sizes of vehicles are chosen. For example, 70 of the 90 households who said vacation travel was the defining purpose of their vehicle choice chose natural gas or reformulated gasoline vehicles in Choice Situation Two. The majority of the twenty remaining "vacation" choosers selected the longest ranged regional electric. Similarly, those choosing "hauling loads" selected natural gas and reformulated gasoline. Within the defining purposes of "commuting" and "chauffeuring children", more households choose regional EVs than chose gasoline vehicles.

Life-cycle: Effect of age and presence of children on choices

We found in previous research (Turrentine et al 1992) that households of mid-aged adults with children favored EVs more than other household types. We surmised that these households had stronger ties to community health goals (for their children), more routine driving patterns and higher incomes. We also found that households of retired persons tended to reject EVs more strongly than other household types. We find similar results in this current study. Households of two or more adults whose youngest child is 15 years old or younger are more likely to buy a regional EV than they are to buy a gasoline vehicle.

We develop a model that links household life cycle, and defining purpose of the next new vehicle to vehicle type choices. Analyzing life cycle, defining purpose for the vehicle, and vehicle type choices reveals that young families were very much more likely to choose an EV than any other type of vehicle, if their defining purpose for the vehicle was either to chauffeur children or commute to work or school. Commuting in general was associated with a higher probability of choosing an EV, regardless of life cycle. Among those households that did not choose EVs were those retired households selecting a vehicle for weekend and vacation travel.

How green is the market?

Prior to the ZEV mandate there had been little politicizing of automobile purchase choices along environmental lines. Fuel efficiency has never really entered consumer deliberations about vehicle purchases in the same way that some EV proponents and opponents assume emissions will. Primarily because of uniform vehicle emission standards (until the advent of CARB's low emission vehicle program), consumers have not chosen among cars differentiated by, or marketed based on, their emissions. Certified differences in emissions of new cars are minor and not advertised to consumers. Neither are differences in emissions part of any public health campaign. Thus a zero emission vehicle market is an entirely new development.

It remains to be seen what consumers will do in this market. It isn't clear yet what the social context of such a household choice will be. We don't know the extent to which car makers will want to promote or differentiate vehicles on environmental attributes, whether a public health campaign will be waged to draw consumer attention to the emissions benefits of ZEVs or ULEVs, or what kinds of promotional and counter-promotional infrastructure will be put into place by communities and interest groups to influence consumers.

Any number of opinion polls and market research projects (including our own) have shown broad public support for electric vehicles. Despite such general support, there are serious doubts about whether consumers will shoulder any of the financial burden of electric vehicles. Our previous research, though informal, seems to confirm the opinion that not many consumers will pay extra for electric vehicles. Cars are already expensive: the buyers we interviewed were already stretching their budgets to buy the cars they wanted. Large additional cash (or credit) outlays for "green" autos were not realistic for most of these households. Only a minority of affluent, environmentally conscious households could afford to pay premium prices to express their environmental proclivities through their automobile purchases. While we expect these buyers to be important in the early years of EV markets and to influence other buyers, their numbers are small and should not be counted on for reaching mandates in later years of the market.

In this survey though, a high percentage of all our participants put the environment high on their list of concerns. They show strong support for electric vehicles and public health campaigns. Over 3/4 of our respondents thought that environmental problems are the biggest, or among the biggest, crises of our times. Automobiles are seen as a significant source of pollution. Nearly half our respondents (46%) perceive gasoline to be extremely toxic, and another 37% perceive it to be somewhat toxic. These findings suggest a pervasive concern with environmental degradation and public health, and a perception that gasoline and gasoline vehicles are an important part of the problem.

While we find that practical issues of cost and usefulness dominate the final decision to purchase an electric vehicle among the majority of our participants, environmental concerns have a strong influence over their information search behavior. That is, their concern for low emissions encourages them to seek out and evaluate electric vehicles for purchase consideration. Finally, all things equal, most households are more interested in electric vehicles rather than gasoline vehicles because of the emissions benefits.

Conclusions and recommendations

The results of this study give strong evidence of a market for EVs large enough to fulfill the year 1998 and 2001 mandates with current electric vehicle and battery technologies. Our results indicate that fulfilling the year 2003 mandate will require either EVs having advanced batteries and mid-size body styles (in particular mid-size sedans and minivans), or sufficient sales of EVs to commercial or government fleet and to household market segments outside our sample of potential hybrid households.

We believe that it is more important to market less expensive battery-powered EVs capable of providing driving ranges of 40 to 120 miles than to develop more expensive battery-powered vehicles with ranges in excess of 150 miles. So long as people persist in believing EVs must mimic the long range and short fueling times of gasoline cars, practical EVs will elude us until new electric energy storage technologies can be commercialized. However, we argue that the utility of short range, home recharged EVs lies in their complementary relation to gasoline vehicles and in their ability to provide diversified transportation services in a hybrid household. Marketed as such, it appears to us that both the state of the art in technology and consumer demand are adequate to launch the market for ZEVs.

This study assumes EVs will be priced comparably to gasoline vehicles. There are concerns that EVs will cost much more. We recommend that the California Air Resources Board investigate the probable prices of mass produced EVs and identify strategies to mitigate large price differences, if such differences should be found to exist. For meeting the 1998 mandate, such an investigation should focus on determining the costs of small and compact vehicles with driving ranges from 60 to 150 miles. There is a demonstrated need to convince policy makers and consumers that such vehicles are technologically viable and economically competitive with gasoline vehicles. For meeting the 2003 mandate or long term goals, the possible price of mass-produced mid-size EVs should be investigated.

The estimate we offer for the portion of the annual light-duty vehicle market represented by hybrid households (35-40%) is conservative. Given the importance of understanding the nature of the stocks of vehicles that households buy and own (at the household level, not some aggregate level) it is important that data on household vehicle stocks be publicly available. This data could offer a better estimate of the hybrid household segment.

The many different possible designs of hybrid electric vehicles pose complex research, policy and market problems. Consumer response to hybrid EVs, whether a particular hybrid EV design satisfies ULEV or ZEV definitions, and the technological hurdles to building a hybrid EV are all intertwined. We tested household responses to one possible hybrid EV. In the near future, CARB may wish to investigate more fully household response to hybrid vehicles.

Finally, we suggest that CARB or the appropriate state agency prepare consumers for the coming market for electric vehicles by educating potential hybrid households of the possible benefits and lifestyle implications of EVs in a household fleet.

INTRODUCTION

The California Air Resources Board will soon require that auto-makers offer for sale "zero emission vehicles" (ZEVs) in California. Starting in 1998, the auto-makers subject to this mandate will be those who sell more than 35,000 vehicles in California whose laden weight is less than 3,750 lb. They must offer for sale ZEVs in sufficient numbers that at least 2 percent of all the vehicles (under the weight limit) that they offer for sale, are ZEVs. This mandate is flexible in two ways, that ZEVs sales in weight categories between 3,750 lb. and 5,750 lb. will count for credits and that manufacturers can obtain credits from other manufacturers who exceed their quotas. This 2 percent level increases to 5 percent in 2001. In the year 2003, the mandate changes in two ways. First, any auto maker who sells more than 3,000 vehicles that are under the weight limit will be subject to the mandate. Second, the proportion of ZEVs offered for sale rises to 10 percent. Currently, the only type of vehicle to meet the ZEV definition is electric-powered vehicles (EVs) that store their energy in batteries. The idea behind the mandate is to kick start a competitive industry for clean cars that need no emissions systems testing, suffer no long term degradation of emissions control equipment, and will help to eliminate emissions from urban centers in California.[1]

The auto-makers are resisting and criticizing the mandate, claiming consumers will not want these electric vehicles because of their limited driving range. Given current vehicle technologies, the only type of vehicle that will meet the zero emission definition is electric vehicles (EV) that store their energy in batteries. But currently available batteries have low energy densities, which results in greatly reduced driving ranges compared to gasoline vehicles. Also, typical battery recharging times are measured in hours, not minutes. Limited range and long recharge times create uncertainty and skepticism about the possibility of selling battery electric vehicles to consumers habituated to long driving ranges and quick, ubiquitous refueling.

Market research on ZEVs is difficult because, besides having no tailpipe emissions, electric vehicles are different from gasoline vehicles in ways which are unfamiliar to consumers, most notably the way in which energy to drive the wheels is stored, used and replenished. Compared to the fuel tanks of gasoline vehicles, which store at least 300 miles of fuel, current EV battery technologies store a very limited amount of energy. Most existing EVs must be recharged after 60-120 miles of use depending on the type of batteries, vehicles and driving. Compared to refueling gasoline vehicles, recharging electric vehicles can take hours, depending on the voltage and sophistication of recharging equipment. However, there are potential advantages to electric vehicles which mitigate these limits, primarily that recharging can take place at many locations where cars are parked, including home, work and public parking, thus eliminating special trips to refueling stations. EVs can also be pre-cooled, heated or defrosted while they are being recharged. Electric vehicles will have new

[1]Throughout this report we use the terms "car", "automobile", "light-duty vehicle" and "vehicle" interchangeably. We do so for variation in the text. In each instance, unless expressly defined otherwise, we mean light-duty passenger cars and trucks, including minivans, pickup trucks and sport utility vehicles.

driving, braking and sound characteristics which may appeal to some drivers. Finally, some drivers who dislike gasoline for its smell, toxicity or combustion dangers as well as prefer a vehicle with no tailpipe emissions may prefer electric propulsion.

This report summarizes the responses to a statewide survey and other research by the authors on consumer response to limited range, electric vehicles[2]. We conceptualize household response to limited range vehicles as the *hybrid household hypothesis*. We develop the hypothesis in greater detail below, but it can be stated simply as: potential hybrid households will find EVs to be practical and desirable choices for at least one of their household vehicles. A household that combines EVs and gasoline vehicles in its stock of vehicles is one example of what we call a *hybrid household*. In contrast to a hybrid electric vehicle that combines electric and heat engine drive systems in one vehicle, a hybrid household chooses two vehicles with different types of energy systems and then must allocate household travel accordingly. We note that a household that chooses a hybrid electric vehicle is also a hybrid household.

This research directly tests whether consumers will buy EVs in sufficient numbers to satisfy the ZEV mandate. Our conclusions are based on the results of a statewide survey of households that buy new cars. The survey is the culmination of three years of research into the household market for EVs. As such, we include results of some previous studies that provide insights germane to our research design. We define our central hypothesis—the hybrid household hypothesis—in the next section. We follow that with a discussion of our research and survey instrument design. That section includes a review of past research, including our own and that of other researchers, that was instrumental in our formation of the hybrid household hypothesis and guided the design of our survey instrument. Next we describe how we selected our sample and compare it to other samples of new car buyers and other samples of households. We develop the details of our estimate of the proportion of the total light-duty vehicle market that we believe our sample represents. We then report the results of our test of the hybrid household hypothesis and provide an expanded discussion of the choices of driving ranges and vehicle recharging options made by our respondents. We develop a detailed image of one plausible future light-duty vehicle market and use that image to explore changes in household vehicle choices and the types of households who buy EVs. The last section of results provides an in-depth discussion of environmental dimensions of vehicle choices within our choice experiments and their possible implications for the sale of environmentally more benign vehicles. We close with a section of summary conclusions and recommendations.

[2]In fact, the survey includes natural gas vehicles too. We address both electric and natural gas vehicles in this report, but the fundamental premises of this research, the basic design features of the survey instrument, in fact, the very reason for this entire study is the market for electric, not natural gas, vehicles. We include natural gas vehicles because they are part of a plausible future scenario for light-duty vehicles, because they are intermediate between EVs and gasoline vehicles on certain vehicle attributes, and because our original proposal to one of the sponsors of this research included an assessment of the market potential of natural gas vehicles.

THE HYBRID HOUSEHOLD HYPOTHESIS

In a broad sense, the initial target markets for EVs are commercial, utility and government fleets and the growing number of multi-car households. We focus on the household market in this report. The new technical features of electric vehicles indicate a niche market for consumers; multi-vehicle households that prefer to specialize the types of vehicles in their household fleet. In such a market niche, EVs should not be seen as simple one-for-one substitutes for ICEVs. EVs offer new limitations as well as new capabilities. They comprise an alternative travel technology that owners must learn to integrate with familiar gasoline vehicles.

Who are Hybrid Households?

A household that combines electric and gasoline vehicles in its stock of vehicles is one example of what we call a *hybrid household.* In contrast to a hybrid electric vehicle that combines electric and heat engine propulsion systems in one vehicle, a hybrid household chooses two vehicles with different types of energy systems and then must allocate household travel accordingly. We note that a household that chooses a hybrid electric vehicle is also a hybrid household.

The criteria used to select households for this study identify those whom we believe represent the largest single group of *potential hybrid households.* These households already make vehicle purchase decisions that render the formation of a hybrid household fleet most plausible—they already own multiple vehicles, they buy new vehicles, and they own at least one vehicle of the body-styles most likely to be offered as EVs.

This group does not represent all households that may buy EVs. Other potential EV buyers include: households that do not buy new cars but would buy a new car to buy an electric vehicle; households that do not own vehicles of the likely EV body-styles, but would buy one to get an electric vehicle; and single car households that would become two car households by purchasing an EV. These households would have to make some change to their vehicle purchase behavior in order to buy an EV. To focus only on those households who face the least barriers to EV purchase, we exclude them from the sample for this study and focus only on those we have defined to be potential hybrid households.

The hybrid household hypothesis

With our definition of a hybrid household, we can state the research hypothesis—the overarching question to be answered by this study. We call this the *hybrid household hypothesis:*

> *A driving range limit on one household vehicle will not be an important barrier to the purchase of an EV by a potential hybrid household.*

If the hypothesis is true, then we expect over a long period of time (long relative to the period of time between new car purchases within a household) that potential hybrid households will actually choose to buy an EV about once every *N* times they buy a new car, where *N* is the number of vehicles they own. Thus if a household in our sample maintains ownership of two vehicles over a long period of time, we assume that 1/2 of the time they buy a new car, it will be an EV. This is based on the assumption that a hybrid household always maintains ownership of at least one long range vehicle. (We assume for this study that such a vehicle will be a gasoline vehicle but conceivably it could be a hybrid electric, natural gas, methanol or some other type of vehicle).

Based on our interactive stated preference interviews we know that not all potential hybrid households will find a limited range vehicle to which they can adapt (Kurani, et al 1994). In that study, four of the fifty one households were unable to find a limited range to which they could adapt. (We note that we did not include hybrid EVs in that study and all four of those households might have overcome any of their range problems through the use of a hybrid EV of the type we included in this study.) As an initial extension of that result, we hypothesize that 8 to 10 % of our sample of potential hybrid households in this study will also be unable to adapt to any of the limited range vehicles offered. We call such households *non-hybrid households.*

Now, this study does not cover a long period of time. We do not observe repeated choices by households across time; we ask only about the next new vehicle purchase decision. We have only a cross-section of this one group of potential hybrid households. We make the following strong assumption. All the factors that determine whether the next vehicle purchased by these households is an EV or an ICEV are distributed throughout our sample such that $1/\mu$ of our households choose to buy an EV for their next new vehicle, where μ is the average number of vehicles owned by all households. In the sample $\mu = 2.43$. The potential hybrid households that do not choose to become hybrid households by purchasing an EV in this, their next new vehicle purchase decision, are either non-hybrid households (as defined above) or simply remain potential hybrid households—perhaps choosing to buy an EV at some point in the future.

We can now state the hybrid household hypothesis in a manner that can be tested. If the hybrid household hypothesis and its related assumptions are true, then about 8% of our survey sample are in fact non-hybrid households and will not choose an EV. Of the remaining 92% of our sample, 41% (1/2.43 x 100%) will choose to buy an EV and thus become hybrid households. The other 59% will choose to buy an ICEV this time, but remain hybrid households who may buy an EV at some later date. Thus we restate the hybrid household hypothesis as:

> *H_O: We expect the proportion of our original sample of respondents who choose an EV in this study to be about 38% (41% of 92%)*

How many hybrid households are in the California new car market?

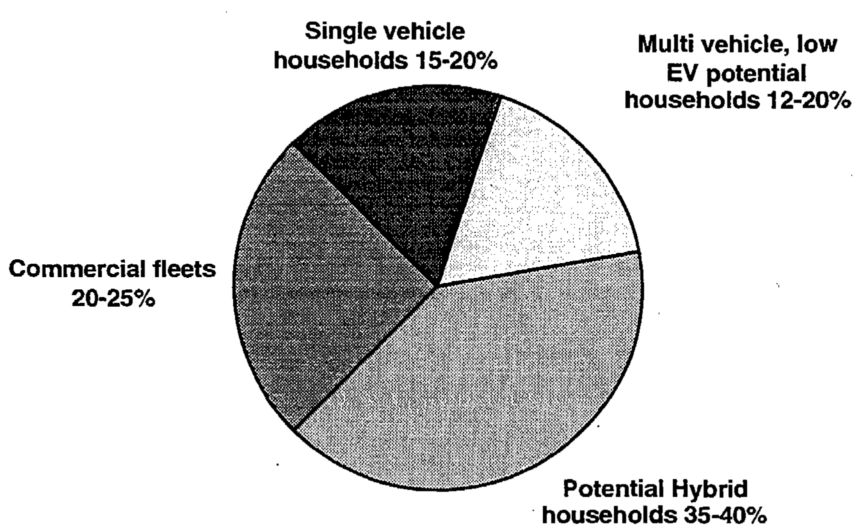
The target period for the study is 1998-2003, the first five years of the ZEV mandate. Therefore we need an estimate of the likely level of new cars sales starting in 1998. The California light-duty vehicle (under 6000 lb.) market in 1992 was about 1.4 million vehicles (Polk 1992). The national new car market was largest in 1988, decreasing every year until 1993. New light-duty vehicle sales in California have followed these trends. Thus, despite the fact that many studies, especially those of the auto companies, forecast continued growth of vehicle sales, it would be prudent not to forecast auto sales much over the 1992 or 1993 levels. In this study, we use 1992 as a representative year, thus we base our market share estimates on a total 1998 market of 1.4 million vehicles in California.

For the purposes of this study, we divide this annual market into four market segments: 1. Commercial and government fleets, 2. Single vehicle households, 3. Potential Hybrid Households and 4. Multi-vehicle, non-potential hybrid households. This last segment includes a number of multi-car households that fit our hybrid household definition, but are unable or unwilling to adapt to a limited range vehicle. They include households whose vehicle use patterns require long distance capabilities for all their vehicles; households that want only full-sized vehicle body styles, or households that demand that the newest vehicle always be a long range vehicle (because the other vehicle is either not new or not maintained well enough to serve as a long distance vehicle). We estimate that *potential hybrid households* buy between 35 and 40% of all new vehicles in California every year.

Given these market size estimates, we can restate the hybrid household hypothesis in terms of total vehicle sales. If the annual sales in California for light duty vehicles are 1.4 million vehicles, if our sample buys between 35 and 40% of new light-duty vehicles, and if 38% of potential hybrid households choose an EV, then...

.....we expect 13.3 to 15.2% of all light-duty vehicle sales, or 186,000 to 213,000 vehicles per year, would be limited range electric vehicles sold to this hybrid household segment.

Figure 1: California light duty vehicle market for 1992



RESEARCH AND SURVEY INSTRUMENT DESIGN

Previous market research on EVs

Some auto companies and other critics have lobbied to dismantle the California ZEV mandate, primarily on the grounds that consumers will not buy electric vehicles. Car companies have argued that their research shows that electric vehicles are going to cost more than comparable gasoline cars, yet consumers will want to pay less because of the range limitations. Conservative sales estimates in turn lead to yet higher cost estimates because costs are spread over few vehicles. High cost estimates iteratively reinforce minimal EV market estimates.

There are problems in relying on auto company sponsored research as a basis for public policy. The market for automobiles is highly competitive and thus a proprietary area of research. Information generated by the car companies about the market is rarely openly presented and debated.

Much of the publicly available research on markets for EVs has focused on predicting the size of the market at the expense of understanding market dynamics for a fundamentally new consumer product. Many of these studies have relied upon convenient rather than appropriate data samples. Almost all, we believe, rely on an implausible set of assumptions regarding consumer behavior. Such shortcomings exist precisely because there are no sales data for EVs. In the absence of sales data, researchers have tried three methods to develop estimates of EV market potential—attitude studies, travel behavior analyses, and stated preference surveys.

These three research streams present an apparent paradox. Attitude studies and travel behavior analyses tend to show EVs to be a practical and desired technology, but stated preference studies typically conclude consumers are unwilling to consider EVs at anything but "fire sale" prices. This paradox calls for close scrutiny of the methods and findings in these studies.

Attitude Surveys

A number of *attitude surveys* and some focus group studies by auto manufacturers, electric utilities and auto market analysts have found a sizable percentage of consumers who are interested in, and favor, electric vehicles and other alternatives to gasoline (Buist, 1993; Kirchman, 1993; Fairbanks, Maulin and Associates, 1993; Dohring 1994). It appears that electric vehicles in particular have a special fascination over other propulsion systems because they have the most progressive technical and environmental image (Turrentine, et al, 1992). However, these attitudes are far removed from vehicle purchase and use; they represent the ideals of consumers and not their full decision process. Additionally, these studies often report conflicting attitudes. They report that on the one hand consumers strongly favor electric cars, but on the other, want similar driving range as their gasoline vehicles.

An important flaw exists in those attitude studies that start with the premise that the market for EVs is a "green" market. These studies unduly constrain their search for EV market segments. Ford Motor Co. (Buist, 1993) reported using this approach; first, find the environmental consumer, and then cull those willing to pay the purchase price premium Ford projects for EVs. This approach may be interesting to manufacturers for several reasons. It captures those consumers with certain strong convictions about EVs; it may identify some consumers who are willing to pay more for an EV than a gasoline vehicle; and it may even identify consumers who have not previously purchased a new vehicle, but might buy an EV. However, many of those with strong environmental convictions have neither appropriate vehicle use nor purchase behavior to consider buying an EV. By limiting the possible buyers of EVs through this "green" filter, studies such as Ford's eliminate a wide set of consumers for whom EVs offer practical advantages as part of a household fleet. We have found in previous studies (Turrentine, et al, 1992) and in this work that broader lifestyle issues are better primary filters for the EV market than are environmental convictions.

Travel Behavior Studies

Travel behavior studies (sometimes called "constraints analyses") have largely focused on the issue of limited range. Typically such studies attempt to count the households that have more than one vehicle and travel habits that can accommodate a limited range EV. The primary assumption in these studies is that potential EV-owning households must have at least two vehicles. The other common assumption is that there can be no pattern of vehicle use in the household such that *all* household vehicles travel beyond the expected range of EVs on a daily basis. The data used in these studies often come from the Nationwide Personal Transportation Survey (NPTS) or the American Housing Survey (AHS). The NPTS contains a one day travel diary. The AHS asks only about typical travel and commute travel. For examples of these constraints analyses, see Deshpande (1982), Kiselewich and Hamilton (1982) and Nesbitt, et al (1992).

In general, such studies conclude that 55 to 60 million households could accommodate a 100 mile range vehicle. This is based on the finding that more than 90 percent of two car households could use one vehicle with 100 miles of daily range and that most "second" cars are used more than 100 miles on only a few days per year.

One of the more recent of these studies added a further constraint—the household must have a logical place to recharge the EV. They found about 28% of American households (28 million households) could accommodate an EV (Nesbitt, et al, 1992). Greene (1985) used the travel behavior approach but distinct data; he analyzed multi-day refueling diaries, and inferred underlying distributions of travel. He concluded that with 95% probability, half of all household vehicles travel less than 105 miles per day on 95% of all days. There was no substantive difference between vehicles in single and multi-car households.

A recent study by General Motors, aimed at understanding the market for electric vehicles, concurs that the majority of any household's travel required minimal range or passenger payloads (Dables, 1992). Potential EV owners kept three-week driving logs in that study. GM reported 84% of their sample drove less than 75 miles a day and in only 5% of trips were more than two persons in the car.

All these studies present reassuringly large market potentials. But the limitation of the travel behavior approach is that it doesn't measure consumer preferences or observe vehicle purchases. While measuring a "potential market", these studies don't examine attitudes or social processes that will shape consumer lifestyle choices. Additionally, they analyze vehicle stocks, not new car sales. Skeptics of the potential market for EVs have criticized constraints analyses, arguing that regardless of how people actually use their vehicles, consumers probably won't give up unlimited range or fast refueling of ICEVs. Hamilton complained that such studies were merely wishful thinking (Hamilton, 1983). The third approach to EV market studies, stated preference techniques, appear to support this argument quite forcefully.

Stated Preferences

Stated preference studies of vehicle markets present consumers with choice sets of vehicles, then ask which one vehicle from each choice set they would be willing to buy. Each vehicle is described by attributes common to all the vehicles. The attribute levels are varied over several trials to elicit different choices. With this data, econometric models can be used to assign partial utility values to consumer preferences for vehicle attributes. The partial utilities for driving range have often been used to estimate a purchase price penalty for limited range vehicles.

Virtually every stated preference study has estimated huge average price penalties for limited range vehicles. For example, consider the average discount you would have to give on a 50 mile range vehicle, compared to a 200 mile range vehicle, as estimated by the following three studies: Morton, et al (1978), $10,000; Beggs and Cardell (1981), $16,250; and more recently, Bunch, et al (1993), $15,000. In a slightly different study, Calfee (1985) calculated household-specific price penalties. The range of estimated penalties is large, but many are close to the average penalties reported above—even for consumers who chose EVs.[3] Considering that the average price of a new automobile in 1991 was $16,700 (MVMA, 1992), these studies suggest that, on average, consumers would be indifferent to the choice between two cars that were identical, except one was free and had a 50 mile range, and the other, for which they must pay full price, had a 200 mile range. Using these large average penalties for limited range, projected EV sales are very low. Market penetration estimates in these studies range from 2% down to 0%.

[3]The variable of range is separated from other refueling or recharging attributes such as type of fuel, speed of recharging or refueling. We selected from the data in these studies the 50 mile range to fit the bottom end capabilities of EVs and the 200 mile range to represent the possible result of advanced battery technology. These advanced battery systems have been demonstrated in full pack size but not yet perfected. All prices are in $1991.

We are skeptical regarding this conclusion for two reasons. First, the average utility is irrelevant to the dynamics of market development. The average penalty for limited range makes an apparently compelling argument for those opposed to the introduction of EVs. But "average" consumers are not, by definition, the first buyers of something new. It is the distribution of disutilities that matters. The appropriate objective of an econometric approach then, would be to determine how many consumers assign positive, or relatively small negative, total utilities to EVs as compared to gasoline vehicles. Our second reason for skepticism is the underlying assumptions regarding consumer behavior in stated preference studies and the contradictions to these assumptions we find in our work. We address these issues next.

The underlying assumptions about consumer behavior contained in these econometric models seem untenable to us. A complete critique is provided elsewhere (Turrentine and Sperling, 1992). Here, we focus briefly on the characteristics of preferences. In order to make inferences about the value placed on driving range, it must be assumed that respondents have well formed preferences for range. Preferences have specific properties, e.g. transitivity and communativity. Most importantly for purposes of forecasting future market shares, preferences must be stable or there must be enough longitudinal data and an adequate theoretical understanding to also forecast the rate of change of preferences. These are highly speculative assumptions for attributes with which consumers have no experience. We have shown consumer "preferences" for driving range shift dramatically based upon small increments of information. Such shifts are evidence of instability and may result in non-transitivity of "preferences" for different driving range, home recharging, and other novel attributes of EVs (Kurani, et al, 1994).

Preceding market research by ITS-Davis

Our critiques of many previous studies were developed in the course of completing two years of preparatory research for this statewide survey. It was during this time that we observed the behaviors that lead us to examine the state of consumer "preferences" and to explore the conflict between the conclusions of stated range preferences and actual travel behavior. As part of a drive test clinic of electric, compressed natural gas and methanol fueled vehicles in 1990 in Pasadena, California, we conducted 11 focus groups with drive clinic participants (Turrentine, et al, 1992). In the focus groups, we elicited initial estimates of needed driving range from each participant at the start of the session. Then we discussed range needs in a number of different ways. We asked participants to estimate their actual daily driving, and then to make trade-offs between range, fuel prices and vehicle prices to explore the stability of their initial range need estimates. The primary finding was that participants' stated preferences for range were extremely volatile and changed dramatically under the influences of new information, attitudes expressed by other group members, and attempts of the moderator to influence responses by suggesting range related problems. Some respondents' stated needs increased, but overall, there was a pattern of drastic reductions in stated daily range needs. This finding suggested there was a learning curve for driving range. With conventional gasoline technology, driving range is an infrequent problem for even the most extreme driving needs, so households have not paid attention to their own travel routines in a way that would help them evaluate the impact of a limited range vehicle on their lifestyle. While our sample was small and the setting informal, we found nothing to support the extreme average penalties reported in stated preference work, if people did reflect on their range needs.

We then developed an innovative household interview technique we call PIREG (Purchase Intentions and Range Evaluation Games). Fifty-one suburban California households kept one week diaries of their driving and participated in a two hour *interactive stated preference* interview. By interactive, we mean the role of the interviewer was not to ask questions, but rather assist the household in forming what they thought were the important criteria for evaluating the utility of limited range vehicles. We learned from the PIREG interviews that a range limit on one household vehicle was not a barrier for most of these households. The problems caused by a range limit were few and were solved rather easily by common vehicle allocation strategies (Kurani, et al, 1994). In that work, we first formulated the *hybrid household hypothesis*.

Design of the survey instrument

The preparatory work reported above lead us to conclude that innovative survey methods were needed to provide both consumers and researchers with an adequate context to understand and measure potential consumer demand for products that embody fundamentally new attributes. As the review of previous studies shows, standard techniques were clearly not resolving the issue of consumer response to the limited range of battery electric vehicles. Overall, the goals of this research were to educate households about potential EV technologies and their lifestyle impacts. Only then do we offer a plausible future market scenario in which we ask whether they would buy an EV.

Fundamental Design Assumptions

Any research design makes basic assumptions that are not themselves directly tested, but serve as the foundation upon which the research is built. We describe three basic premises that shape the design of this research and the survey instrument. First, households are the fundamental unit of vehicle purchase and use decisions. Second, the research instrument must create an information context appropriate to the decisions being studied. Third, research that relies upon hypothetical choices can, and should, be improved through the use of reflexive designs that allow respondents to construct images of their own lifestyles. Additionally, we also discuss what might be the most controversial portion of our research design—our choices of vehicle prices in the Choice Situations.

Household based study

We assume the unit of automobile purchase and use decision-making is the household. We designed the survey instrument so that all members of the household can participate. If the household members makes joint decisions in the Choice Situations, they report this in Part Four of the questionnaire. In households that contain more than one person, the structure of the household relationships and responsibilities will affect such fundamental choices as vehicle body style and amount of household resources committed to vehicle purchase. A

Newsweek study of new car buyers reported that only 8% of respondents said they were not influenced by their spouse. Children played a role in vehicle choice in most households; only 27% of households reported not being influenced by children. Adult children are the most independent in making their own vehicle purchase decisions, still the majority (56%) are influenced by their parents (Newsweek 1991).

In the long term, households move through life cycles, defined by the size of the households, the age of its members and their employment status. Such life cycles have been shown to exert a systematic influence on vehicle purchase choices. As a corollary to this assumption about household decision making we add: households' vehicle purchase decisions are made within the context of the vehicles they already own. In particular, it is the attributes of vehicles that the household already owns that exert the greatest influence on the formation of the choice set from which the household selects its next vehicles.

As a final design choice based on the choice of the household as the unit of analysis, we chose a mail out/mail back survey that required households to spend several days to complete the questionnaire. The Newsweek study cited above reported that on average, households required six weeks to make a car purchase decision. Thus a telephone survey would be an inappropriate context to pose vehicle purchase questions. (Telephone contact could be used to retrieve responses to a questionnaire households had had time to ponder.)

Lifestyle and Life cycle

Two important concepts in this study are lifestyle and life cycle. Life cycle refers to the composition of households as they move through some developmental phases that affect travel needs and wants, and therefore affect decisions about the composition of each household's fleet of vehicles. Life cycle phases are defined primarily by the presence of children, the age of children, the age of heads of households, the presence of one or two heads of household, and school, work or retirement status of household members. These developmental phases are not universal; there is much variation in the population as to what constitutes a household.

Lifestyle, on the other hand, relates more to the consumption goals of a household as those are shaped by social class, ethnicity, local values and other received values. Significant lifestyle expressions include choices of home location, recreation and other expressive activities, and career. Lifestyle and life cycle can overlap considerably when choice of a life cycle is an expression of consumption choices rather than simply an expected pattern. One example would be retirement. A household may become a "retired household" (a life cycle change), without altering its lifestyle, or the household may chose retirement as part of a lifestyle change. The importance of "lifestyles" to this study is that, especially in multi-car households, vehicles are a strategic technology for achieving lifestyle goals and travel patterns are at the heart of the organization of lifestyle goals. For some households, limited range creates severe blocks to lifestyle plans. In others, electric vehicles may become a more appropriate expression of values, as well as a practical technology to achieve their lifestyle goals.

Information rich survey

Consumers do not have adequate knowledge of electric vehicles to form preferences or to make hypothetical choices that reliably reflect real purchase intentions. A frequent comment from our previous work was that respondents were surprised that EVs look and drive like conventional vehicles. Many respondents expect EVs to look futuristic and perform like golf carts. In our drive test in Pasadena, most respondents said the EVs performed much better than they expected.

In this statewide survey, we don't have vehicles for participants to test drive. Instead we offer an informational video that shows a number of natural gas, electric, and hybrid electric vehicles being refueled, recharged, driven on city and freeways, being parked, etc. We found that for many participants, this visual information was a necessary adjunct to written materials for grasping the fundamentals of EV use. We also included reprinted articles on EVs from the popular press. Finally, we included detailed brochure-like information on each of the hypothetical vehicles being offered to participants in the choice section of the survey.

Reflexive Survey Techniques

The purpose of *reflexive* techniques is to reflect back to subjects their own behavior and decisions as context in which they can learn the impacts of new technologies or ideas on their lifestyle choices. This study was designed to reflect back to participants the impact of a limited range vehicle on their lifestyle. We used a number of methods to encourage this reflection and learning, including travel diaries, maps of household activity locations and reflexive questioning. The reflexive questions refer back to the diaries, maps and earlier questions in the survey to link vehicle choices to real elements of the household's life. This study was designed to both educate participants on the design features of electric vehicles and the effects of a daily range budget as well as home and away-from-home recharging on their lifestyle as we would expect in a real purchase situation.

Overview of the survey instrument

This survey was divided into four parts and was designed to be completed over several days to encourage critical evaluation of the options. A copy of the entire survey (except for the video and maps) is included in Appendix A. The four parts are summarized below.

Part One: Initial survey of household vehicle holdings, purchase intentions for next new vehicle, demographics, and environmental attitudes.

Part Two: Three day travel diary for two primary household vehicles, a map on which the household plotted their activity locations, and a survey of the travel and refueling patterns of the two primary drivers.

Part Three: Information video and reprinted articles from major media that explain and demonstrate distinct refueling and recharging routines, emissions and other new features of compressed natural gas, battery powered electric, hybrid electric and neighborhood electric vehicles. References for the reprinted articles are given in Appendix B.

Part Four: Household is presented with two Choice Situations for their next vehicle purchase. The first situation is a test of the hybrid household hypothesis. The second situation develops a more detailed picture of market segments for electric vehicles. We explain this section in greater detail immediately below.

Vehicle Choices in the ITS Survey

The automotive market place is complex, with a broad range of vehicle brands, body styles and models. The trend is toward increasing diversity with each new model year. This complexity is increased greatly by the introduction of alternative-fueled vehicles. They introduce entirely new lines of market segmentation. We use the following terms throughout this discussion and this report to distinguish between vehicles and market segments for those vehicles:

Vehicle type refers to the type of propulsion system, i.e., electric, gasoline, or natural gas.

Body style refers to the shape and design of the body, e.g., sedan or minivan.

We include two Choice Situations in Part Four of the questionnaire. Each is constructed as a distinct experiment. *Situation One* is designed as a robust test of the hybrid household hypothesis. It makes relatively few assumptions about EV technology or future markets for vehicles. It is a choice between a conventional, gasoline-fueled vehicle and a limited ranged, home recharged, electric vehicle. This is a simple test to see how many households select a limited range vehicle as their next vehicle. *Situation Two* is designed as one plausible market scenario that could occur in the next five to ten years. That market includes six vehicle types: reformulated gasoline, compressed natural gas, hybrid electric, two types of freeway capable battery electric, and a neighborhood electric. Because it is much richer in detail, this scenario relies on many more assumptions than does Situation One. This richness of detail though allows us to build a more detailed image of market segments defined by vehicle types, body styles, and driving range.

In both scenarios, we offered electric vehicles only in the body styles we expect them to be offered in during the next few years. These *EV body styles* include sports cars, small sport-utility vehicles, small (sub-compacts) sedans, compact sedans, mid-size sedans and minivans. Gasoline and natural gas vehicles were offered in the full range of body styles, including full sized sedans, pick-ups, vans and sports utility vehicles.

Part Four of the questionnaire included two booklets, a *Price-Workbook* and an *Answer Booklet*. The Price-Workbook contains eight vehicle brochures, one for each of the two vehicle types in Choice Situation One and one for each of the six vehicle types in Choice Situation Two. Each brochure is a two page folio. One page is a description of the vehicle type and the other is a one page price sheet. The price sheet is formatted as a table of body style and vehicle options, as well as prices. Participants recorded their vehicle choices in the Answer Booklet. Part Four ends with a few final de-briefing questions about household decision strategies and post-survey perceptions of EVs.

It is important to understand that the choice experiments are not intended primarily to be forecasts or predictions of future vehicle market scenarios. They are intended to maximize the information we gain about household response to driving range limits and home recharging. As such, the differences and similarities between vehicle types expressed in the choice experiments are a blend of existing, expected, and experimental design features. For example, it is both an existing and expected feature of electric and natural gas vehicles that they will have shorter driving ranges than gasoline vehicles. It is part of our experimental design that we have limited natural gas vehicles to ranges that are shorter than those already demonstrated for some natural gas vehicles.

As an example, the information contained in the Price Workbook brochure for the electric vehicle offered in Choice Situation One is shown on the next page. The associated price sheet is shown on the following page. All brochures for all vehicle types have a moderate promotional tone, drawing attention to the distinct features of each vehicle type.

Electric vehicle

(Description provided in Choice Situation One.)

Recharging: Do most of your refueling at home; no gasoline on your hands or fumes.

Slow charge 110 volt wall socket (8-10 hours if batteries fully discharged).

OR

Normal charge Install a 220 volt (2-4 hours if batteries fully discharged) circuit and outlet in your garage, carport or driveway of your home, condominium or apartment. Utility rebates available for installing new circuit.

Optional Fast charging: Recharge up to 80% of your battery in around 20 minutes at special fast charge stations.

Optional Solar: panels for roof and hood provide 10 extra miles on sunny days or can extend range by offsetting air-conditioning load.

Electricity Costs: 1-2 cents per mile, when charged at night,
6 cents per mile for daytime charging.

Battery pack options:

Type 1: 80-100 miles per charge depending on model, (replacement cost $1200).

Type 2: 100-120 miles per charge depending on model, (replacement cost $2000).

New range instrumentation: Indicates how many miles are left on the vehicle. "Smart instruments" estimate range based on how you drive.

Drive train: 120 horsepower, 3 phase, alternating current motor (no transmission in electric vehicles)

Top speed: 80 mph (speed is governed at 80 mph to reduce drain to batteries)

Acceleration: 0-60 in 10 seconds (some sports models faster).

Air conditioning: Interior of vehicle pre-cooled or heated while recharging.

Option: Heat-pump, high efficiency air conditioning

Maintenance: Battery and check up service each 10,000 miles. Battery life estimated at 25,000 miles

Warranty: 2 years or 24,000 miles warranty on electronics, 8 year or 100,000 mile warranty on motor and drive train, 25,000 mile warranty on batteries.

Meets Zero Emissions Vehicle requirements for State of California ($4,000 tax credits)

No smog check required

Economy models come with AM FM radio, pre-cooled and heated seats.

Standard models come with AM/FM and Cassette, anti-lock brakes, drivers air-bag, power windows and cruise control .

Luxury models come also with CD Stereo system, heat pump climate control, dual airbags, all power accessories, sunroof, keyless entry.

Table 1: Electric Vehicle Price Sheet from Choice Situation One

Body Style:	Sports car two-seater o	Compact pick-up o	Small sport-utility o	Small sedan o	Compact sedan o	Mid-size sedan o	Minivan o
	Choose economy, standard or luxury (air conditioning included in luxury model)						
Economy Base price	$17,000 o	$13,000 o	$14,000 o	$14,000 o	$17,000 o	$19,000 o	$19,000 o
Standard Base price	$20,000 o	$16,000 o	$17,000 o	$17,000 o	$20,000 o	$22,000 o	$22,000 o
Luxury Base price	$24,000 o	$20,000 o	$21,000 o	$21,000 o	$24,000 o	$26,000 o	$26,000 o
Tax Rebate	Zero Emission Vehicle Tax Rebate: Subtract $4000 from base price above						
	Choose battery type / preferred range option						
Type 1 standard equipment	100 miles o	80 miles o	80 miles o	100 miles o	100 miles o	80 miles o	80 miles o
Type 2 battery	120 miles $800 o	100 miles $800 o	100 miles $800 o	120 miles $800 o	120 miles $800 o	100 miles $800 o	100 miles $800 o
	Choose options (heat pump air conditioning standard for luxury model)						
Fast charge setup	$900 o	$900 o	$900 o	$900 o	$900 o	$900 o	$900 o
solar panels setup	$1200 o	$1200 o	$1200 o	$1200 o	$1200 o	$1200 o	$1200 o
Four door	not applicable	not applicable	not applicable	$1000 o	$1000 o	$1000 o	not applicable
Wagon or extended cab	not applicable	$800 o	not applicable	$800 o	$1000 o	$1000 o	not applicable
heat pump air condition	$800 o	$800 o	$800 o	$800 o	$800 o	$800 o	$800 o

Please add your base price, subtract tax rebate, and add options.

Total price of your package $__________.00

Vehicles Prices in the Choice Situations

Another difficulty in designing EV market studies is that the prices at which electric vehicles will be sold in the future are extremely uncertain. The price of a single vehicle will be a complex function of development and production costs and total vehicle sales. These in turn depend on the precise performance characteristics of the EVs being offered for sale. Longer range electric vehicles will cost more to build, will therefore be priced higher, and likely will be sold in minimal numbers. Implicit in our premise that the market for EVs can be segmented by driving range is the assumption that many more, lower cost, shorter range EVs can be sold than indicated by previous research. In order to focus on consumer response to driving range and home recharging, we designed choice situations in which all vehicle's prices are roughly comparable. With the exception of optional equipment and replacement costs of batteries, the base prices of all vehicles in this study are made equivalent through purchase incentives for ultra-low and zero emission vehicles. Thus respondents had little incentive to choose between vehicles based upon price alone.

One potential criticism of this study may be that we have priced EVs too low. The price of EVs is a central issue in the ZEV debate, but it is a highly uncertain and politicized variable. Some auto companies claim that electric vehicles will be priced at much more than the $4,000 price differential between gasoline and regional electric vehicles we use in this study. Most of this concern comes from the currently high price of batteries.

We counter this argument thus. The cost, and therefore price, for an EV is related to driving range. The technical features and performance levels we offer in EVs are in many cases very modest, and well within the capabilities of existing EV and battery technologies. For example, we define range classes of "neighborhood" and "community" EVs that are modest in terms of their range and performance; several examples of such vehicles are already on the road. We see little reason for such vehicles to persistently cost any more than gasoline vehicles of comparable body styles. (We note that neighborhood EVs are offered to respondents at prices very much lower than any other vehicle type.)

Thus, by examining whether the market can be segmented by range, we design a study that both focuses on driving range and speaks to the issue of future prices for EVs. If we demonstrate there exists a viable market for shorter range EVs, then the discussion of prices for those vehicles (under conditions of large-scale production) is made much less speculative. The technologies to build those vehicles, and their prices, are better known than those of the hoped-for super battery.

The prices of gasoline and reformulated gasoline vehicles presented in the study are based on average prices of a sample of gasoline vehicles in each vehicle size class. We used price data from the 1992 model year (Automotive News Market Data Book, 1993). For example, we took the average base price of the five best selling compact sedans in 1992 to provide a standard price for the compact gasoline and reformulated gasoline sedans. All vehicles were offered with economy, standard and luxury option levels to reduce bias based on the perceived image of any class of vehicles. That is, we did not want responses biased by the possibility that compact cars are generally perceived to be "economy" cars. Differences in prices between option levels were also calculated based on 1992 prices. The price of options such as six cylinder engines, air-conditioning, automatic transmissions, etc., were also based on 1992 prices. No vehicle brand names were used.

The base price of electric, hybrid, and compressed gas vehicles were higher than gasoline vehicles of the same body style (see Price Work Book in Appendix A to see all prices). We offered "ZEV" or "ULEV" credits that largely offset the higher offered purchase prices, thus equilibrating the final purchase prices of electric, natural gas, and gasoline vehicles.

The use of purchase incentives was meant to communicate a plausible scenario. We found in previous studies that many respondents had heard that EVs are expected to be expensive, so these participants already expect higher prices. We explain that those prices reflect early market costs and that the government may play a role in fostering development of the market by attempting to mitigate the initial purchase price penalty of new vehicle types.

The replacement prices of lead acid batteries for neighborhood and community electric vehicles in Situation Two are based on prices and recycling value of currently available lead-acid, deep-discharge batteries. The replacement costs of advance lead acid batteries used in the EVs in Situation One are based on expected prices for Horizon advanced lead acid batteries and their expected recycle value. The replacement costs for the batteries in the regional electric vehicles in Situation Two are based on expected mass production prices of Ovonic's nickel metal hydride batteries and their expected recycle values.

Perceptions about EVs before and after the survey

Because of the large amount of information we provided to our respondents, we wanted to gather some sense of the impact of that information on their general perceptions of electric vehicles. The process of completing their travel diaries and maps, reviewing the informational material, and completing the choice exercises generally improved respondents opinions of EVs.

We asked participants at the start and end of the survey to respond to a number of statements about EVs. They were asked to indicate which statements best matched their opinion of EVs. Multiple responses were allowed. Their responses are tabulated in Table 1. On the whole, respondents were more likely to believe EVs will work with a little planning, will be clean and will be cheap to operate after the survey than they were before the survey. In Part One, 58 percent of our sample of potential hybrid households believed EVs would work with a little planning. After they had completed the survey, 70 percent thought so. Sixty-eight percent thought "EVs are clean cars" prior to the main survey, 81.5 percent thought so afterward. Opinions of EVs' speed and performance also improved, though not as dramatically. Only a tiny fraction of respondents felt "EVs are a bad idea", either before or after the questionnaire.

Additional information regarding electric vehicles improved general perceptions of EVs. This speaks to the possible changes and improvements in consumer response to EVs as more information is made available to consumers in the remaining time between now and the year 1998.

Table 2: Initial and post-survey opinions of EVs

Answer:	Frequency in Part One pre-survey	Frequency in Part Four post-survey
EVs are a bad idea	9	15
EVs would work with planning	264	316
EVs are small cars	156	118
EVs are cheap to operate	101	181
EVs are clean cars	310	370
EVs are not powerful	172	146
EVs are fast cars	9	34
EVs pollute like any other car	12	12
EVs are just golf carts	34	30
Never heard of EVs	5	-
Know very little about EVs	183	-

Note: - not asked at end of questionnaire

SAMPLE DESIGN AND SELECTION

We selected households we believe belong to the largest and most likely group of *potential hybrid households*. Our selection criteria were that households: own two or more vehicles; buy new vehicles; own one 1989 or newer vehicle *and* one 1986 or newer vehicle; and at least one of their vehicles not be a full sized sedan, van, sport-utility vehicle or pick-up truck. The ages of recruited participants were matched to the age distribution in the California new car market. We sought to fill quotas for minivans, sports utility vehicles, and sedans based on recent proportions of those vehicles in the California market. Also, we matched the split of foreign and domestic makes, 50-50 in California, of the most recently purchased vehicle.

A total of 740 households were recruited by 8 market research firms in 6 metropolitan areas of California: the San Francisco Bay Area, Sacramento, Fresno, Santa Barbara, Los Angeles and San Diego. Participants were selected by each market research firm from their own data bases to fill our survey quotas. Each firm then contacted the households to see if they would be willing to participate in the study. Participants were offered an incentive of $50 because of the time demands of the survey and to keep the study from being biased toward those interested in the subject.

Percentage of participants to complete survey

Of the original 740 households we recruited, 454 completed the study. Between 60-80% of the recruits from each market firm completed the study except for one firm was unable to deliver more that 35%. To compensate for that low rate of completion, a second round of recruiting was contracted for the Los Angeles and Santa Barbara areas. The final, composite response rate was 61%. The relatively high rate of completion in this study gives higher confidence that the sample was not biased to those interested in alternative fueled vehicles.

How representative of the market are those who completed the study?

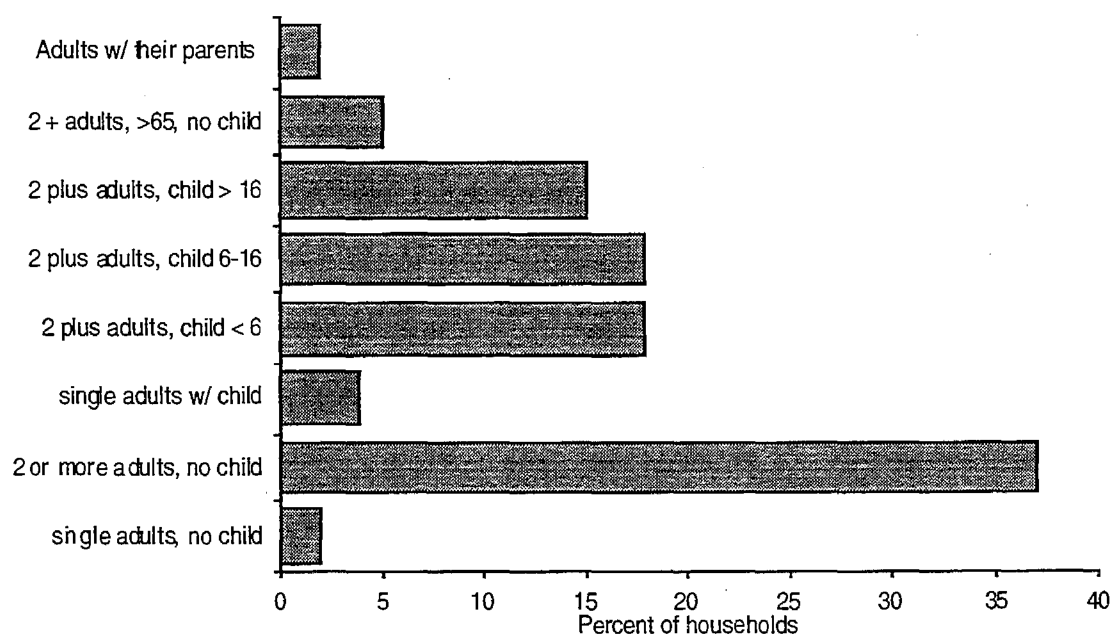
The sample selection criteria we use to identify potential hybrid households are different from those used in any other study of the market for light-duty vehicles. Because of this, it is difficult to establish how our sample compares to other households that buy new cars. It is even more difficult to determine how our potential hybrid households compare to households who buy only used cars. The greatest difficulty is establishing what percent of the total market for new light-duty vehicles our sample of potential hybrid households represents. Because of the importance of this last problem, we present several comparisons of our sample to those in other studies.

In the next few paragraphs we present various demographic measures of our sample and compare them to two other studies of the auto market, an R.L Polk study of new vehicle registrations in 1992 and a nationwide Newsweek survey of 13,692 new car buyers conducted in 1990. We also make some comparisons to the national sample of households in the Nationwide Personal Transportation Survey (NPTS). These comparisons provide a sense of how our sample of new car buyers compares to samples in other studies of the total light-duty vehicle market.

Life cycle

This is a study of households. One comprehensive measure used in transportation research to capture the effects of different household structures is the *life cycle*. The most significant aspects of life cycle measures are the number, age, work or school status and family relationships of people in the household. We adapted the 10-category life cycle measure used by the Nationwide Personal Transportation Survey (NPTS). In our sample, only 6 of the 10 categories have an appreciable number of households in them because of our sampling scheme and the correlation between life cycle definitions, income and vehicle ownership. Our sample contains very few households of single adults—with or without children. We make one modification to the NPTS definitions. We distinguish households of adult children living with their retired parents from other types of all adult households. Figure 1 below shows the distribution of the ITS survey respondents across life cycles.

Figure 2: Life cycle distribution of the ITS-Davis sample



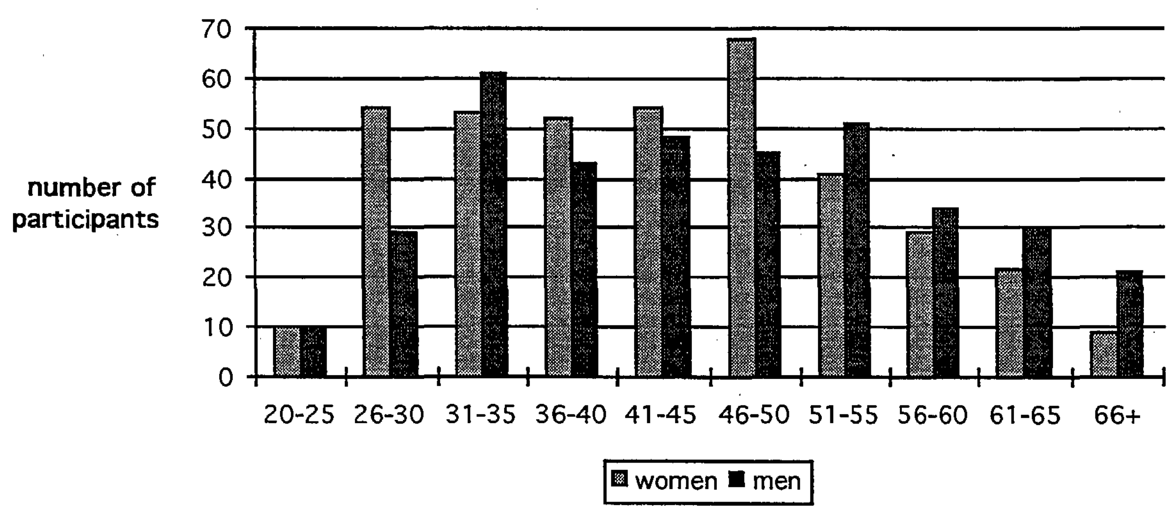
Note: The age categories for children refer to the age of the youngest child in the household.

The life cycle distribution of our sample does not appear to precisely match that of the Newsweek study. However, the differences are small and the same general distributions are evident in both samples. In the Newsweek study, people were asked if they were married; we do not specify whether the adults in the household are married or not. Also, the ages of children used to distinguish different life cycles are not the same in both studies. Still, households of two, non-retired adults with no children at home make up the largest group in both samples. They account for about 37% of our sample and 32% of the Newsweek sample. While households of two adults whose youngest child is less than 6 years old constitute about 18% of our sample, households of married adults whose youngest child is less than 6 years old made up 10% percent of the Newsweek sample. Households of two adults whose youngest child was between the age of 6 and 16, inclusive, were about 18% of our sample; households of married adults with children between the ages of 5 and 17 constituted 17.3% of their sample. Households of adults whose youngest child living at home was older than 16 made up 14% of our sample; married adults with children 18 and older made up 9.1% of their sample. We conclude overall though that our sample is similar to the much larger (and national) Newsweek study. Nothing about the life cycle distribution of our sample appears so different that it would lead us to believe our sample is not representative of households that buy new cars.

Age

The age distributions of the female and male household heads in our sample are shown in Figure 2. The median age for women in our study was 43 and for men, 45. The median age of all people in the 1990 Newsweek study was 44.6. That study reported only the age of one person in the household.

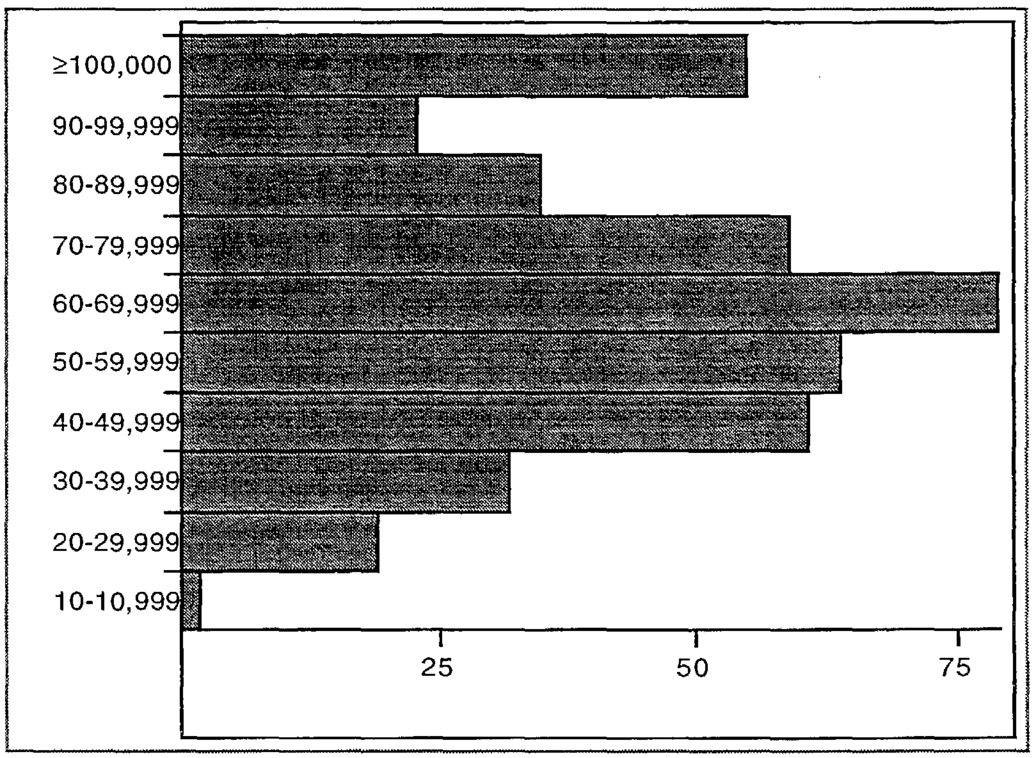
Figure 3: Age distributions of heads of households in ITS-Davis sample



Household income

We believe our sample accurately reflects the incomes of multi-car households that buy new cars. The median income reported for our sample was $60,700. This does not compare closely to the Newsweek study that reported a median income of $48,000. However, that study included one car households, nearly half (47%) of whom had incomes under $30,000. Only 5.5% of our households had annual household incomes less than $30,000. Seventeen percent of all the households in the Newsweek study earned under $30,000 per year. While it appears the average household income is higher in our sample, the difference is largely attributed to the absence of one vehicle households in our sample.

Figure 4: Frequency distribution of household income in the ITS-Davis sample, 1993$



Current Vehicle Holdings

One of the primary household selection criterion for this study was that households own two or more cars. In Table 2 below, we compare the number of vehicles owned by households in our sample with household vehicle ownership in the sample of new car buying households in the Newsweek study and the national sample of all households in the NPTS. The NPTS data includes all households, not just households that buy new cars.

Table 3: Household vehicle ownership for three samples

Sample:	Number of Vehicles None	One	Two	Three	Four or more
ITS-Davis	0%	0%	67%	23%	10%
Newsweek	0%	23%	40%	19%	17%
1990 NPTS	11.5%	33.7%	37%	17.3% (three or more)	

Clearly, we have sampled households that not only buy new cars, but currently own more cars than either the national sample of new car buyers in the Newsweek study or the national sample of all households in the NPTS. (The Newsweek sample contains a higher proportion of households that own four or more vehicles.) This is likely due to our additional selection criteria on the age of the vehicles. The newest vehicle in our households could be no older than a 1989 vintage vehicle—four years old at the time of our survey.

In Table 3 we compare the body styles of the vehicle holdings of our sample with the distribution of new light duty vehicle registrations in 1992. We did not have access to a more recent version of the Polk report, but the data are no more than two years older than the data on the vehicle holdings of our sample. Still, since there is a trend toward greater sales of sport-utility vehicles and minivans to all households, it seems that our sample owns fewer of these vehicles than we might expect. Still, the differences appear small.

Table 4: Comparison of vehicle body styles in ITS-Davis sample to new vehicle registrations

Sample:	Body Styles Sedans and sports cars	Sports utility and minivans	Pick-ups and full sized vans
ITS-Davis	72.5 %	11.5%	16%
1992 new vehicle registrations for California[1]	66.2%	14.9%	16.9%

1. Source: R.L. Polk, 1992

Table 4 and 5 compare the distribution of domestic and foreign vehicles makes in our sample with that of new 1992 vehicle registrations. As in Table 3, the vehicle registrations data are from Polk. While the sample of domestic makes is slightly skewed toward Ford vehicles, this is due to the nature of the data base of one of our market research firms. The bias is slight, and overall the makes of vehicles owned by our households are distributed similarly to the distribution of all vehicle registrations in 1992.

Table 5: Distribution of domestic makes in the ITS-Davis sample compared with distribution of registrations of new domestic light duty vehicles in CA

	Domestic Manufacturer			
Sample:	GM	Ford	Chrysler	Total domestic
ITS-Davis	18%	26%	8%	52%
All 1992 CA Registrations	22%	21%	10%	53%

Table 6: Distribution of foreign makes in the ITS-Davis sample compared with distribution of registrations of new foreign light duty vehicles in CA

	Foreign Manufacturer				
Sample:	Toyota	Nissan	Honda	Other	Total foreign
Davis study	15%	8%	13%	12%	48%
All 1992 CA Registrations	14%	7%	10%	15%	47%

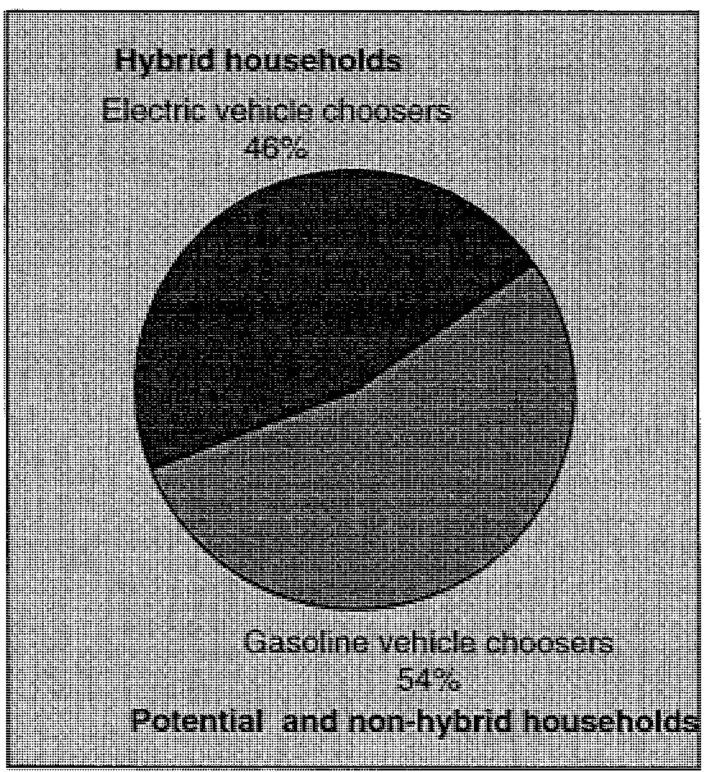
We conclude that our sample of potential hybrid households meets the original sample selection criteria we set. We conclude that the national NPTS sample is not an appropriate basis from which to determine what portion of the market for new cars our sample represents. Further, we conclude that, while neither is an ideal source, the Newsweek study and the Polk registration data will provide an adequate basis to provide an initial estimate of the proportion of the light-duty vehicle market our sample represents.

HYBRID HOUSEHOLD HYPOTHESIS - IS IT SUPPORTED?

Choice Situation One is the most robust test of the hybrid household hypothesis. It is a fairly simple scenario in which we make relatively fewer assumptions. The scenario contains a simple choice between moderate range electric vehicles—80 to 120 miles—and conventional gasoline fueled vehicles. Prices of the vehicle types are made comparable through purchase incentives, yet still reflect that there may be potentially higher purchase costs for EVs. Participants are not offered electric vehicles in full sized body styles.

We hypothesized above, that over a long period of time, the hybrid household hypothesis would predict that roughly 38% of our sample of potential hybrid households should choose an electric vehicle in any given year. The results in Figure 2 show that even more households choose an EV than the hybrid household hypothesis predicts. Almost half of our sample, 46%, said they would purchase an electric vehicle as their next new vehicle.

Figure 5: Percentage of households choosing EVs in Choice One



Competing explanations of EV choice

The hybrid household hypothesis predicts that 38% of our sample will choose an EV. We observe that 46% of our sample does so. Thus the hybrid household hypothesis explains about 83% of observed vehicle type choices. Below we present a discussion of why more households chose EVs than the hybrid household hypothesis alone predicts. We present a series of charts that show the relative effects of household attitudes and demographics on vehicle type choice. In each chart, we show how many households chose EVs or gasoline vehicles. If these other variables do not affect vehicle type choices then we would expect the ratio of EV choosers to gasoline choosers for each response level of these attitudinal and demographic variables to be the same as the overall response rate across all levels *and* equal to the proportions predicted by the hybrid household hypothesis—38% EV to 62% gasoline. Significant deviations from this ratio would indicate these other variables are affecting vehicle type choices.

Initial Likeliness to Buy an EV

Of all the variables to compete with the hybrid household hypothesis as explanatory factors of EV and ICEV choices, the existence of a prior willingness to buy an EV is the strongest alternative explanation. Prior to presenting any information about electric vehicles or choices of electric vehicles, we asked respondents the following question:

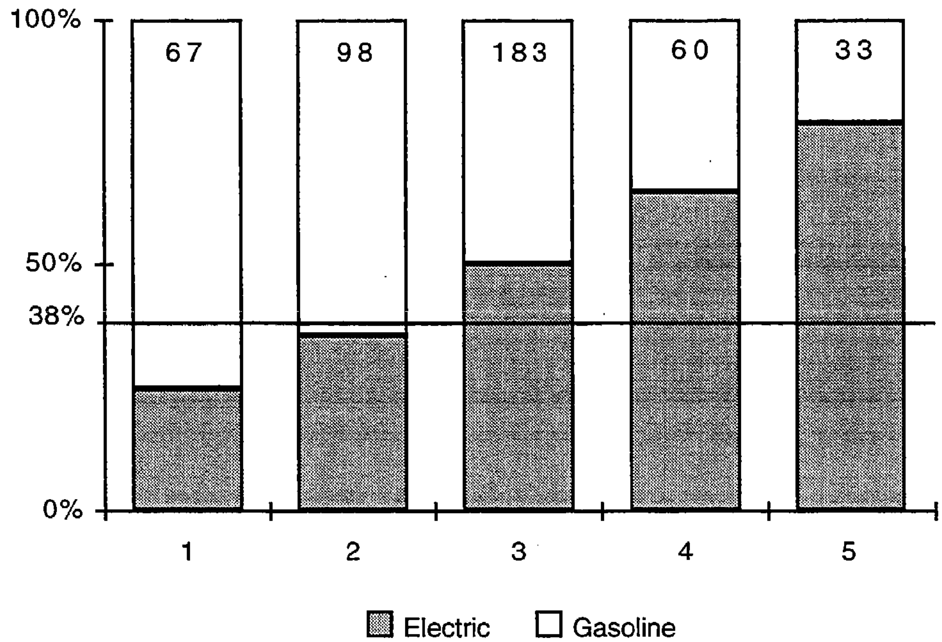
Question 1.20*. Given what you know about electric vehicles, if an electric car was available to buy next time you buy a car, how likely would you be to purchase one, if it were the same price as a gasoline car?*

(1) Very unlikely (2) unlikely (3) not sure (4) likely (5) very likely

Responses to this question, cross-tabulated by the choice of an electric or gasoline vehicle in Situation One are illustrated in Figure 6. The number at the top of each column is the total number of people in that response category. The shaded area within each column shows the proportion of those people who chose an EV. The line across the chart at 38% indicates the proportion of EV choices predicted by the hybrid household hypothesis. For example, we see that 67 households stated they were very unlikely to buy (1) an EV in Part One of the questionnaire. Of these, only 25% chose an EV in Situation One. This is less than the 38% predicted by the hybrid household hypothesis.

The figure shows that initial likeliness to buy an EV had an effect on subsequent choice of an EV. A very high percentage of those who felt they were likely to buy an EV chose an EV. A very high percentage of those who felt they were unlikely to buy EVs, chose gasoline vehicles. We note though, that nearly half our entire sample was undecided (3), yet even among this group, the ratio of EV to gasoline choices exceeds the predictions of the hybrid household hypothesis. While a pre-disposition to buy an EV indicates a strong likeliness of choosing an EV, it does not appear as if even a moderate pre-disposition to buy an EV is a prerequisite for choosing an EV.

Figure 6: Initial willingness to buy an EV by vehicle type choice in Situation One



Environmental Attitudes

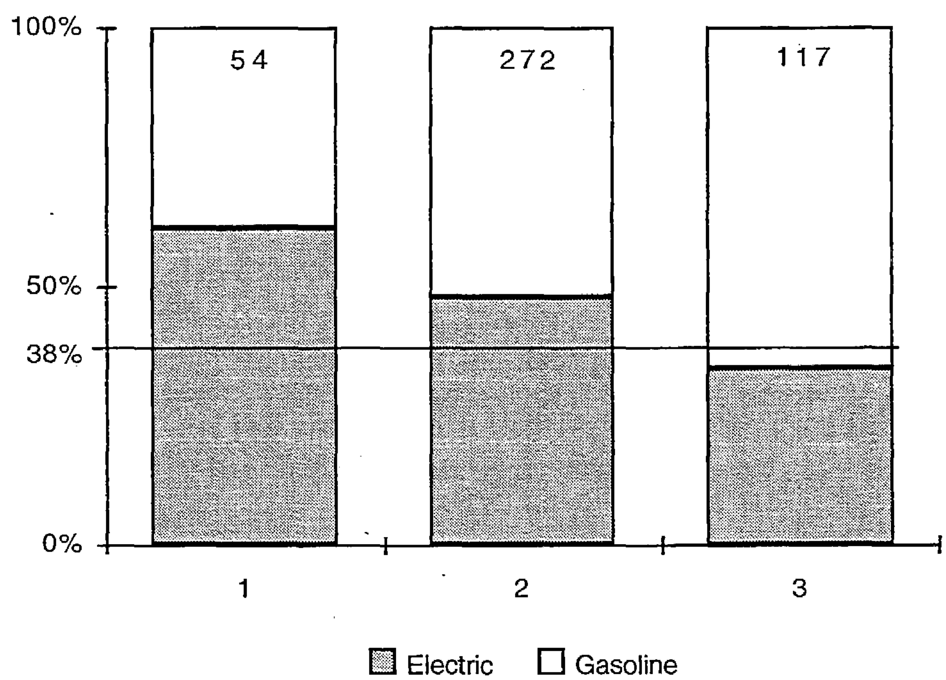
In addition to pre-conceptions regarding EVs, more general environmental attitudes have been used in attempts to identify market segments for EVs. In order that our measures of environmental attitudes would be most comparable to those in other studies, we asked people about these attitudes in Part One, before they had completed their travel diaries and activity maps, before they had seen the information on electric and natural gas vehicles, and before they had completed the choice exercises.

We present here an analysis of the effect of two measures of "environmentalism" on choices between electric and gasoline vehicles in Situation One. The first measured how important people believe environmental problems are compared to other problems. Rather than a simple scale of "importance", we asked people to indicate the degree of lifestyle change they believe they must make to solve environmental problems. The responses to this question are cross-tabulated by choice of vehicle type in Situation One. The data are presented in Figure 7. The text of this question was:

Question 1.12*. How would you characterize your feelings about the world's environmental problems?*

1. *The biggest crisis and challenge of our times. The solutions require immediate international effort and major changes in our economies and lifestyles.*
2. *Among our biggest problems. The solutions require cooperation of government and citizens. Time to reconsider our lifestyles and make changes.*
3. *Environmental problems exist, and need some attention, but are minor compared to other problems in our world.*
4. *Environmental problems are not an important problem. There is no need to change the way we live.*

Figure 7: Lifestyle changes to solve environmental problems by vehicle type choice in Situation One



Note: The number of households in each category is given by the number at the top of each column. Thirty-eight percent is the predicted proportion of EV choices under the hybrid household hypothesis.

The degree to which people felt the solutions to environmental problems will require life style changes is correlated to their choice of an electric or gasoline vehicle. First, we note that only 3 households indicated they believed environmental problems simply are not important (Life Change = 4), so these people are dropped from Figure 7.. In Figure 7, we see that a strong belief that lifestyle changes are warranted to solve environmental problems is associated with a greater likeliness of choosing an EV. People who do not believe environmental problems are particularly pressing are more likely to choose a gasoline vehicle, though more than a third of these people choose an EV.

Willingness to pay more for non-polluting goods

The second measure of environmental attitudes was willingness to pay for less polluting products. In the questionnaire, we asked the following question in Part One. Responses are cross-tabulated by vehicle type choice in Situation One. The data are presented in Figure 8.

Question 1.17*. How much* ***more*** *are you willing to pay for products which don't pollute compared to products which do pollute?*

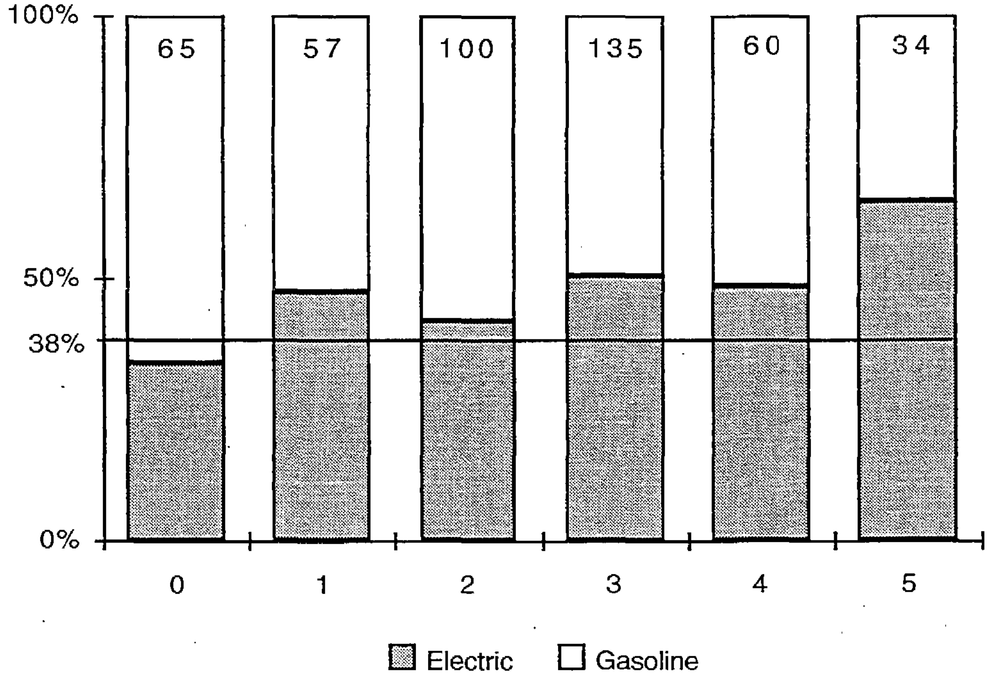
0. 0% 1. 3% 2. 5% 3. 10% 4. 20% 5. ≥30%

There is neither a statistically significant nor well-ordered relationship between willingness to pay more for goods that are less polluting and the choice between an EV or ICEV in Situation One. Only the relatively few people willing to pay virtually nothing more for non-polluting products chose EVs at a rate less than that predicted by the hybrid household hypothesis. Households willing to pay as little as 3 percent more for less polluting products chose EVs more frequently than predicted by the hybrid household hypothesis.

Demographics and Income

Age and sex of household heads had little systematic effect on choices between electric and gasoline vehicles in Situation One. The average age of female and male heads of households was not significantly different between households that chose electric or gasoline vehicles. There was no systematic or significant relationship between age of household heads and vehicle type choices. Households with younger female and male heads of household were neither more nor less likely to choose an EV than households with older female or male heads of household. Many other studies have found that younger buyers were more receptive to EVs than older buyers. We believe the reason our study finds otherwise is that, once households take time to reflect on their travel needs, the travel patterns and vehicle purchase habits of young households make them less likely, though not unlikely, buyers for EVs.

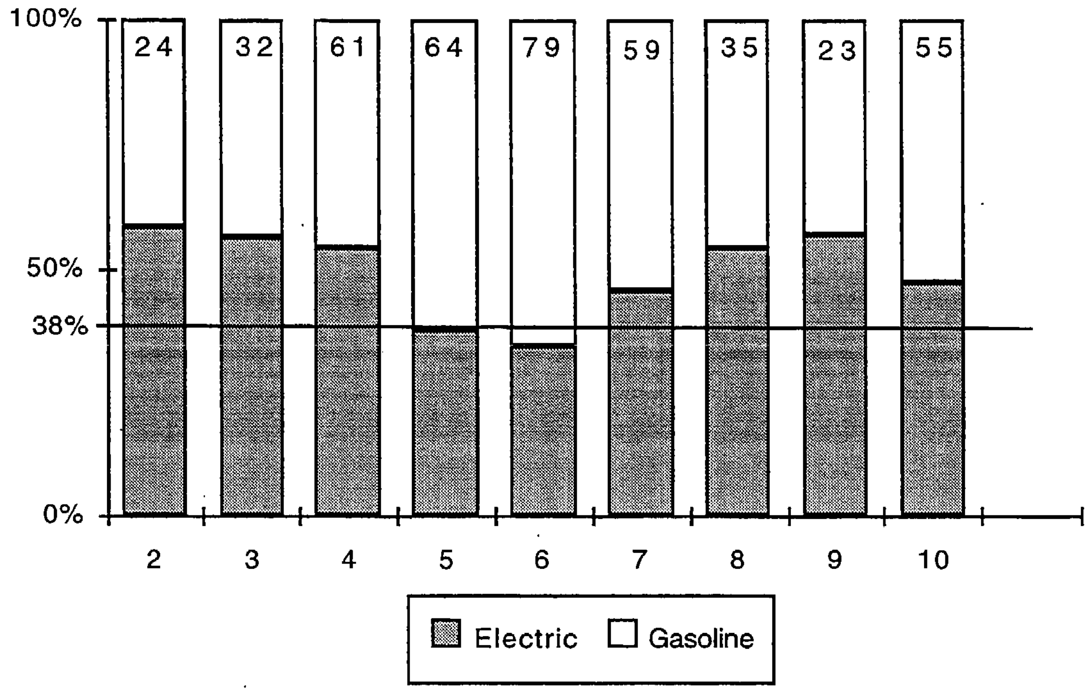
Figure 8: Willingness to pay for green products and Choice One



Note: The number of households in each category is given by the number at the top of each column. 38 % is the predicted proportion of EV choices under the hybrid household hypothesis. The response categories 0 to 5 are defined in the text.

Neither was household income a significant variable in explaining choices between electric and gasoline vehicles. Figure 9 on the next page shows there was no systematic effect of income on the choice between electric and gasoline vehicles. In all income categories but one, more households chose EVs than we expected based on the hybrid household hypothesis. It does appear that a higher proportion of lower income households in our sample chose EVs than the overall sample proportion. Some of the higher income households also chose EVs more often than the whole sample, but the highest income households chose EVs only as often as the sample proportion. The test of the hypothesis of independence indicates there is no statistically significant relationship between income and choice of an electric or gasoline vehicle in Situation One.

Figure 9: Household income by vehicle choice in Situation One



Note: The income categories are 10,000s of thousands of dollars. The category number corresponds to the lower limit of the category, e.g., category 2 is $20,000 to $29,999. Category 10 is open-ended; $100,000+.

The number at the top of each column indicates the number of households in that income category.

Why do so many households choose an EV?

The choices of our respondents indicates the hybrid household hypothesis is plausible. A driving range limit on one vehicle is not a substantial barrier to the purchase of an EV by our sample of potential hybrid households. In fact so many households chose an EV in the choice exercise, that their numbers far exceed our prediction. We find there exists a high level of pre-disposition to buy EVs across much of our sample, and this prior willingness to consider buying an EV is associated with a greater likeliness of choosing an EV in Situation One. A greater sense that immediate lifestyle changes are required to address environmental problems is also associated with an increased likeliness to choose an EV, but even those households who are relatively unconcerned about environmental problems chose EVs at a rate almost equal to that predicted by our hypothesis. Neither willingness to pay more for less polluting products nor household income provide a systematic explanation of the high rate of EV choices. Age and sex of household heads are also relatively uninformative.

We offer two non-exclusive explanations for why so many households chose EVs. First, only after households have considered the lifestyle impacts of limited range and have been given increased information about EVs, do their environmental attitudes begin to shape vehicle purchase decisions.

The second relates to a possible artifact of our research design. It may be that more of our sample of potential hybrid households chose an EV in the choice exercises than would actually choose an EV for their next vehicle. The immediacy of the survey process or the newness of EV themselves may make households indicate they would buy an EV for their next vehicle, when in fact, their EV choice would be delayed until some later time. In terms of our assumptions, the *long-term* EV purchase rate may be proportional to the number of vehicles the households own (μ from page 40), but early in the market, across all potential hybrid households, they may buy EVs, or say they will buy EVs, at a faster rate than implied by our assumption.

RANGE, RECHARGING AND BATTERIES

The decision to purchase a limited range vehicle is a new consideration for households. The limited range of electric vehicles is considered by all researchers to be among EVs' defining features and by many to be a fatal flaw. We agree the range limitations of electric vehicles are a central feature that will reduce their market appeal for many users. We argue however, that limited range is not a fatal flaw, but rather a new attribute on which the market for vehicles will be segmented.

Moreover, previous research has not framed the response of consumers to limited range in a sophisticated way. We argue that consumer response to limited range is conditioned by many variables: the travel routines of households and the subsequent allocation of driving tasks; and demand for home recharging, away-from-home slow charging (such as a workplaces), and fast charging at special stations. Additionally, the instrumentation of electric vehicles is still rudimentary—given the limited range of electric vehicles and the differences in refueling locations, range instrumentation will play a major role in consumer responses to electric vehicle range.

Travel Routines of households and range selections

As stated in the hybrid household hypothesis, households' travel routines and their ability to complete those routines will be central to decisions to purchase any type of limited range vehicle. With that said, this next statement will sound somewhat contradictory; while travel routines are central to our study, in the sample we have chosen, differences in travel routines between households have only a minimal effect on vehicle type choices. The reason for this (as found in many prior travel behavior studies, including those reviewed in the Introduction of this report) is that seldom do any multi-vehicle households encounter situations in which they could not access their routine activity space using their fleet of household vehicles—even if that fleet contains one limited range vehicle. That is to say, rarely do households use all their vehicles simultaneously to accomplish long range travel.

Providing a complete assessment of the households' routine activity spaces is beyond the scope of this study. However, we expect that so long as the vehicle holdings of multi-vehicle households include at least one "unlimited" range vehicle, then vehicles with ranges of 80 to 100 miles (as offered in Situation One) would suffice for 90-95% of all travel days for all such households. We do provide the following indicators of the geographical extent of the routine activity spaces of households in our sample in Table 7. As found in other travel behavior studies, the vast majority of households in our sample have routine and important destinations well within the range of an electric vehicle.

Table 7: Activity Space of Participating Households

Median one-way commute distance	10 miles
Ninetieth percentile of one-way commute distances	35 miles
Median distance to the critical destination[1]	11 miles
Seventy-fifth percentile of distance to the critical destination	23 miles
Ninetieth percentile of distance to the critical destination	50 miles.

1. The critical destination is an activity destination the driver feels they must be able to reach even if an "unlimited" range vehicle is not available. Different households, indeed different drivers in the same household, will have different activities that define the critical destination. In general, the critical destination is some activity location that is central to defining the household's lifestyle goals.

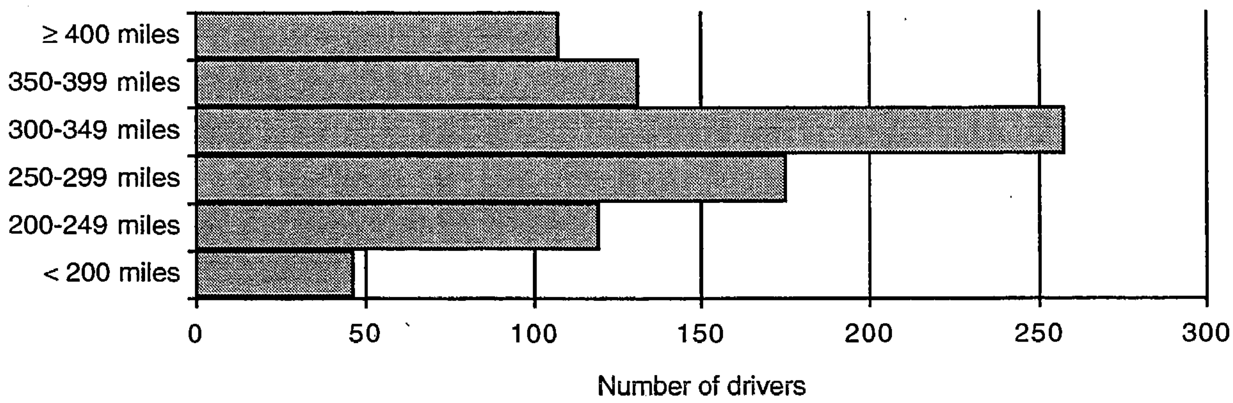
Driver response to range information

In this section we explore the complexity of driving range. We demonstrate why we believe that consumer preferences for range are a complex function of vehicle instrumentation, the intended use patterns for the vehicle, and the convenience of home refueling compared to station refueling. This study was designed to allow drivers to reflect on these three aspects of driving range.

Econometric studies conceptualize household preferences for driving range as a continuous variable. Econometric models use continuous preferences for range to estimate consumers' partial utilities for driving range, regardless of the fuel being used. Several of these studies purport to show that consumers attach very high cost penalties to short range; estimated average penalties are often equal to the purchase price of the vehicle.

In our research, we found this approach to be erroneous for several reasons. First, consumers usually have little experience with differences in range. Typically they have owned and driven only vehicles with driving ranges equivalent to modern motor cars. Those consumers who have experienced ranges different from gasoline cars are most likely to have experimented with longer ranges in diesel vehicles or vehicles with two fuel tanks. Lacking any basis in experience, households are ill-prepared to consider the effect of a range limit. Respondents in interviews and focus groups exhibited responses to driving range that indicated they had no well-formed preference. Further, several households in our statewide survey sample demonstrated they were unfamiliar with the range of the gasoline vehicles they now drive. Figure 10 illustrates the vehicle ranges that drivers in our study reported for their vehicles. One-third of our sample reported implausibly low ranges for the vehicles they have been driving for months or years.

Figure 10: Perceived range of household vehicles in ITS-Davis sample



We had previously found in interviews with car drivers that the driving range/fuel level instrumentation of gasoline vehicles is relatively imprecise for day to day use and gives them only an approximate sense of how much fuel, and thus how much range, is left in the tank at any point in time. Existing fuel instrumentation on most gasoline vehicles shows fuel reserves varying from full to empty on an analog scale. Very few cars have instrumentation that reports remaining miles of range. A few luxury vehicles now have this added feature of digital range instrumentation. However, they still use the same internal float mechanisms in the tank as do cars equipped with analog gauges and therefore are of dubious accuracy. We know of one such vehicle with a digital range readout that simply switches to a "low fuel" warning when the estimated range falls below 50 miles.

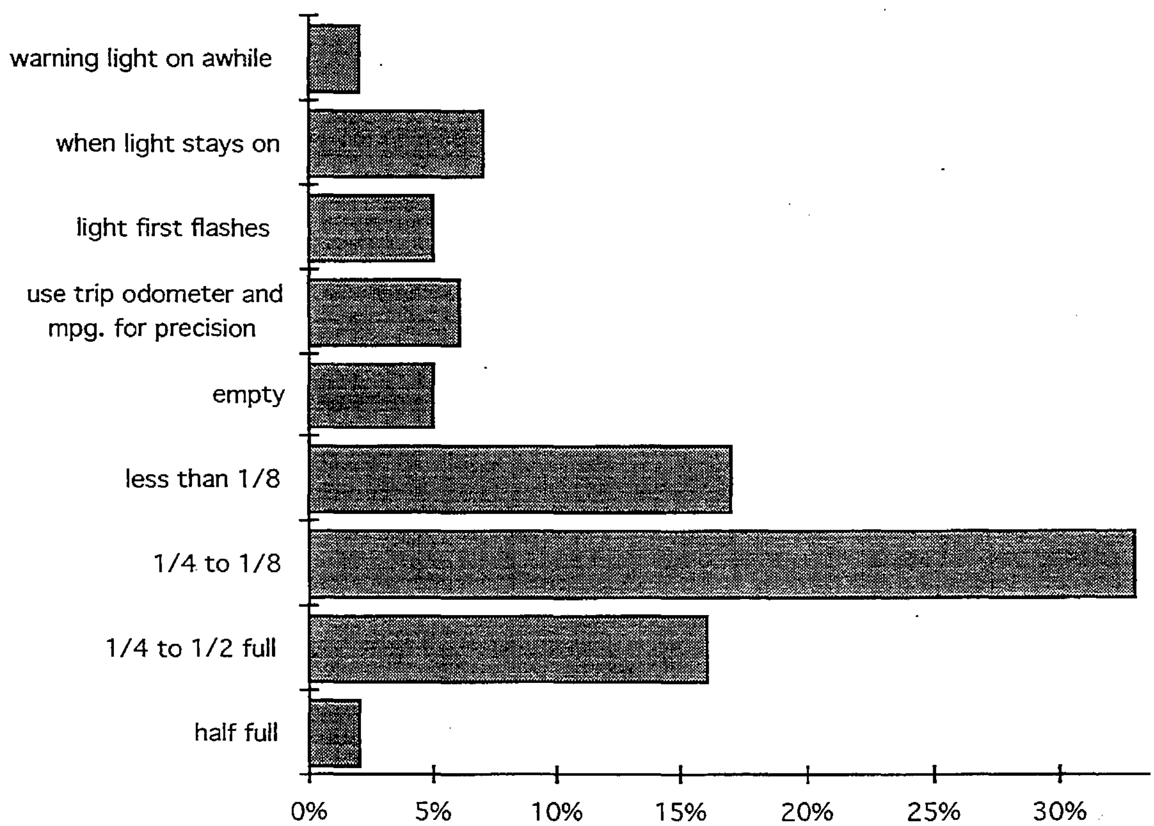
We highlight the importance of experience with short range by examining driver information about fuel levels in their current gasoline cars and their responses to that information. Most current fuel gauges advise drivers to refuel either by an indicator warning light that flashes on at a low fuel point or simply by an needle entering an "empty" indicator range on an analog dial. Five hundred thirty-four drivers in our study (59% of drivers) reported they have a low fuel warning light in the vehicle they most often drive. We asked these drivers how many miles they thought they could still travel when that warning light comes on.

- 25% thought there was less than 15 miles of range on the vehicle
- 25% thought there was 16-30 miles of range on the vehicle
- 25% thought there was 31-45 miles of range on the vehicle
- 25% thought there was 46-80 miles of range on the vehicle

In addition to the wide range of beliefs about how much range is left on a gasoline vehicle when the low fuel indicator light goes on, these drivers showed a wide range of responses to that information. We asked both primary drivers in the household when they typically refuel. The responses of those drivers who had low fuel indicator lights are shown in Figure 11. Fewer than 15 percent of these drivers use the information provided by the low fuel indicator light to determine when they typically refuel. Some participants try to circumvent the limited accuracy of current range instrumentation by using odometer readings and an estimate of their fuel economy to determine when to refuel. However, the vast majority of these drivers, and of drivers who do not have a low fuel indicator light, refuel when their analog gauges indicate they have one-eighth or more of a tank of gas left.

Herein lies the difficulty in assuming people have formed a preference for driving range that encompasses the driving ranges of EVs. Based on their assessment of when they refuel, most drivers refuel their cars when they have between 40 and 80 miles of range remaining. The instrumentation on their vehicle makes it difficult to do otherwise. They are looking to replenish their range back to its full amount, at just about the distance at which an EV (based on current technology) would still be somewhere between half and fully charged. This clearly indicates very few drivers have experience operating their gasoline vehicles with the same types driving range as EVs will have, even when fully charged.

Figure 11: Refueling behavior of drivers in the ITS-Davis sample



We see a need for much more accurate range information being provided to drivers of EVs. To explore the effect of improved range information, we asked respondents to imagine their own vehicles were equipped with accurate, digital gauges that provided information on the number of miles of travel left in 1 mile increments. We then asked them to consider refueling in a variety of situations. We learned that the point at which people refuel is not just a function of distance, but also of familiarity with the area or region in which they are driving and their proximity to home.

If people are close to home or are in a familiar area, then on average they would wait until there were only 25 miles worth of gasoline left before refueling; half the sample would wait until there were only 10 miles left. In an unfamiliar part of town, the average driver would refuel with 42 miles left; half would wait until only 30 miles range remained. Lastly, if they were driving on a long highway trip and did not know how far it was to the next fuel station, the average driver refuels with 68 miles of range left; half would wait until only 50 miles remained. Based on these, it is clear the fuel tank capacity, reserve range and existing range instrumentation of gasoline vehicles are clearly designed for long-distance, highway travel situations, not for around town driving in which more accurate instrumentation and knowledge of daily travel routines would figure more strongly. The singular issue for gasoline refueling and preference for the range of gasoline vehicles is the intended use of the vehicle—whether it is intended for long distance touring or local and regional use.

Range Choices by Households in Situation One

The hypothetical electric vehicle choices in Situation One in Part Four of the questionnaire included vehicles with ranges based upon types of batteries we expect to be available by 1998. The electric vehicles offered in Situation One were designed with advance lead acid batteries in mind (see page 3 of the *Part Four Price Work Book* in Appendix A). The battery prices used in the choice experiments were chosen after consultation with several battery companies regarding expected mass production prices.

Situation One: Initial choices in a limited hypothetical market for EVs

In Situation One, respondents were provided only a limited selection of EV driving ranges. We offered two battery options, a *Type One* standard battery pack that is included in the base price of the vehicle. The Type One battery offered 80 miles of range in most vehicles, and 100 miles of range in Sports cars and Small (sub-compact) Sedans. The replacement cost, after core rebate, was given as $1,200. The optional *Type Two* battery pack offered an additional 20 miles of range for $800 more than the Type One battery. The replacement costs of the entire Type Two battery pack, after core rebate, was given as $2,000. The intention of this price increment was to offer additional range at a high price, to see how many consumers felt an additional 20 miles was very important. As seen in Figure 12, almost two-thirds of the EV choosers in Situation One choose the extra 20 miles of range.

Figure 12: Choice of battery type in Situation One

Type One is the base battery, Type Two is the optional, longer range battery.

In addition to a choice of two driving ranges, participants were offered a *fast charging* option. We described fast charging as the ability to obtain 80% of a full recharge in about 20 minutes at special recharging stations. Current research indicates such recharging is technically possible. This option was priced at $900. This is one example of an attribute whose level we assigned based on the conditions and intentions of our experimental design. We have no particular reason to believe that fast charging capability might actually cost that much. However, we specified this price here simply because we wanted consumers to have to make a strong commitment in order to get fast charging. If we had offered it for free, there would be no reason not to take it, and therefore no reason for households to reflect on whether they actually wanted it. In order to further increase their reflection on this choice, if the household selected fast charging, they were also asked to go back to their activity map from Part Two of the questionnaire and indicate at least one location on their map where they would like a fast-charging station to be located.

Overall, 70 % of those households that chose an EV as their next new vehicle also chose fast charging. Choice of fast charging was strongly related to battery choice as shown in Figure 13. Among those who chose the longer range, Type 2 batteries, 83% also selected fast charging. Among those who chose the base Type 1, only 49% chose fast charging too.

If we look at the body styles choices of those who chose each battery type, shown in Figure 14, we find that those who chose a mid-size sedan, compact pick-up truck or sports car are more likely to have also chosen the longer range battery. Households that chose small and compact sedans and small sport utility vehicles were more likely to stay with the base Type One battery. Buyers of minivans evenly split on range choice.

Figure 13: Choice of battery and fast charging option in Situation One

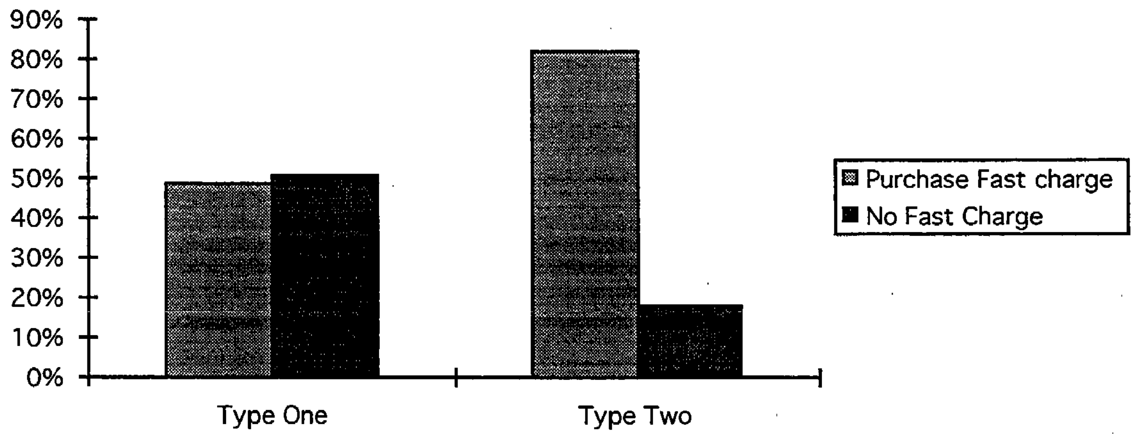
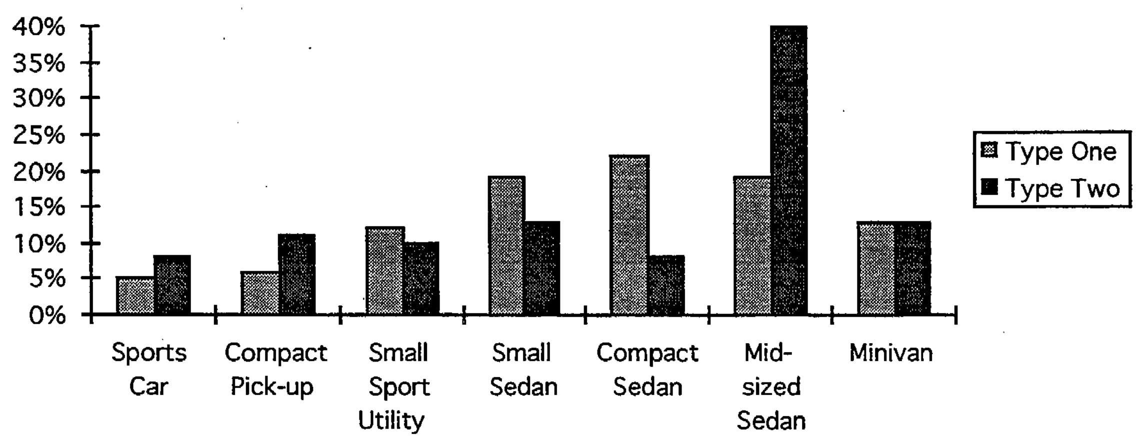
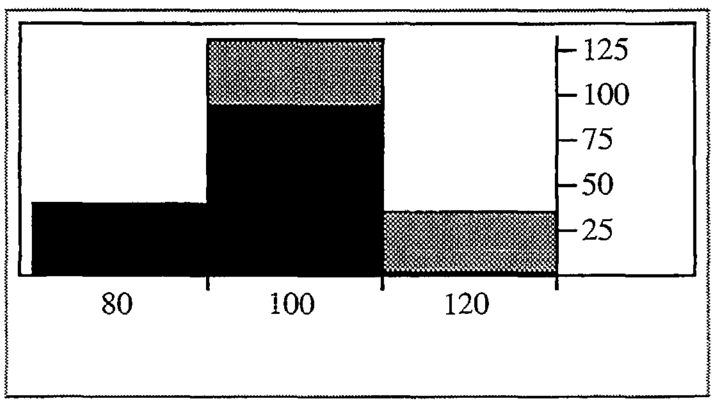


Figure 14: Battery choice and vehicle body style in Situation One



The greater than two-to-one preference for Type Two batteries among mid-size vehicle buyers must be interpreted with care. We specified that given the same type of battery, mid-size vehicles, compact pick-up trucks, and minivans would have shorter ranges than the smaller vehicles. For example, the Type Two battery provides 100 miles of driving range in a compact sedan, but only 80 miles in a mid-size sedan. The distribution of driving range choices (as opposed to the battery type choices in Figure 12) are shown in Figure 15. The darker shading indicates mid-size sedans, minivans, small sport-utility vehicles and compact pick-up trucks. Households that chose these mid-size body styles tend to buy the longest range they could, given their body style choice. Range is not seen as so important that households abandon a body style choice, in order to get the longest range EV possible.

Figure 15: Driving range choices in Situation One, miles



Note: Dark shading indicates larger body styles, light shading indicates smaller sports cars and compact sedans.

Range Selections in Situation Two

Two reasons for the specific design of Situation Two were to test our premise that the market for EVs may be segmented by demand for driving range and to test whether there is a market for EVs that can, and are, being built with current technology. We find evidence that both are true.

The variety of driving range options offered to respondents in the second choice experiment are shown in Table 8. As in Situation One, EVs (except Neighborhood Electric Vehicles) were offered with a Type One base battery or a longer range, more expensive, Type Two battery. A hybrid electric vehicle with 40 or 80 miles range on its electric propulsion system and an additional 100 miles of range from a "range extender" ICE was offered. Natural gas vehicles were offered with one or two CNG storage cylinders. The number of households who selected each range option is also shown in Table 8.

Table 8: Vehicle choices by range for electric and natural gas vehicles in Situation Two

Vehicle Type	Range, miles	Number of Households choosing Range and Type
Neighborhood EV	40	19
Community EV with Type I batteries	60	10
Community EV with Type II batteries	80	18
Natural gas vehicle with single tank	80	28
Natural gas vehicle with double tank	120	60
Regional EV with Type I batteries[1]	120/130	52
Regional EV with Type II batteries[1]	140/150	63
Hybrid EV with Type I batteries	140	6
Hybrid EV with Type II batteries	180	37
Reformulated gas vehicle	300	154

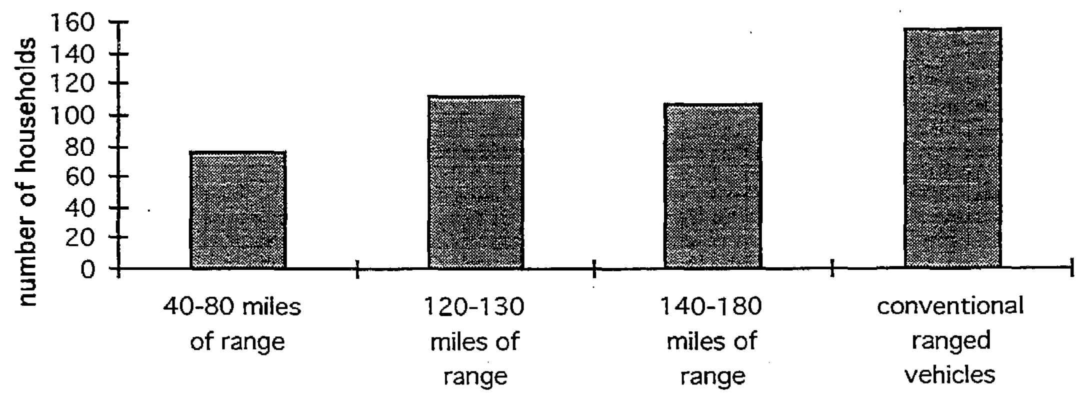
1. Range of regional EV is also dependent on body style.

Figure 16 shows the data from Table 8 in categories that illustrate a feature of our research design. As we mentioned above, it is not part of our research design to estimate price elasticities for driving range or average price penalties for limited range. Instead, we designed groups of vehicles defined by three types of energy storage technologies. The Neighborhood and Community EVs and the shorter range Regional EVs are based on two battery technologies that are already commercially available or have been demonstrated in on-road vehicles. The longer range regional EVs are based on battery technologies widely expected to be commercially available before 1998.

In our experimental design, the single tank, low range CNG vehicles are grouped with low range EVs, and hybrid EVs and higher range CNG vehicles are grouped with longer range EVs. The CNG range categories are not based on differences in available and expected technology, but on our specific desire to create an "intermediate" vehicle between electric and gasoline vehicles.

What this means is that range choices in our study are "lumpy". We have respondents make only two vehicle choices, not several as is the case in many stated preference studies. We make no inference of some underlying distribution of "preferences" for range. Rather we wish to simply observe whether different households will choose vehicles of distinctly different range from along some distribution of driving range possibilities. Figure 16 provides evidence the market for EVs can be segmented by demand for driving range and that some households will buy vehicles built with existing EV and battery technology.

Figure 16: Driving range choices (by group) in Situation Two



In addition to observing range choices across the whole sample, we wished to track individual household's range choices from Situation One to Situation Two. In order to force households who chose an EV in Situation One to reconsider their choice in Situation Two, we intentionally did not offer EVs in Situation Two that are identical to those in Situation One. At the very least, the household must decide whether it wants more or less range. Thus the absence of EVs with driving ranges between 80 and 120 miles from Situation Two is a design feature of our choice experiment, not an expected development in a future market for EVs.

Of the households who chose an electric vehicle in both Situation One and Two, 19% (39) chose a shorter range EV in Situation Two than they had selected in Situation One. More dramatically, 46% of the households who had chosen a gasoline vehicle in Situation One, chose a shorter range electric, hybrid electric or natural gas vehicle in Situation Two. Across all vehicle types, 32% of households chose a shorter range vehicle in Situation Two than they had chosen in Situation One. We conclude that households will make choices from across a spectrum of range possibilities. A sizable portion of our sample chose very short range vehicles, even when offered longer ranges in the same type (electric or natural gas) of vehicle. This is further evidence that the market for EVs will be segmented by demand for driving range.

In addition to choices of range, households made choices of refueling and recharging capabilities and locations. Their choices are shown in Table 9. Households that chose Neighborhood EVs and Community EVs were limited to home recharging only. Buyers of Regional EVs had the option of purchasing the ability to recharge at a fast charging station, as in Situation One. In addition to refueling at stations, households that selected natural gas vehicles had the option of purchasing or leasing equipment to allow them to slow fill their tanks at home. A home refueling appliance was offered that they could either buy for $2,500 or lease for $60 per month. Hybrid EVs had the built in option of refilling with gasoline at a station and recharging from an electric outlet. Fast charging was offered as an option for hybrid EVs. Reformulated gasoline vehicles can only be refueled at gas stations.

Table 9: Home and away-from-home refueling choices in Situation Two

Home and Away-from-Home Refueling		**Away-from-Home Refueling Only**	
Neighborhood EVs	19	Natural gas without home refueling	52
Community EVs	28	Reformulated gasoline	154
Regional EVs without fast charging	27		
Regional EVs with fast charging	92		
Hybrid EVs	44		
Natural gas with home refueling	36		
Totals	246		206

Over half the sample, 246 households, chose vehicles that could be recharged or refueled both at home or away-from-home. Away-from-home locations could be either an electrical charging site at such locations as large employers and shopping malls, a specialized fast charging station, or a compressed natural gas filling stations. This suggests to us that home recharging and refueling may be a highly valued attribute of electric (and possibly natural gas) vehicles. We touched earlier on the combined role of home recharging and improved driving range instrumentation to mitigate and largely eliminate any day-to-day difficulty that a limited driving range might create. The large proportion of households that select a vehicle capable of restoring its driving range while parked at home is consistent with the argument that many households believe this to be true.

Conclusions

As noted in several of our previous studies, understanding consumer response to limited range requires careful attention to household fleet composition, consumer learning processes (especially as consumers have previously not considered the impact of reduced range on lifestyle choices), the recharging infrastructure (home, work, and station recharging), and possible changes in vehicle range instrumentation.

As in previous studies, we find here that consumer travel patterns are less of an obstacle to limited range choices than are lack of experience and knowledge among consumers with the technology of electric vehicles. Additionally, previous market research has failed to consider consumer response to the whole package of EV instrumentation, recharging infrastructure and home recharging. Further, participants in many prior studies were not presented vehicle choices in the context of their overall fleet composition. The findings presented here on household travel patterns, use of current gasoline instrumentation, and refueling patterns add further evidence that gasoline vehicles currently do not meet consumer wants for much of their local driving tasks; a job that electric vehicle technology may do better.

Finally, some have argued that to make it in the market, electric vehicles must have equivalent driving ranges and refueling times to gasoline vehicles. We believe this is an extreme, and now insupportable, position. Such goals are unreachable for battery powered EVs; they are also irrelevant. We argue there is a viable niche market for electric vehicles as complements to long range vehicles in multi-vehicle households.

We believe from the results of this study and previous studies we have done, that it is more important, and will be more profitable, to market less expensive battery-powered EVs capable of providing driving ranges of 40 to 120 miles than to develop more expensive battery-powered vehicles with ranges in excess of 150 miles. The marginal utility for electric vehicles with ranges beyond 150 will be small so long as there are gasoline vehicles on the road that have 300-400 miles of range. Therefore, so long as people persist in believing that EVs must mimic the long range and short refueling times of gasoline cars, practical and profitable EVs will elude us until new electric energy storage technologies can be commercialized. However, we argue that the utility of short range, home recharged EVs lies primarily in their complementary relation to gasoline vehicles, in their ability to provide diversified transportation services in a hybrid household. Marketed as such, it appears to us that both the state of the art in technology and consumer demand are adequate to launch the market for ZEVs.

CHOICE SITUATION TWO: A FUTURE MARKET SCENARIO

Choice Situation Two represents one plausible future market for personal, private transportation. In Situation Two, the households revisit their purchase decision about their next new vehicle in a more detailed scenario. Households choose from a set of vehicles that includes expanded driving range options for EVs, natural gas vehicles that have some features of both EVs (shorter range and the possibility of home recharging) and gasoline vehicles (full-size body styles and away-from-home fast refueling—faster than electric fast charging) and reformulated gasoline vehicles. To insure that households reconsider their vehicle choices rather than just repeat them, we do not offer households vehicles in Situation Two that are identical to those in Situation One. At the very least, households who chose an EV in Situation One must choose an EV with either shorter or longer driving range in Situation Two. Even the reformulated gasoline vehicles in Situation Two are not identical to the gasoline vehicles offered in Situation One. Thus the expanded range choices for EVs in Situation Two tests our hypothesis that the market for EVs can be segmented by demand for driving range. We sought additional insights into households' choices in Situation Two by asking them to indicate both their first and second choice of vehicle type, again, where vehicle types are defined by the propulsion systems (and within the electric vehicle type, by range and speed).

This section develops the image of the market for private motor vehicles within our sample of potential hybrid households. We discuss market segments defined by vehicle types and body styles. While we have already established that the market for EVs can be segmented by demand for range, we provide more evidence in this section. Further, we examine households' choices of vehicle holdings, not just the purchase of one vehicle. We see the impact of changes in the travel needs that the next new vehicle is expected to fulfill. We also look at vehicle choices made by households in different life cycle categories. These categories are defined by the age and relationships of people in the household.

Types of EVs offered in Situation Two

We observed in previous work that many households shift their driving range choices as they began to explore what it meant to be a hybrid household (Kurani et al, 1994). These shifting choices within households and the very different range choices made by different households suggested an EV market segmented by demand for range. We used this idea to create four classes of electric and hybrid-electric vehicles in our survey. Range, speed and sample price characteristics of all the vehicle types offered are summarized in Table 10. Complete descriptions of vehicles and options are in the survey document in Appendix A. The vehicles with the shortest driving range are neighborhood electric vehicles (NEVs). They are also defined to be non-freeway capable. *Community electric vehicles* (CEVs) have longer ranges and top-speeds compared to NEVs that make them capable of traveling on freeways. *Regional electric vehicles* (REVs) have still longer ranges and higher top speeds. We also offered our respondents a *hybrid electric vehicle* (HEVs) that has the longest (total electric plus ICE) driving range of any electric vehicle in our study.

Table 10: Range, speed and sample price characteristics of vehicles in Situation Two

Vehicle Type:	Driving Range, miles	Top Speed, mph	Comparative Prices, $x1000[1]
Neighborhood Electric Vehicle (NEV)	40	40	3.5 - 7.1
Community Electric Vehicle (CEV)[2]	60 to 80	75	8.0 - 16.8
Regional Electric Vehicle (REV)[2]	120 to 150	85	11.5 - 22.1
Hybrid Electric Vehicle (HEV)[2, 3]	140 to 180	85	14.0 - 24.9
Natural Gas Vehicle (NGV)[4]	120 to 150	85	9.5 - 17.4
Reformulated Gasoline Vehicle (REV)	—[5]	—[5]	10.0 - 18.9

1. Comparative prices are calculated for a sub-compact sedan. The lower limit is for the lowest trim level and no other options added. The upper limit is for the luxury trim level, and all available engine, transmission and energy storage options. Price includes the different purchase incentives for the different vehicle types. The sub-compact sedan is used for comparison because it is most similar in body style to the Neighborhood Electric Vehicle, which is only offered in one body style. The actual price "paid" by our respondents is of course a function of their actual choice of vehicle type, body style, trim level and other options.
2. Vehicle range depends on body style and choice of battery options.
3. The battery-only driving range options are either 40 or 80 miles.
4. Range depends on choice of one or two fuel cylinders.
5. Comparable to existing gasoline vehicles.

The vehicle type choices made by the households in Situation Two are summarized in Figure 17 and Table 11. As Figure 17 indicates, the single largest vehicle type group is reformulated gasoline vehicles, followed by regional EVs and natural gas vehicles. The frequencies in Table 11 show that 34 percent of households chose a reformulated gasoline vehicle, 26 percent chose a regional EV, and 20 percent chose an NGV. All EVs, including hybrid EVs, account for 47 percent of the vehicles chosen in Situation Two.

Figure 17: Frequency distribution of vehicle type choices in Situation Two

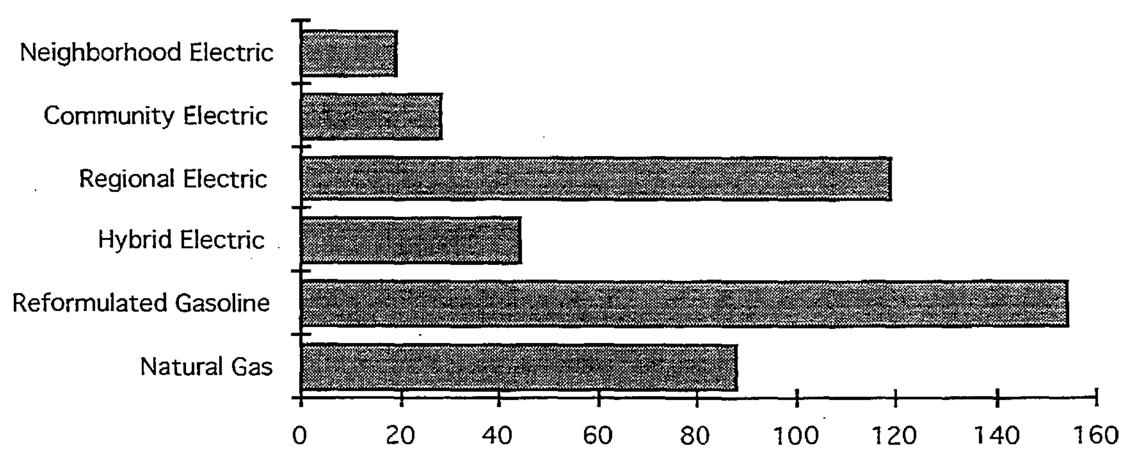


Table 11: Vehicle type choices in Situation Two

Vehicle Type Choice	Count	Probability	Cumulative Prob.
Neighborhood EV	19	0.042	0.042
Community EV	28	0.062	0.104
Regional EV	119	0.263	0.368
Hybrid EV	44	0.097	0.465
Gasoline, Reform	154	0.341	0.805
Natural Gas Vehicle	88	0.195	1.000
Total	452		

Neighborhood Electric Vehicles

Neighborhood electric vehicles were described as non-freeway vehicles with a top speed of 40 miles per hour and a range of 40 miles. They were offered in three models—2, 3 and 4 seat sedans—with the option of a convertible top. Despite their low top speed, we specified the NEVs were fully certified to meet the Federal Motor Vehicle Safety Standards. Fast charging was not offered as an option to reinforce the image of a NEV as a vehicle intended for local travel. The prices at which NEVs were offered were substantially lower than any other vehicle type. Households could chose NEVs that ranged in price from $5,500 to $10,000 depending on seating and other options. Buyers were given a $2,000 zero emission vehicle (ZEV) credit.

A total of 19 households (4.2 percent of the sample) selected NEVs. This is unexpectedly large, but we had very little in the way of previous studies to gauge response to this type of vehicle. However, the number of NEV choosers might have been even higher according to comments made by participants—some respondents complained about the boxy styling of the only NEV presented in our informational video.

Community Electric Vehicles

The community electric vehicle was presented as a moderately priced electric vehicle, with a 60 mile range as "standard equipment" and 80 mile driving range as an $800 option. Fast charging was not offered. CEVs were available in all the "EV body styles"—small, compact and mid-size sedans and wagons, small pickup trucks and sport-utility vehicles (SUVs), and minivans. In this class of EV, body style did not affect range. As with all other vehicle types expect NEVs, CEVs were offered in three trim levels and with other additional options. They were eligible for a $4,000 ZEV purchase rebate. A total of 28 households (6.2 percent of the sample) chose a community EV.

Regional Electric Vehicles

The regional electric vehicle was presented as having longer range (120 to 150 miles depending on battery options and body style), higher performance, and a longer lasting battery (50,000 miles as opposed to 25,000 miles) than community EVs. Additionally, fast charging was offered as a $900 option. They were eligible for a $4,000 ZEV purchase rebate. A total of 119 households chose regional EVs (26.3 percent).

Hybrid Electric Vehicles

Hybrid electric vehicles were also offered with two battery packs—40 or 80 mile electric-only range—and an additional 100 miles range from a 40 hp reformulated gasoline engine, for total combined ranges of either 140 or 180 miles. The HEV we offer was a "range extender". The vehicle operates on battery power until it reaches a pre-determined depth of discharge. At that point, the IC engine provides power for battery charging. Of all the possible hybrid EV designs, we chose this as a representative hybrid because it was relatively simple to explain and is intended only to extend range, not to provide continuous base power, peak power, or to meet some other performance goal. A $1,000 Ultra-Low Emission Vehicle (ULEV) rebate was offered on the purchase of a hybrid EV. A total of 44 households chose hybrid EVs (9.7 percent).

Compressed Natural Gas Vehicle Vehicles

Compressed natural gas vehicles (NGVs) were offered in the complete range of vehicle body styles including full-size. Households that wanted an NGV had a choice of two range options—80 or 120 miles. A home refueling appliance was offered separately under lease or sale from the gas utility. NGVs came with a $1000 rebate for meeting ULEV emissions standard. Eighty-eight households (20 percent) chose an NGV. Twenty-one of these (22 percent of NGVs), were vehicles with full-size body styles not offered as electric or hybrid electric vehicles. Forty-one percent of households that chose an NGV also chose to buy or lease a home refueling appliance.

Reformulated Gasoline Vehicles

Reformulated gasoline vehicles were described as identical to today's gasoline vehicles in every way except that their emissions were improved to meet Low Emission Vehicle (LEV) standards. LEVs were not offered a tax credit. A total of 154 households chose reformulated gasoline vehicles. Forty-eight (31%) of these vehicles were of the full-size body styles not available as electric or hybrid vehicles.

Transitions in choices of vehicle type between Situation One and Two

Households frequently chose different types of vehicles in Situation Two than they had chosen in Situation One. These transitions are tabulated in Table 12. The cells highlighted in **bold** indicate the number of households that defected from their original type choice (electric or gasoline) in Situation One. When offered an expanded array of alternative fuel and electric vehicle options, 113 of 241 (47%) households defected from gasoline. Half of these defected to one of the variety of electric vehicles and half defected to natural gas vehicles. Fifty-eight of 211 households (27 percent) defected from electric vehicles to either gasoline or natural gas, with about half defecting to each type.

Table 12: Vehicle type transitions from Situation One to Situation Two

Situation Two: Observed Count	**Situation One** Electric	Gasoline	**Total**
Neighborhood EV	9	**10**	19
Community EV	24	**4**	28
Regional EV	95	**24**	119
Hybrid EV	25	**19**	44
Gasoline, Reform	**26**	128	154
Natural Gas	**32**	**56**	88
Total	211	241	452

Defectors from EVs

We originally hypothesized that defectors from EVs to natural gas and reformulated gasoline may have been motivated by an attitude that NGVs and reformulated gasoline vehicles were "clean enough" and allowed the household to go back to a preferred body style. However, we find little evidence that body style choices motivated switches between vehicle types. Only 4 of the 26 people who defected from electric to gasoline and 9 of the 32 who defected from electric to natural gas chose a full-size vehicle that was not available to them as an EV. Most defectors from EVs to gasoline vehicles (16 of 26 households) indicated that a desire for longer range motivated their choice. These statements were contradicted though by the fact their most frequent "second best" choice was a natural gas vehicle—a vehicle that shares the limited range of EVs. Those who defected to natural gas did not provide a clear consensus as to why. Some, but not all, the defectors perceived NGVs to be more economical, more reliable and safer than EVs. We return to the role of body styles in defining market segments later in this section.

Defectors from gasoline vehicles

Households that defected from gasoline to one of the EVs support our argument that the market for EVs can be segmented by driving range and that an expanded choice of driving range options can pull some households into the EV market that otherwise would choose to buy gasoline vehicles. Not surprisingly, the largest group of defectors from gasoline to EVs chose regional EVs. Seventeen of these 24 households indicated they switched to an EV because the REV provided them with adequate driving range. Nine others indicate they switched because they believe REVs were the best "environmental" vehicle.

While we expect longer range EVs to bring some gasoline vehicle choosers into the EV market, we also see that the availability of shorter range, lower cost EVs encourages some households to switch from gasoline vehicles. Fourteen households defected from gasoline to a community or neighborhood electric vehicle. This is too few to provide a basis for discussing their motivations for choosing short range EVs, but the simple fact that any households that previously chose a gasoline vehicle would choose a low cost, short range EV is evidence that the entire market for EVs does not depend on the development of long range batteries. We note these choices of short range vehicles were substantiated by the fact that within this group of households, NEVs and CEVs were also the most frequently selected "second best" vehicle type.

Defectors to hybrid electric vehicles reflect the complex characteristics of HEVs. Nearly equal proportions of these households stated that the fact HEVs are cleaner than gasoline vehicles, more economical than gasoline vehicles, or can be refueled at home as their reason for switching from gasoline. In many ways in our experimental design, HEVs are more like natural gas vehicles than they are like either gasoline or "pure" electric vehicles. HEVs and NGVs can both be refueled at home or away-from-home. Both are cheaper to operate, but more expensive to buy, than gasoline vehicles. Both have limited range compared to gasoline cars, but longer range than most of the electric vehicles. The perceived similarities between these vehicles are seen in the "second best" vehicle choices of households that defect from gasoline to HEVs. These households second choices are most frequently reformulated gasoline and natural gas vehicles. The one feature that distinguishes HEVs from NGVs is the lack of full-size body styles for HEVs. Yet we saw above that body style choices do not play a large role in the defection of EV choosers in Situation One to natural gas in Situation Two. We return to a discussion of the role of body styles in defining vehicle markets in a later section.

We hypothesized that the defectors from gasoline to natural gas very much wanted a cleaner car, but were unwilling to give up a full-size vehicle in Situation One—that is, they would have chosen an EV in Situation One if EVs had been offered in full-size body styles. This hypothesis is based on the fact that limited driving range and the ability to refuel at home are common to NGVs and EVs—only body style is markedly different. Our respondents' choices do not support this hypothesis. If the hypothesis is true, people who chose natural gas vehicles in Situation Two should also have chosen full size body styles in both Situation One and Two—only 12 of the 56 defectors to natural gas did so.

Instead, it appears that those who defected from gasoline to natural gas chose a vehicle that was intermediate between gasoline and electric vehicles. Twenty of the 56 people who defect from gasoline to natural gas said the most important reason was their belief NGVs would more economical than gasoline vehicles. Indeed, the costs of each vehicle type in the survey were structured so that NGVs were intermediate between electric and gasoline vehicles. Nineteen people choose NGVs because they could refuel them at home (a characteristic of EVs) and another 11 said they chose an NGV because it refueled faster than EVs (a characteristic of gasoline vehicles).

EV Shares of the New Light Duty Vehicle Market from Situation Two

We estimate the lower bound on the annual market share for the neighborhood, community and regional EVs in our study to be between 13 and 15 percent of the new light-duty vehicle market. If we include hybrid EVs, the annual market share for electrified vehicles rises to between 16 and 19 percent.

The choice probabilities in Table 11 do not themselves represent annual new car market shares. To provide a lower-bound estimate of annual market shares we must make three adjustments outlined below and previously discussed in detail in the Hybrid Household section. First, recall our sample of *potential hybrid households* buys between 35 and 40 percent of the new cars and light duty trucks sold in California every year. Second, we hypothesize that over a long period of time, hybrid households will choose to buy an EV once every *N* times they buy a new car where *N* is the number of vehicles they own. Third, we found in previous work that about 8% of another sample of potential hybrid households were unable to adapt to limited ranges because of their travel needs.

Given the assumptions in our experimental design, the market share estimate above must be regarded as a lower bound for the following reasons. The estimate assumes that people who did not choose an EV for their next new vehicle will never chose an EV. This ignores those households that did not choose an EV in this choice exercise, but will buy an EV during a later vehicle purchase decision. Further, our sample of *potential hybrid households* does not include representatives of all households who may buy EVs. Other households that may buy EVs include:

- households that do not now buy new cars but would do so to buy an EV;
- households that become two car households by purchasing an EV; and
- households that do not now own cars of the likely EV (or NEV) body styles but would buy such a vehicle in order to buy an EV.

While this study sheds no light on the number of households in the first two categories, we do observe that some households chose smaller vehicles than their "preferred" body style when they chose an EV in the Choice Situations. If households in our sample will change body styles in order to choose an EV, we surmise households outside our sample may too. We return to this issue in a later section on how households select their vehicle holdings. Lastly, this market share estimate for EVs is extremely conservative because it does not include any potential EV sales to commercial or government fleets.

Market Segments by Vehicle Body style

In this section, we describe the market represented by the vehicle type and body style choices of our sample. This description provides clues to ZEV market development and provides insights into the types of life style changes households made to incorporate a limited range, electric vehicle into their vehicle holdings—i.e., to become hybrid households. The body style and vehicle type choices made in Situation Two are cross-tabulated in Table 13. The remainder of this section is devoted to understanding the distribution of choices shown in this table. We explore the impact of these results on the ZEV mandate. We see how households made these body style choices and how they structured their vehicle holdings to accomplish their desired travel. We look at households' adaptations through changes in body style choices and changes in the intended uses of their vehicles. Lastly, we examine the role of household demographics and income on vehicle type and body style choices.

We warn the reader that this section involves more technical and complex analysis that in other sections of this report. This is because of the more demanding task of examining multiple variables and special sub-sets of our sample.

Body styles and the ZEV Mandate

The row totals in Table 13 show that across all propulsion systems, the single most common body style choice is a mid-size sedan. Minivans are a distant second, followed by compact sedans, small sedans and full-size sport utility vehicles. (NEVs of course are only offered in one of the special NEV body styles.) The single most frequently chosen vehicle is a mid-size, regional electric sedan, representing about 9 percent of the total sample. Though some of the major motor vehicle manufacturers are developing EVs in mid-size body styles, the range capability of the regional electric vehicles in our study have to date only been demonstrated in compact and small (sub-compact) vehicles.

If the single largest market segment (defined by vehicle type and body style) for any vehicle in our sample has not as yet been demonstrated in an actual vehicle, what are the prospects for the ZEV mandate? NEVs and CEVs of all body styles have either already been demonstrated or are straightforward applications of existing EV technology. Furthermore, regional EV capability has been demonstrated in small and compact body styles. Fifty-four of the households who chose a regional EV also chose one of these small, "EV body styles". NEVs, CEVs and these smaller REVs represent 23 percent of the vehicles chosen by our sample. Subject to the same assumptions regarding the conversion of our sample proportions to California market shares as made previously, these households represent approximately 7 percent of the annual new light-duty vehicle market in California. This far exceeds the 2 percent mandate in the year 1998.

Based on this analysis, the ZEV mandate can be met in its first few years with sales of vehicles that have already been demonstrated to households in our *potential hybrid household* sample. We remind the reader that our sample includes neither the several types of households who may buy EVs but are not in our sample, nor fleets. Meeting the 10 percent mandate in the year 2003 will depend on sales to these other market segments or advances in ZEV technology that bring mid-size vehicles up to the regional EV performance level. This last is potentially very important. If EV technology makes this advance, large new markets, well beyond the mandate requirements, will be opened.

Table 13: Chosen body style by vehicle type

Body Style	**Vehicle Type**						**Total**
Observed Count	NEV	CEV	REV	HEV	Gasoline	NGV	
NEV	19	-	-	-	-	-	19
SUV, full size	-	-	-	-	24	11	35
SUV, small	-	3	7	7	5	3	25
compact pickup	-	2	9	2	10	10	33
compact sedan	-	3	13	5	14	6	41
compact wagon	-	1	0	1	1	2	5
full size pickup	-	-	-	-	6	5	11
full size sedan	-	-	-	-	12	3	15
full size van	-	-	-	-	4	2	6
full size wagon	-	-	-	-	2	0	2
mid-size sedan	-	4	41	13	35	21	114
mid-size wagon	-	0	2	1	1	0	4
minivan	-	3	20	3	23	15	64
small sedan	-	7	17	6	6	3	39
small wagon	-	0	0	1	0	0	1
sports car	-	5	8	4	9	6	32
Total	19	28	117	43	152	87	446

Note: Cells marked with a dash indicate body style/vehicle type combinations that were not available in the choice set. "SUV" is an acronym for sport-utility vehicle.

Household Fleet Formation

As part of their decision context, households make vehicle purchase decisions based, in part, on the vehicles they already own. During any given vehicle purchase decision, households consider whether to add another vehicle to their holdings or replace an existing vehicle. They consider what types of travel the new vehicle is expected to accomplish and how other travel will be apportioned to other household vehicles (or other modes of travel). In this section we analyze the vehicle choices made in Situation Two, our future market scenario. We look for changes in body style choices and vehicle use assignments. We discuss the impact of household life cycle on these vehicle and body style choices.

Changes in Body style

We have stated that body styles choices are a reflection of household lifestyle. To analyze whether households make lifestyle adjustments to buy an EV, adjustments that are reflected by changes in their body style choice, we first define two groups of body styles. Body styles in which EVs are offered—small, compact and mid-size sedans and wagons, small pickup trucks and SUVs, and minivans—are defined as "EV body styles". The full-size vehicles that were only offered as ICEVs are defined to be "non-EV body styles". Neighborhood EVs are defined as their own "NEV body style". These definitions apply regardless of the source of motive power. For example, a compact, natural gas powered sedan is an NGV of an EV body style. Body styles are grouped by these definitions and cross-tabulated by motive power (EV or ICEV, where all EVs are grouped in the EV category and reformulated gasoline and natural gas vehicles are grouped together in the ICEV category) in Table 14.

Table 14: Chosen motive power by chosen body style category in Situation Two

Chosen Motive Power	**Chosen Body Style Category**			**Total**
Count	"EV body styles"	"NEV body styles"	"non-EV body styles"	
EVs	188	19	0	207
ICEVs	170	0	69	239
Total	358	19	69	446

These data tells us that, irrespective of their vehicle type choice, the vast majority (80%) of all households chose a vehicle that was of the smaller "EV body styles". Within the group of 358 households who chose "EV body styles", the proportion of electric to ICE vehicles is nearly equal. Only 15 percent of households (69 of 446) actually chose one of the larger "non-EV" body styles in the choice experiment. The zero values in the table are part of our research design. Households that chose EVs, cannot choose a non-EV body style; households that chose a gasoline or natural gas vehicle cannot chose a NEV body style.

Next we consider whether the body style choices in Table 14 reflect the households' preferences for body styles. In Part One of the questionnaire, we asked households to tell us about the next new vehicle they thought they would acquire. We asked them what the body style of that vehicle was most likely to be. We define this to be their *preferred body style*. If we group households' preferred body styles in the same groups (EV and non-EV) as we did their chosen body styles and cross-tabulate chosen by preferred body style, we get the data in Table 15.

Table 15: Chosen body style in Situation Two by preferred body style for next new vehicle

Chosen Body Style in Situation Two	**Preferred Body Style for next new vehicle**		**Total**
Count	"EV Body Styles"	"non-EV Body Styles"	
"EV Body Style"	259	90	349
"non-EV Body Style"	14	52	66
Total	273	142	415

Note: Households that chose NEVs are excluded from this table since they could not have expressed a prior preference for a NEV body style based on familiarity with such body styles.

First we note that the column totals indicate a third of our sample (142 of 415) indicated they preferred a full-size body style for the vehicle they thought they would next acquire. If the lifestyle choices expressed through their desire for a larger vehicle were particularly important, then we would not expect households to choose smaller body styles in the Choice Situations. Our first clue that a preferred, larger body style is not a binding constraint on vehicle type choices is contained in Table 15. Of the 142 people who, prior to Situation Two, indicated they preferred a large vehicle, nearly two-thirds (90) chose a smaller vehicle in the choice experiment.

The question remains, do the people who prefer a larger car, forego an EV in order to get their desired body style? In Table 16 we cross-tabulate the preferred body style group by the motive power of the chosen vehicle type in Situation Two. We have split the ICEV category into reformulated gasoline and natural gas. In this table we test the null hypothesis that choice of vehicle type is independent of the preferred body style. This is the same as saying we are testing to see whether the column percents in Table 16 are equal in each row. The chi-square statistic tell us we cannot reject the null hypothesis. The choices between electric, natural gas and gasoline vehicles made by our sample were independent of their preferred body style for their next new vehicle. That is, the choice of propulsion system was not determined by a prior preference for a particular size class of vehicle.

Table 16: Chosen vehicle type in Situation Two by preferred body style

Chosen Vehicle Type Observed Count Column Percent	**Preferred Body Style** "EV Body Styles"	"non-EV Body Styles"	**Total**
EVs	141 48.79	63 42.28	204
Natural Gas	52 17.99	33 22.15	85
Reformulated Gas	96 33.22	53 35.57	149
	289	149	438

Chi-Square Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	1.923	0.3822
Pearson	1.928	0.3813

Note: The category "EV" includes households that chose NEVs since this tabulation does not rely on actual body style choices, but only on the prior preferred body style.

Having established that a prior preference for a full-size body style does not appear to determine choices between vehicle types, we now wish to determine whether actual body style choices affect vehicle type choices. In Table 17 on the following page, we compress the data from Table 13 into fewer categories. We suppress the "wagon" variation of each body style into the corresponding size class (e.g., compact station wagon is recoded as compact sedan), eliminate all NEV choosers since their body style choices are treated as being entirely different than any other body styles, group all other EVs into one category, but separate ICEVs into natural gas and gasoline vehicles.

According to the data in Table 17, we conclude that choices of vehicle type were independent of choices of body style, given our design restrictions on possible vehicle type and body style choices. Given that people could not have chosen a full-size EV, there does not appear to be a relationship between chosen vehicle type and chosen body style.

Table 17: Body style choice by choice of electric, natural gas, or gasoline vehicle in Situation Two

Body Style Choice Observed Count Expected Count	Vehicle Type Choice Electric	 Natural Gas	 Gasoline	Total Observed Count
full size sport-utility	- 0	11 12.74	24 22.26	35
full size pickup	- 0	5 4.00	6 7.00	11
full size sedan	- 0	3 6.19	14 10.81	17
full size van	- 0	2 2.18	4 3.82	6
small sport-utility	17 13.13	3 4.32	5 7.55	25
compact pickup	13 17.33	10 5.70	10 9.97	33
compact sedan	23 24.16	8 7.95	15 13.89	46
mid-size sedan	61 61.97	21 20.40	36 35.64	118
minivan	26 33.61	15 11.06	23 19.33	64
small sedan	31 21.01	3 6.91	6 12.08	40
sports car	17 16.80	6 5.53	9 9.66	32
	188	87	152	427

Test	chi-square	Prob.>chi-square
Likelihood Ratio	24.75	0.074
Pearson	24.22	0.085

Note: Because it is impossible within our research design to choose full-size EVs, those cells of the table are "structural zeros" and the formula for computing the expected values in all other cells must be modified to account for the fact those cells do not contain zeros by chance, but by design. Thus, the expected values in this table cannot be obtained by reference to the row, column, and table totals as would be the case if there were no structural zeros.

Choice of electric vehicles and the preferred body style

It appears that prior preference for a larger or smaller body style affects neither actual choice of a body style from within the broad categories of "EV body style" and "non-EV body style" (Table 16) nor choices from within the broad categories of vehicle type (Table 17). We wish to determine whether these prior preferences for body style affect the choice of a specific type of EV—NEV, CEV, REV or HEV. The data to investigate this question are shown in Table 18. Again, we conclude that even within the most specific vehicle type classifications, choice of vehicle type is not related to choice of body style. The fact a household may prefer that their next new vehicle be smaller or larger does not affect their choice of the specific type of EV or of any type of vehicle in general. Households are able and willing to imagine and rethink their entire expected vehicle holdings when offered an expanded variety of vehicles.

Table 18: Detailed vehicle type choice by grouped body choice in Situation Two

Vehicle Type Choice	**Preferred Body Style**		**Total**
Observed Count	"EV Body Style"	"non-EV Body Style"	
Neighborhood EV	12	6	18
Community EV	21	5	26
Regional EV	81	37	118
Hybrid EV	27	15	42
Gasoline, Reformed	96	53	149
Natural Gas Vehicle	52	33	85
Total	289	149	438

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	4.239	0.5155
Pearson	3.998	0.5498

Summary of body style choices in Situation Two

Given the assumptions in our choice experiment, our sample represents a market in which at least 7 percent of new, light duty vehicles sold will be EVs, given available technologies. These households indicate they would buy, as their next new vehicle, an EV. These vehicles are sub-compact, compact and mid-size vehicles and minivans that have ranges of 60 to 80 miles, sub-compact and compact sedans, small sport-utility vehicles, compact pickup trucks with ranges between 60 and 150 miles, and Neighborhood EVs. The market share these vehicles (not households) represent would likely be larger than this estimate as we include in our sample neither several types of households who may buy EVs nor fleets. Additionally, if storage technologies for electrical energy are improved to the point where mid-size vehicles achieve our regional EV range capability, the market for EVs will more than double.

The importance of body styles to the market for EVs should not be overstated based on people's prior preferences for the body style of their next new vehicle. The fact that one-third our sample imagine their next new vehicle to be a full-size vehicle appears to be bad news for EVs. However, we found that such prior preferences for body style had no correlation to either the body style choices made by households or the choice among EVs, NGVs and ICEVs. The large proportion of people who chose a smaller body style than they preferred and the lack of any affect of this on choices between types of vehicles suggests that such body style shifts are not perceived as large sacrifices of lifestyle goals.

Changes in the Defining Purpose

We have argued that households make vehicle purchase decisions within the context of their entire stock of vehicles. We saw in the previous section that, within our choice experiments, households will choose a vehicle of a different body style than they had previously indicated they preferred. Further evidence of households' willingness and ability to construct a fleet of specialized vehicles to accomplish their travel needs is provided by changes in the *defining purposes* for their next new vehicles. While a household may use a vehicle for all types of travel, the choice of a particular body style is often determined by the desire to access one particular type of activity. Thus, while one household member might commute to work everyday in a sport-utility vehicle (SUV), the reason the household bought an SUV, rather than any other body style, may have been to access recreation activities on weekends. In this case, the *defining purpose* is weekend recreation travel, not commuting. When offered new vehicle types with different range, speed and recharging or refueling characteristics than they have been offered before, households may make different choices of vehicles based on changes to the defining purpose of their next new vehicle. We define these seven categories of defining purposes:

- Commute to work or school on a regular basis;
- Chauffeur children or other non-drivers;
- Chauffeur business clients and associates;
- Run business-related errands;
- Take weekend and vacation trips;
- Haul large loads;
- Vehicle Styling and Other.

We recognize that not all vehicle purchase decisions are made for purely practical reasons. As seen in the list of defining purposes, we did allow households to indicate that vehicle styling or some other non-travel related reason defined their choice of a particular body style and vehicle type.

We asked households to identify the defining purpose each time they were asked to indicate a preferred body style or a body style choice. Thus, we asked them to identify the defining purpose of their preferred body style in Part One of the survey, and again in choice Situation One and Two. In Table 19, we cross-tabulate the defining purpose for the preferred body style of their next new vehicle as stated in Part One of the survey by the defining purpose of their chosen body style in Situation Two. The column totals in Table 19 show that commuting to work defined the preferred body style of the next new vehicle for about one-third of our households, followed by weekend/vacation travel, hauling large loads, vehicle styling and chauffeuring children. The row totals show a pronounced shift across the whole sample toward commute trips and hauling large loads as the defining purposes of the body style choices in Situation Two.

Table 19: Defining purposes for the chosen body style in Situation Two by defining purpose for the preferred body style

Defining purpose of chosen body style in Situation Two	**Defining purpose of preferred body style in Part One**								**Total**
Count	1	2	3	4	5	6	7	8	
1	**90**	19	2	3	25	4	27	18	188
2	6	**26**	0	0	8	0	2	2	44
3	4	0	**1**	0	2	0	0	1	8
4	2	0	0	**9**	4	0	1	0	16
5	19	15	1	0	**31**	3	12	10	91
6	3	0	0	2	1	**13**	0	0	19
7	8	0	0	1	5	0	**17**	5	36
8	5	2	0	2	10	0	7	**11**	37
	137	62	4	17	86	20	66	47	439

Note: Trip purposes are identified as:

1 = commute
2 = chauffeur children
3 = chauffeur business clients
4 = business errands
5 = weekend/vacation
6 = haul large loads
7 = looks/styling
8 = other

When presented with an expanded variety of vehicles in Situation Two, most households redefined the defining purpose of their next new vehicle. The diagonal shown in **bold** in Table 19 indicates those households that did not change their defining purpose between their preferred body style and their chosen body style. Taken together, they constitute less than half the sample. Offered an expanded variety of vehicles, our sample demonstrates a willingness and ability to redefine the uses of the vehicles they plan to acquire next. This reinforces our belief that market research based only on past vehicle purchase behavior will fail to identify markets for radically new vehicles such as ZEVs.

We now determine whether the choice of a vehicle type is associated with defining purposes. We expect to see that the defining purposes of natural gas and gasoline vehicles are weekend and vacation travel and hauling large loads more often than we would expect if defining purpose and vehicle type were independent. This is because natural gas and gasoline vehicles can be quickly refueled away from home, have longer ranges (in the case of gasoline vehicles) and come in full-size body styles. The cross-tabulation of vehicle type by defining purpose from Situation Two is shown in Table 20.

Table 20: Vehicle type choice by defining purpose in Situation Two.

Chosen Vehicle Type in Situation Two	**Defining purpose of the chosen body style in Situation Two**								**Total**
Count	1	2	3	4	5	6	7	8	
Neighborhood EV	11	2	0	1	0	0	0	4	18
Community EV	13	1	0	2	3	1	5	3	28
Regional EV	57	20	1	7	13	3	11	7	119
Hybrid EV	22	4	4	2	4	1	4	3	44
Gasoline, Reform	56	9	1	5	46	10	11	13	151
Natural Gas	29	11	2	0	24	4	5	7	82
Total	188	47	8	17	90	19	36	37	442

Note: Trip purposes are identified as:

1 = commute
2 = chauffeur children
3 = chauffeur business clients
4 = business errands
5 = weekend/vacation
6 = haul large loads
7 = looks/styling
8 = other

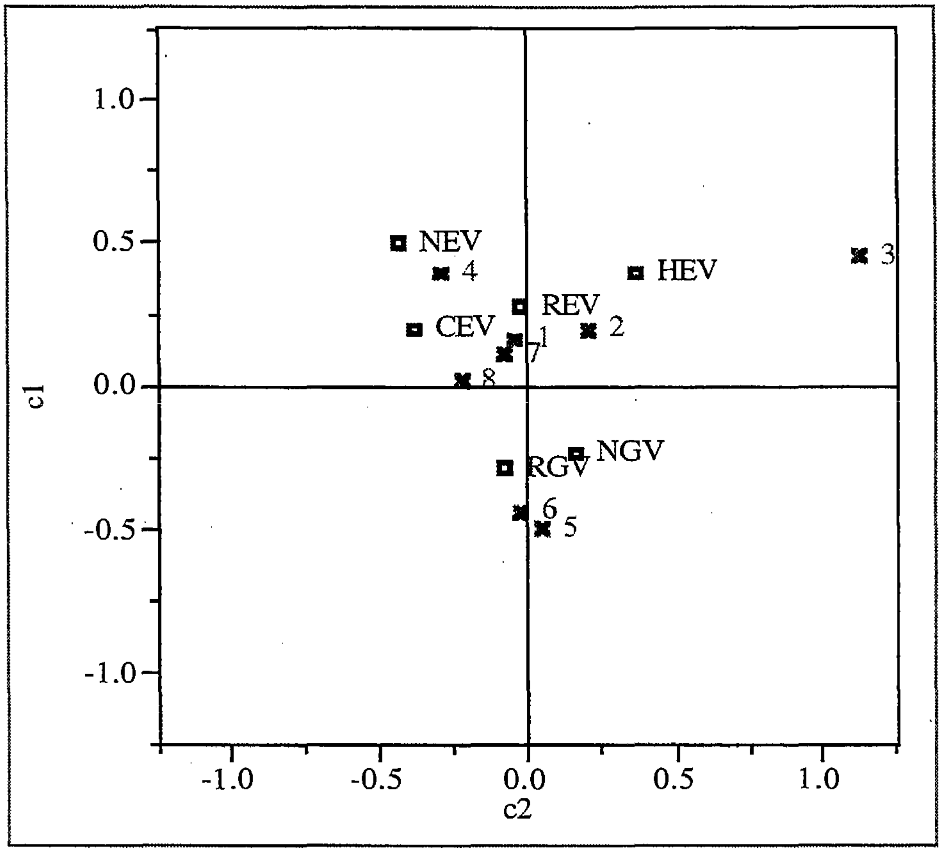
For the vehicles chosen in Situation Two, the commute trip is by far the most common reason for choosing a particular body style across all vehicle types except reformulated gasoline and natural gas. We see that a substantial number of gasoline and natural gas vehicles were chosen for weekend and vacation travel. Seventy of the 90 households who said that weekend and vacation travel was the defining purpose of the body style they chose in Situation Two, chose natural gas and gasoline vehicles. Not surprisingly, households that chose the EVs with the longest range, regional EVs, make up the majority of the remaining households that chose a weekend and vacation vehicle. We also note that despite the fact that many more people chose a reformulated gasoline vehicle than chose a regional EV (151 to 119), within the defining purposes of commuting and chauffeuring children, regional EVs outnumber gasoline vehicles.

Figure 18 is a graphical representation of the data in Table 20. Correspondence analysis provides a visual image of the relationships in a cross-classification table. In particular, correspondence analysis illustrates in which rows (and columns) the data are distributed in similar proportions. Rows (and columns) that lie on one side of an axis indicate the data are more alike than rows (and columns) that lie on opposite sides of that axis. We see that all the EV types are grouped together on one side of the y-axis (c1) and natural gas and gasoline vehicles together on the other side of the axis. Thus, the defining trip types of all the EVs tend to be distributed more like each other and less like those of the ICEVs. This axis places weekend/vacation travel and hauling loads on the same side of the axis as gasoline and natural gas vehicles. It also separates them from other defining purposes. The correspondence analysis illustrates how the choice between an EV or an ICEV and the defining trip type are related.

The overall shift toward commuting and weekend/vacation travel suggests these two trip types may define choices between electric and ICE vehicles since only ICEVs were offered in the larger body styles appropriate for hauling loads and in long ranges suitable for travel to weekend and vacation destinations that tend to be further from home than other, more routine, activity locations. We examine these shifts in more detail next.

A review of Table 19 shows that four of the defining purposes—commute trips, weekend and vacation travel, chauffeuring children, and vehicle styling—account for two-thirds of the households' choices. To explore the relationship between vehicle type, body style, and the defining purpose in greater detail, we select for further analysis only those households whose defining purpose for both their preferred body style and their chosen body style in Situation Two were one of these four defining purposes. The data on defining purpose from these 310 households are cross-tabulated in Table 21. The diagonal shown in **bold** shows the households that did not change their defining purpose from that of their preferred body style.

Figure 18: Correspondence analysis of defining purpose and vehicle type choice in Situation Two



Note: Trip purposes are identified as:

1 = commute
2 = chauffeur children
3 = chauffeur business clients
4 = business errands
5 = weekend/vacation
6 = haul large loads
7 = looks/styling
8 = other

The largest group of people (90 of 310) stated the body style of their next new vehicle would be defined by its use as a commute vehicle and then retained this same defining purpose when they chose a vehicle in Situation Two. All told, 53 percent of the households whose defining purpose for their preferred next new vehicle was commuting to work or school, weekend and vacation travel, chauffeuring children or vehicle styling chose a vehicle based on that same defining purpose in Situation Two. These households are indicated by the diagonal shown in **bold** in Table 21. Since fewer than half of all households retained the same defining purpose between their preferred and chosen vehicles (Table 19), we conclude that the choices of households who preferred body style was determined by one of these four trip purposes were less subject to change than were the choices of households whose preferred body style was determined by one of the defining purposes not included in Table 21.

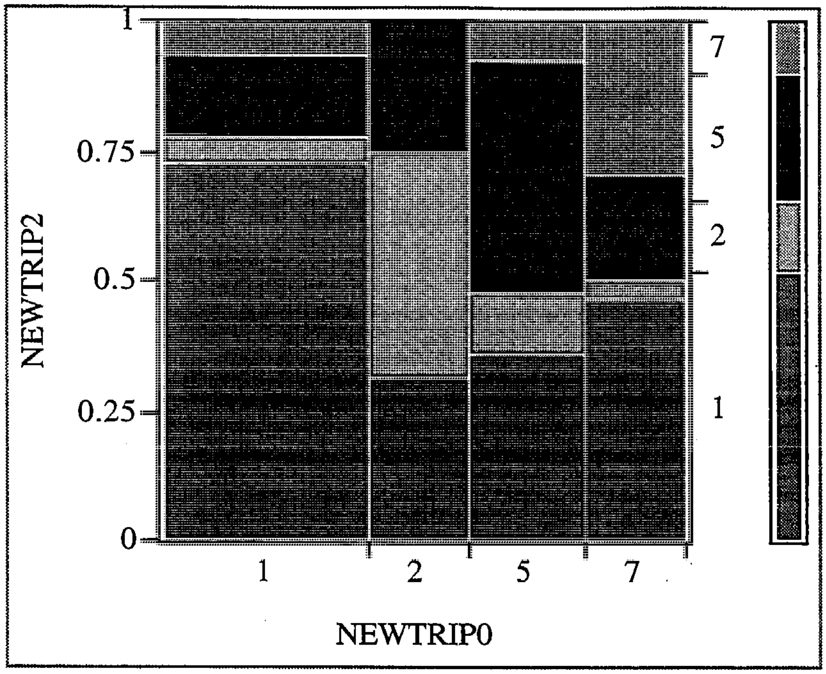
Table 21: Defining purposes for the chosen body style in Situation Two by defining purpose for the preferred body style in Part One

Defining purpose of chosen body style in <u>Situation Two</u> Observed Count	**Defining purpose of preferred body style in <u>Part One</u>** Commute	Chauffeur	Weekend/	Styling	**Total**
Commute	**90**	19	25	27	161
Chauffeur Children	6	**26**	8	2	42
Weekend/Vacation	19	15	**31**	12	77
Styling	8	0	5	**17**	30
	123	60	69	58	310

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	102.153	0.0000
Pearson	116.290	0.0000

Figure 19 shows a mosaic plot of the data in Table 21. Given the defining purpose of the preferred body style, the mosaic plot shows the percentage of households that chose each of the four defining purposes for their chosen body style in Situation Two. For example, nearly three-fourths of the people who state that commuting to work or school (NEWTRIP0 =1) defines their preferred body style retain that defining purpose when choosing a body style in Situation Two. However, fewer than half the people who chose one of the other three defining purposes retain that same defining purpose. In particular, 71 percent of the households for whom the defining purpose of their preferred body style was vehicle styling shifted to some more practical application to define their choice of a body style in Situation Two. Forty-three percent of those households who initially indicate that chauffeuring children and 45 percent of those who indicate weekend and vacation travel are the defining purposes of their likely next new vehicle stay with that choice.

Figure 19: Mosaic Plot of Table 21



Note: NEWTRIPO is the defining purpose of the preferred body style of the household's next new vehicle identified in Part One. NEWTRIP2 is the defining trip of the body style chosen in Situation Two.

Trip codes are the same as in Table 21:
1 = commute
2 = chauffeur children
5 = weekend/vacation
7 = styling

While we show the statistics for the test of independence between the defining purpose of the preferred body style and the chosen body style below Table 21, this hypothesis is of little interest in this case. We *expect* that people will *not* change the defining purpose of their body style choice. Thus we expect to reject the null hypothesis of independence and such a test does little to inform us about the nature of the changes we do observe. Two other hypotheses provide greater insight. The first is a test for *marginal homogeneity*. If Table 21 displays marginal homogeneity, then the defining purposes of the chosen body styles in Situation Two are distributed in the same way as the defining purposes of the preferred body style. Marginal homogeneity implies that the same number of people define their preferred body style by each purpose as define their chosen body style by each purpose. The second hypothesis is a test for *symmetry*. In a symmetrical table, as many households will change *to* a particular defining purpose as change *from* that purpose. The null hypotheses are that *symmetry* and *marginal homogeneity* exist in Table 21.

We reject both these null hypotheses. The marginal distributions (the row and column totals) are significantly different. Across the sub-sample of potential hybrid households whose defining purposes are commuting, chauffeuring children, weekend and vacation travel, or vehicle styling, the distribution of choices of a defining purpose for the vehicles chosen in Situation Two is different from the distribution of defining purposes for the preferred body styles of these households. (Likelihood Ratio Chi-Square = 24.29; degrees of freedom = 3). Also, the transitions between defining purposes are not symmetrical (Likelihood Ratio Chi-Square = 26.72; degrees of freedom = 6).

Simply put, this somewhat arcane statistical discussion tells us we are more than 95% certain the changes we observe in households' defining purposes for their next new vehicles did not occur by chance alone. Faced with a new choice set of vehicles from which to choose, households will change the defining use of their next new vehicle to allow incorporation of a novel vehicle into their vehicle holdings. Table 21 shows a strong shift toward commuting as the defining purpose of the vehicle chosen in Situation Two and a lesser shift to weekend and vacation travel, with a shift away from chauffeuring children and vehicle styling. These changes in defining purpose also define choices of vehicle type. Households that chose any of the electric vehicles were more likely to say the defining purpose of the body style they chose was commuting. A disproportionately large number of households that chose gasoline and natural gas vehicles state that weekend and vacation travel or hauling large loads determined their choice of body style.

The effects of life cycle and income

Household life cycles are typically defined in terms of the number, ages and relationships of people in a household. The "cycles" are intended to capture the effects of: the presence or absence of children; children entering "school years"; children obtaining their own driver's license; children leaving home; and the concomitant aging and retirement of their parents. Income is not an explicit element in most life cycle definitions, never-the-less, life cycles are correlated with income. We adapted the 10-category life cycle measure used by the Nationwide Personal Transportation Survey (NPTS). In our sample, only 6 of the 10 categories have an appreciable number of households in them because of our sampling scheme and the correlation between life cycles, income and vehicle ownership. Our sample contains almost no households of single adults—with or without children—except those in which the oldest child was older than 16 years.

The definitions of the life cycle categories that do appear in our sample are given below.

- C0As = no children at home, two are more adults (not retired)
- C1As = youngest child age 5 or less, two or more adults (not retired)
- C2As = youngest child between the ages of 6 and 15 inclusive, two or more adults (not retired)
- C3As = youngest child aged 16 or older, two or more adults (not retired)
- C3SA = youngest child aged 16 or older, single adult (not retired)
- NCRAs = no children at home, two or more retired adults

Life Cycles and Electric Vehicles

In a previous study (Turrentine, et al 1991), we identified a group of middle-age adults who responded more favorably to EVs than people in other age groups. Based on that conclusion and other results from that study, we speculated that households in the life cycles that contain middle-aged parents with children responded favorably to EVs because they tended to: have higher household incomes; own more vehicles and have more vehicles per driver; have more routine driving patterns; and be more cognizant of fuel savings and life cycle costs. We also surmised they had stronger ties to their communities than households without children. What these conclusions revealed was a complex set of relationships between the market for EVs and household structure. Therefore, we do not expect responses to vehicle types in this study to be a smooth function of progression through a series of life cycle classifications.

Table 22 which shows choices of vehicle type in Situation Two cross-tabulated by life cycle. The cells shown in **bold** indicate those combinations of vehicle type and life cycle that occur more often than we would expect under the hypothesis that vehicle type and life cycle are independent of each other. When we examine Table 22, we see just the sort of complex relationships discussed above. It is impossible to discern any orderly relationship based on age and number of people in the household. Neither can we reject the null hypothesis of independence. It would appear as if life cycle has no systematic impact on differences in the vehicle types chosen by households.

Despite that conclusion, we make a one observation about Table 22. Households with two or more adults younger than retirement age, whether or not they have children (life cycles C0As, C2As, C2As and C3As) were more likely to choose an EV than were households of retirement age adults (NCRAs). This conclusion is clouded by the NPTS life cycle definitions that fail to distinguish between young adults who do not have children and older (but not yet retired) adults who do not have children (if they ever had them) living at home.

If we select the households that belong to the group "C0As" (no children at home, two or more adults younger than retirement age) and look for a relationship between vehicle type and age of the household members, we get the results tabulated in Table 23. (We have grouped all EVs together in one category.) Within this sub-sample of households, the households whose female head is in the age group 56 to 65 years chose EVs more often than expected under the hypothesis of independence. The younger age groups chose natural gas and gasoline vehicles more often than expected. Thus the NPTS life cycle definitions mask some important differences in vehicle choices.

Table 22: Life cycle groups and EV choices in Situation Two

Vehicle Choice Observed Count	**Life cycle** COAs	C1As	C2As	C3As	C3SA	NCRAs	**Total**
Neighborhood EV	4	**6**	1	**5**	0	0	16
Community EV	**13**	2	5	2	1	1	24
Regional EV	38	**24**	**27**	17	1	4	111
Hybrid EV	**21**	**11**	3	6	2	1	44
Gasoline, Reform.	55	25	26	22	**7**	**9**	144
Natural Gas	32	11	15	12	3	**6**	79
Total Count	163	79	77	64	14	21	418

The five life cycle classifications are defined as follows.

- C0As = no children at home, two are more adults (not retired)
- C1As = youngest child age 5 or less, two or more adults (not retired)
- C2As = youngest child between the ages of 6 and 15 inclusive, two or more adults (not retired)
- C3As = youngest child aged 16 or older, two or more adults (not retired)
- C3SA = youngest child aged 16 or older, single adult (not retired)
- NCRAs = no children at home, two or more retired adults

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	30.612	0.2022
Pearson	28.067	0.3048

The number of cells with expected counts less than 5 does not invalidate our conclusion not to reject the null hypothesis.

Table 23: Vehicle Choice by Age of the female head of household for households in life cycle C0As—no children, two or more adults younger than 65 years.

Vehicle Type Choice Observed Count	**Age Category of the Female Head of Household** 18 to 35	36 to 45	46 to 55	56 to 65	**Total**
All EVs	19	9	16	**22**	66
Natural Gas	**12**	**9**	7	3	31
Reformed. Gas	17	5	**20**	6	48
	48	23	43	31	145

Test	**chi-square**	**Prob.>chi-square**
Likelihood Ratio	16.381	0.0118
Pearson	16.914	0.0096

The age *category* of the female and male heads of household are so highly correlated that both are equivalent proxies for the age of the household. The table of vehicle choice by age of male head of household leads to the same conclusions.

These tentative conclusions point to the complexities of identifying market segments for such diverse vehicles as those in this study. In addition to life cycle, income too, appears to have little explanatory power. For example, both the groups from which no household chose a NEV—single, working adult with youngest child older than 16 and retired adults with no children—on average have the lowest incomes. Thus we might conjecture that higher income households are more inclined to buy NEVs than lower income households. Yet households in life cycle C1As (youngest child age 5 or less, two or more), chose NEVs, REVs and HEVs more frequently than we expect (under the hypothesis of independence) and on average had lower incomes than the two adult households with older children (C3As).

Casting further doubt on the role of income on vehicle choices in our sample, we observe that households in category C1As were more likely to choose the relatively expensive regional and hybrid EVs than expected. In fact, we saw in Table 22 that these households were just as likely to have chosen a regional EV as they were to have chosen a reformulated gasoline vehicle. Households with the lowest average incomes—retired adults and single parents with older children—disproportionately chose gasoline vehicles. This could be related to income as gasoline vehicles were slightly cheaper than other types of vehicles, even after purchase incentives for natural gas and electric vehicles. On the other hand, in retired households it may also have to do with conservatism on the part of older consumers. Faced with fixed incomes, they may be less willing to experiment with a new vehicle type. In households of single adults with older children, household members make relatively autonomous decisions about vehicle purchases. Cross-classification of life cycle by decision-making strategies used to choose vehicles in Situation Two shows that one person made the decisions in households with one adult in which the youngest child is older than 16. Thus despite their high *household* vehicle ownership, individuals within these households make autonomous vehicle purchase decisions and may not have the same flexibility to use more than one vehicle as do individuals in households that make cooperative decisions about vehicle purchases and use.

Life cycles, Body Styles and Defining purpose

We do expect there to be a relationship between a households' life cycle and the body style it chooses. We examine here the question of whether the lack of full size body styles for EVs restricts vehicle choices by households in specific life cycles. Cross-classification analysis reveals the choice of body styles, within the broad categories of "EV body style" and "non-EV body style" was independent of life cycles. Therefore, we examine whether the choice of a defining purpose, rather than of a body style per se, was limited by the absence of full-size electric vehicles.

The defining purpose of the vehicle chosen in Situation Two is cross-tabulated by life cycle in Table 24. This table contains only those households that chose one of the six most frequent defining purposes and belong to one of the six largest life cycle groups. Still, there are a large number of sparse cells, so we do not report tests of independence for this table. We explore the relationship between life cycle and the defining purpose through the correspondence analysis shown in Figure 20 and through analysis of sub-sets of Table 24.

Table 24: Defining purpose of selected vehicles by life cycle category in Situation Two

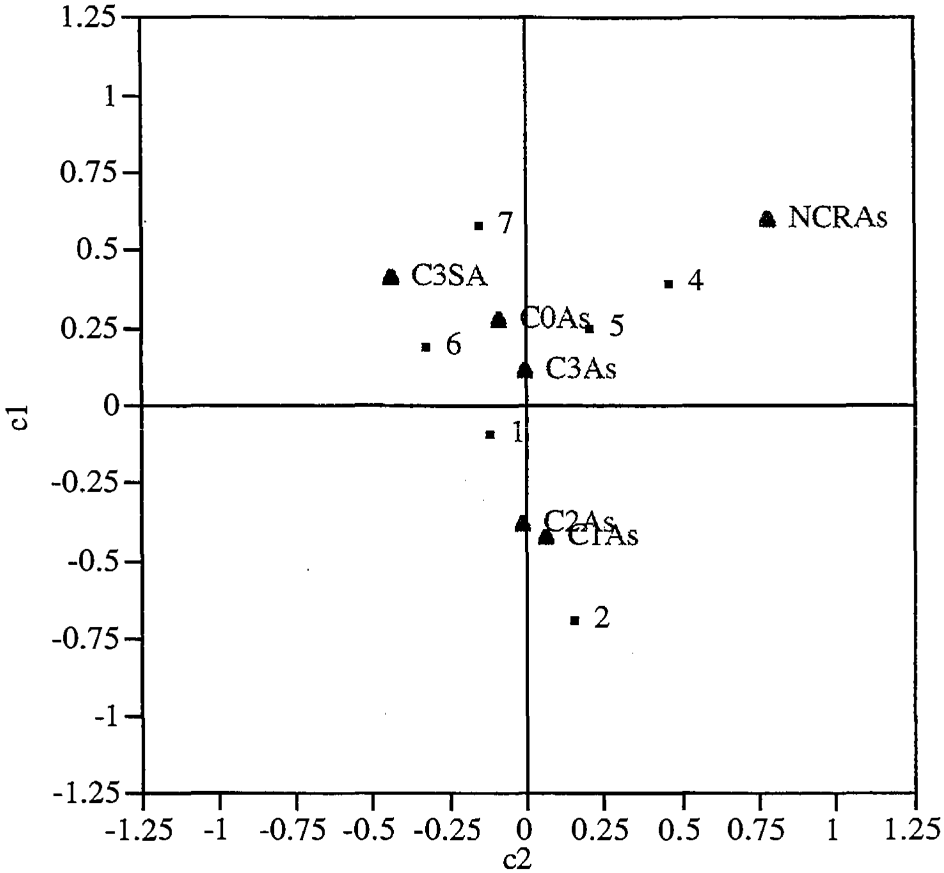
Defining purpose of chosen vehicle type in Situation Two	**Life cycle**						**Total**
Count	C0As	C1As	C2As	C3As	C3SA	NCRAs	
Commute	63	36	38	32	5	2	176
Chauffeur Children	7	18	16	4	0	1	46
Business Errands	5	1	2	4	0	2	14
Weekend/Vacation	37	15	10	13	2	8	85
Haul large loads	9	3	2	2	1	0	17
Vehicle Styling	19	1	3	5	2	2	32
Total	140	74	71	60	10	15	370

The correspondence analysis in Figure 20 shows that households with young children tend to define the use of their next new vehicle chosen in Situation Two differently than do households with older children or no children. Households in which the youngest child is either less than 5 years old, or between the ages of 5 and 16, are more likely to define their next vehicle by its use to chauffeur children than are any other households. Households of retired adults (NCRAs) are distributed differently than all other households. Half of retired households chose a vehicle for weekend and vacation travel. All remaining households are distributed more like each other and less like retired households and households with young children. Though the majority of households with older children and households of adults with no children chose a commute vehicle, they are also the most likely to have chosen vehicles for hauling loads and for the styling of a particular vehicle.

Table 25 shows the distribution of the 275 households who belong to the sub-set of households from Table 24 who satisfy the following conditions:

- they belong to one of the four largest life cycles in our sample; and
- they chose one of the four most frequent defining purposes for the vehicle they chose in Situation Two.

Figure 20: Correspondence analysis of life cycle and trip purpose



Life cycle groups:
C0As = no children, two are more adults (not retired)
C1As = youngest child age 5 or less, two or more adults (not retired)
C2As = youngest child between the ages of 6 and 15 inclusive, two or more adults (not retired)
C3As = youngest child aged 16 or older, two or more adults (not retired)
C3SA = youngest child aged 16 or older, single adult (not retired)
NCRAs = no children, two or more retired adults

Codes for the defining purpose of the body style choices:
1 = commute
2 = chauffeur children
4 = business errands
5 = weekend and vacation
6 = haul large loads
7 = styling

Within this sub-sample, there is a statistically significant relationship between life cycle and defining purpose. While nearly half or more of households in each life cycle chose a commute vehicle, households whose youngest child is 16 or older were most likely to choose a commute vehicle. One-fourth of all households whose youngest child is younger than 16 chose a vehicle for chauffeuring children. Households with no children were the most likely to have chosen a vehicle for weekend and vacation travel and for its styling.