ELECTRIC VEHICLE OWNERS:
Tests of Assumptions and Lessons on Future Behavior from 100 Electric Vehicle Owners in California

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ABSTRACT

This study reports the results of 100 phone interviews with pre-mass market electric vehicle (EV) owners/innovators. The goals of the study are: to characterize current EV owners; to examine their role in the development of an EV market in California; and to learn from their EV use patterns about potential future EV recharging patterns. Taken together these goals allow us to assess the appropriateness of assumptions regarding future EV owners made in past studies of EV markets. The study suggests that EV owners are innovators in the classic sense: they experiment with the use of electric vehicles and promote those vehicles to community leaders and the general public. Further though, there are many entrepreneurs in our study, who are participating in the new EV industry. Our sample of EV owners follow some well known expectations about who will be EV owners -- they are relatively affluent, educated, homeowners. Their use patterns confirm some assumptions of previous studies, but also raise important questions. The households have other gasoline vehicles for long distance travel, and the EV is used primarily for errands and commuting. The range of the EV is sufficient for most travel, although most participants would like more range and more reliable batteries. The desired range depends primarily upon the EV drivers activity space, not prior preferences for gasoline vehicles. Their EVs are recharged primarily at night, but they often recharge their vehicles during the day and often recharge away from home.

INTRODUCTION

Electric vehicles (EVs) are an integral part of plans to reduce motor vehicle emissions. However, because there are few electric vehicles on the road, little is understood about the potential market for electric vehicles, and less is understood about how these cars will be used. The uncertainty about the EV market and potential use patterns of EVs has slowed investment in vehicle development and infrastructure planning.

As we report in greater detail in previous studies, in the absence of actual sales data from an EV market, a number of assumptions have been made about the market potential and probable use patterns of EVs (1,2). Like many new technologies, assumptions have been made which point in two opposite directions, some to a utopian world of clean vehicles and some to market failure. Some past studies of EVs have pointed to a rather sizable potential market for EVs based on the assumptions that in households which own two or more cars, an EV with 50-100 miles driving range could serve most local driving needs (3). EV supporters note polls such as a 1989 Roper survey in which three-fourths of Americans identified themselves as environmentalists. Proponents suggest an electric vehicle market will attract these environmentally conscious buyers. Skeptics disagree. They assume few auto buyers, "green" or otherwise, will accept a limitation such as shorter range, even if they have other vehicles. They further argue consumers will be especially loath to buy such vehicles if they are asked to pay more for them. These skeptics draw their arguments from stated preference surveys in which consumers report they would have to be handsomely rewarded for buying a limited range EV (e.g. 4, 5, 6).

Another common assumption, of particular interest to the electric power utilities, is that EV owners will do their recharging at nighttime, thus utilizing slack off-peak generating capacity. Nighttime recharging would actually reduce the costs of all electricity generation by improving the efficiency of power generation. Based in part on this assumption, one study shows that in Los Angeles alone, a million EVs can be recharged each night, without building new power production facilities (7).

While many utilities have plans to reward nighttime recharging with bargain price electricity, the opportunity value of daytime charging to their customers is still unknown. Further, many of these same utilities are actively promoting daytime recharging through fast charge and opportunity charge infrastructure development. Such infrastructure is meant to encourage sales of EVs, but will also encourage daytime charging. These two factors may combine to create enough additional daytime electricity demand to require new generating capability. Because of the costs involved in building new power plants, it is important to assess the potential for EV users' demand for daytime charging.

This study examines the use and ownership of EVs by an advance contingent of EV pioneers and enthusiasts who have not waited for the major automakers to develop EVs, but instead through their own manufacture and conversion have already built EVs. Although these enthusiasts do not represent all segments of the broad market for automobiles, they nevertheless offer the first glimpse at how EVs will be used. They have important experience with: limited daily ranges; integrating EV and gasoline-vehicle trip planning in a single household; home and opportunity recharging; EV maintenance; and a host of institutional barriers and incentives which gasoline vehicle owners have not experienced. The latter include: the payment of a portion of their transportation costs in their monthly utility bills; opportunity charging at work and at friends; and novel problems in securing vehicle insurance, licenses and registration.

This research is based on phone interviews with a sample of 100 EV owners in California. We asked them about their gasoline vehicles and electric vehicles, their driving patterns and their recharging behavior. We sought to determine how range limits affect EV drivers and how they solved problems associated with range. We sought to examine the assumptions of several previous studies (3,4,5,6,7). The data is drawn primarily from 45 minute phone interviews. Additionally, several EV owners were interviewed in more extensive face-to-face interviews.

Goals of this study

The goals of this study are to find out how current EV owners use and recharge their electric vehicles in concert with the use of their gasoline vehicles. Insights from these users inform us as to likely behaviors of EV owners in the near future. These insights serve as checks on some of the assumptions being made about EVs and EV owners. We acknowledge that the EV owners and vehicles in this study may not be representative of buyers expected in the EV market in California in the late 1990's. Therefore we do not make market penetration estimates based on this analysis.

Current and past modeling of EV markets and use contains almost no behavioral input. Any behavioral content has been based on a series of assumptions about who EV owners are likely to be and how they will use their EVs. One previous study explicitly allowed only renting a gasoline car as an adaptive behavior to owning a limited range EV (10). Yet, for example, results of this survey and our previous research (11) indicate gasoline car rental is seldom chosen to solve any problem with range. Indeed, this study serves as a test of the assumptions incorporated into our own interactive, stated-preference work on consumer perceptions of driving range (11) Further, it is likely that none of the authors of previous research in this area have themselves owned, driven and recharged EVs. This study is a check on the assumptions about EV use and recharging, and on the questions we are asking about future EV markets.

Sample Construction: How Many EV Owners Are In California?

As there is no reliable count of current EV owners in California or the United States, one of our initial challenges was to locate EV owners and estimate how many there are in California. A California Department of Motor Vehicle (DMV) motive power summary reported there were 38,000 electric vehicles registered in California (this probably included some golf carts). This count seemed improbably high to us. Subsequently, we acquired a list of 5000 registered EVs from the California DMV. However, when we began calling , we found no EV owners. We then obtained lists of

EV club members, and began phoning again. This list contained many persons interested in EVs, but again, few actual owners.

We did eventually find 100 EV owners, primarily by the technique of "snowball" sampling. As we found EV owners, we asked them to provide names of other EV owners they knew. Our sample then is non-random, yet it offers several advantages. It reaches beyond any single source and allows us to make inferences about the structure of information flows within the sample. Double checking our list of owners against the DMV list, we found only about 1/3 of our EV owners actually on the DMV list. We surmise the potential error in the DMV list simply overwhelms the small number of actual EVs. The sources of such error are numerable. There is potential for abusing vehicle motive power categories because EVs are exempt from smog fees, so many of those on the list may have gotten their designation illegally. More likely, given the millions of motor vehicles in California, even if the rate of simple data coding errors is tiny, such errors could greatly outnumber actual EVs.

As a result, any estimate of the number of EV owners in California is subject to tremendous uncertainty. We offer an estimate based upon our experience of 500 to 1000 EV owners, less than 0.05% of the autos in California. There may be more EVs in storage and other EVs which were purchased after the last oil crisis in the 1970's but not kept in use. Also, there has been a spate of sales and conversions in the last three years as a result of renewed interest and purchases by governments and utilities. For example, one EV company, Electricar (formerly Solar Electric) reports sales of 104 EVs in 1992. This is more vehicles than they sold in their previous ten years of business. Still, these sales are a drop in a sea of 1,400,000 gasoline vehicles sold annually in California.

SURVEY RESULTS

How To View This Pre-Market Of EV Pioneers.

We do not claim that existing EV owners are representative of buyers of gasoline cars or even that they are representative of the first buyers of

original equipment manufacture (OEM) EVs. But unless those first OEM EVs have radically longer ranges, shorter recharging times, improved acceleration and higher top speeds than the EVs owned by members of our sample, then the day-to-day operating experience of today's EV owners informs us about likely vehicle use behaviors of future EV owners. In this section on EV pioneers, we intentionally adopt a more journalistic, rather than academic, style. In order to best convey an essence of these people, we report much of what they have to say in their own parlance.

Within the diffusion of innovation (DOI) literature and other paradigms of market dynamics, enthusiasts such as our sample of EV owners , are viewed as innovators (12). Innovators act as an advance contingent of experimenters who pave the way for a second wave of opinion leaders. In turn, these influential members of social networks provide information about the innovation and influence the major portion of the population to adopt, or not adopt, the new technology or idea.

So far, this appears to be happening within the EV market. Many of the EV owners we interviewed are actively influencing community leaders to invest in EVs as a way to stop air pollution and dependence upon petroleum. The list of community leaders in California who have joined this advance contingent includes important business leaders such as Disney Corporation's Bill Eisner, and internationally known celebrities such as Leslie Nielson, Alan Alda, Michael Zucker, and Ed Begley, Jr. These celebrities appear in public to promote electric vehicles.

However, the auto market, especially in regards to clean vehicles, is more complex than a simple DOI scenario would suggest. There are moral and revolutionary aspects to EV ownership as well. New air quality legislation involves large corporations, state, national and international legislative bodies in the planning and enactment of a new market. The auto industry is mature and monopolistic; few new auto companies have been able to enter the market place in the last fifty years due in part to tremendous capital demands. And so far, the major auto corporations have been slow to invest in EVs. To them, EVs appear to offer little or nothing in terms of market expansion and even threaten to take away market share

from some of their own models. They do not appear to believe EVs represent an opportunity to develop fundamentally new market segments. Further, the major auto companies would prefer to slow down the pace of development of the EV market because they do not want to bring what they consider to be immature products to market.

In contrast, small EV companies, many started by EV enthusiasts, are working to establish a viable EV market. At least one such company has issued public stock and is building a small factory in Los Angeles. This company hopes to build on the legal mandates for EVs, financed in part by urban development funds. They and others are positioning themselves to take advantage of expertise in the faltering aerospace industry. They believe they can ride the first wave of a green market for motor vehicles.

Thus the EV market so far shows two distinct paths of development, one through legislative demands upon the major auto companies and a second pathway through the efforts of small EV companies to develop intermediate manufacturing methods for the emerging EV market. In this complex market, the role of the EV innovators and opinion leaders is not a simple process of influencing other consumers or facilitating the spread of information about electric vehicles. Many of these EV innovators are not just EV consumers, but are actively working to offer both an alternative vehicle and an alternative distribution system to that of the major automakers.

They claim to have a solution in hand. The title of a new book by a group of enthusiasts is *Why wait for Detroit?* (8). They invite further exploration of lifestyle choices and encourage readers to abandon the oil companies and auto companies. Many EV owners belong to clubs whose main function is to serve as an information location and support service to prospective EV owners. EV entrepreneurs belong to these clubs, and serve as important sources of information, parts and vehicles.

Enthusiasts also cooperate with utilities and environmental groups to demonstrate the possibilities of EVs like the one's they drive. One of the EV owners we interviewed specifically chose the EV as a medium of

information dissemination. He was originally interested in solar powered households. But he switched to EVs because they are a mobile billboard for his transition to a clean, self-sufficient energy source.

EV enthusiasts often present EVs as an adventure in speed, contrary to the "experts" conception of EVs as lower performance vehicles. Speed is conveyed by enthusiasts who run their cars in races and endurance events. The annual Phoenix 500 brings together an eclectic groups of enthusiasts, electric utilities, school engineering departments, and the curious. The race captures the excitement of the Indianapolis 500, not because of the cars or their speeds, which so far are modest, but because of the garage mechanic, do-it-yourself milieu. The technology is new and so the little guy (one of the racing teams is called Little Guy Racing) has a chance.

Recently, an environmental professor from Vermont, Noel Perrin, published a book called *Solo* (9), in which he recounts his crossing the US with a new electric vehicle. He purchased the EV in California and attempted to drive home to Vermont. Anti-climactically, he is forced to tow the vehicle for much of the trip after failing to surmount the 7,239 ft. summit of Donner Pass in California's Sierra Nevada. Rather than a strict informational account or travelogue, the book is written partly as an adventure and partly as an encounter with an unbelieving America, which is not yet convinced of either the seriousness of the negative impacts of gasoline vehicles and the auto lifestyle or the ability of EVs to address these problems.

Thus two elements of this avante guard of EV owners separate it from innovators as presented in DOI studies. First, many of today's EV owners are not just consumers of EVs, they are suppliers too. Second, they believe that gasoline vehicles must go the way of the dinosaur and that the oil companies and big car companies are obstacles -- not conduit -- to the future. Therefore, there is a gospel which goes along with the information -- they are as much interested in beating the odds against the "big guys" as they are in EVs.

Their experiences are framed by their visions. Within our sample there are distinct contingents, with different goals, experiences and lifestyles; but lifestyles which are not wholly unlike those of mainstreet America. Thus they cannot be written off simply as (electric) motor-heads and tree-huggers. Their experiments with EVs and lifestyle are practical. Their behavioral adaptations are mundane. They are not calling for the abolition of personal, private mobility; but rather they seek to demonstrate that subtle alterations in lifestyle can obtain large benefits in environmental quality.

The following is a summary and discussion of details from the interviews. We describe our sample in terms of socio-economic and demographic characteristics. We explore how they use their EVs, including how, where and when they recharge. We delve into their motivations for using an EV, both for any particular trip and as a general, lifestyle choice. We report actual numbers of responses rather than percentages. But actual numbers usually approximate percentages because the sample size was 100.

Who are these EV owners?

Our sample is older and wealthier than the average population of drivers. Mean age of our respondents is 53. Twenty-one are retired. The median income category is $40,000-60,000. Eighty-two own their own home. They are highly educated: 20 have post-graduate education, 30 have college degrees. Twenty-five are engineers, 6 are in computer operations. Eighty-seven said they were handy with cars in a way which made them particularly suited to owning and using an EV.

How did they get involved with EVs?

As we mentioned before, we obtained an initial list of EV enthusiasts from EV club member lists, especially the Electric Auto Association (EAA), which has headquarters in Santa Clara, California and a network of affiliated clubs nationwide. Club members participate in rallies and public demonstrations of EVs to promote EVs as an alternative to gasoline

vehicles. Additionally, the EAA members have a network of EV conversion services and products. Many of the EV owners in this study came into contact with the EAA at public rallies and through friends. Others became involved with EVs through reading about them in environmental energy publications and popular magazines.

By using snowball sampling, we go beyond the EAA member list to other clubs, conversion shops, and autonomous buyers and builders. Many of the EV owners built their own vehicles. Some built them from the ground up; some converted a steel framed gasoline vehicle; and some had conversion shops do the job. Still others purchased a used conversion or factory built EV (most of which were built a decade ago).

For many EV owners in this study, their involvement with EVs cannot be viewed strictly as "consumerism" but rather as a "hobby", with a strong dose of interest in environmental and energy politics. Skeptics of EVs might imagine they are fanatics, but a more accurate word is enthusiast. They do go to a lot of trouble to get an EV, in the absence of OEM vehicles; they provide many of their own services; and rely upon a small community of other enthusiasts, much as do owners of classic or vintage automobiles.

Unlike other critics of the automobile, they are not critics of automobile culture. They do not wish to discard the automobile, they wish merely to substitute clean, efficient vehicles for gasoline vehicles. In this sense, they are reformers, not revolutionaries. Many are far more rational, in an economic sense, than most consumers. They keep records of costs, are budget conscious and know the costs of their EV projects.

What are their EVs like?

The time which our interviewees had owned an EV was often short, an indication of the recent upturn in interest. Of the 100 EV owners, 25 had owned their EV for only one year, 50 for less than three years, 75 for 6 years or less. Their cars are all conversions or kit cars. Fifty-four respondents owned steel frame conversions, 31 owned manufactured EVs, and 7 owned fiberglass kit cars. Most of the EVs are small vehicles, with

a few large vans and trucks. Fifty-four of the EVs are compacts, 10 are sports cars, 12 are vans or trucks, 9 are full size cars, and 3 are micro cars. Fifty-eight have two seats, 39 have four or more seats.

Lead-acid batteries are the only media of energy storage. 82 battery packs are made up of 6 volt batteries, 13 use 12 volt batteries. These batteries are used in multiples to create total battery packs of varying voltages. Thirteen vehicles had total packs under 48 volts, 24 were between 48 and 89 volts, 60 were 90 volts or above. The single most common battery/motor system (34 vehicles) is a 96 volt battery pack matched to a 20 horsepower motor -- a standard conversion kit offered through the EAA. Seventy vehicles retained a transmission and clutch.

Performance and range

The median top speed of the vehicles is 60 mph, and 59 owners reported that their vehicles had sufficient acceleration for freeway merging. Quantiles and moments of the distribution of driving ranges during steady, 35 mph cruising are shown in Table 1. The median range of the vehicles at a 35 mph steady cruise with new batteries is 50 miles For vehicles capable of freeway speeds, the moments and quantiles of the distribution of steady freeway speed cruising range are given in Table 2. At steady, freeway speeds, the median range with a new battery pack is 40 miles.

Table 1: Quantiles and Moments of the Distribution of Steady-Cruise, 35 mph Driving Ranges, Miles

Quantiles		Miles
maximum	100.0%	120
	90.0%	80
upper quartile	75.0%	65
median	50.0%	50
lower quartile	25.0%	40
	10.0%	22
minimum	0.0%	11
Moments		
Mean		52.3
Std Dev		21.9
N		92

Table 2: Quantiles and Moments of the Distribution of Steady Freeway Cruising Driving Ranges, Miles

Quantiles		Miles
maximum	100.0%	80
	90.0%	56
upper quartile	75.0%	50
median	50.0%	40
lower quartile	25.0%	25
	10.0%	15
minimum	0.0%	10
Moments		
Mean		37.2
Std Dev		17.0
N		55

How much do they drive the car?

The amount the electric vehicle is used varies greatly between owners. A very dedicated group, the highest quartile, uses their vehicle 82% or more of the time. The median use of the EV is for (coincidentally) 50% of the interviewee's driving. On average though, the EV is driven many fewer miles per year (3,983 miles) than is the gasoline vehicle (12,000 miles). The mileage driven in the gasoline vehicle is typically due to the respondent and at least one other driver in the household. A few very high mileage households skew both the EV and gasoline vehicle means upward, but the difference in median annual driving distance between the EV (3,000 miles) and the gasoline vehicle (8,000 miles) is still large. Still, some EV owners drive many miles each year. Those in the top 25 percent drive their EV 6,000 or more miles per year.

Vehicles with total system voltages of 96 or greater are driven an average of 4,400 miles per year. This is significantly (α < 0.10) greater than the average 2,900 miles per year driven in vehicles with system voltages less than 96. All else being equal, higher system voltage increases vehicle top speed. Thus EVs which can be driven faster are also, on average, driven farther. Also, the total number of reported miles driven per year in the electric vehicle is a function of the reported

percent of time the EV is used. The more frequently the EV is driven, the more miles it accumulates. This result is not surprising, though its absence would have been.

Use of the household's gasoline vehicle is largely independent of EV use. Total miles traveled per year in the gasoline vehicle is not related to: percentage of EV use; total miles driven in the EV; or total EV system voltage. Simple linear regressions of gasoline vehicle miles onto EV miles and proportion of EV driving yield non-significant results. Also the difference in average miles traveled per year in the gasoline vehicle is not statistically significant between owners of EVs with less than 96 volt systems and those with 96 volt or greater systems.

These results indicate that characteristics of the EV determine EV travel, but do not affect the household's total use of their gasoline car. Households which put relatively few miles on their EV do not necessarily put more or less miles on their gasoline car than households which put many miles on their EV. This is consistent with the hypothesis that EVs fill a specific proportion of the households activity space, a point to which we will return in the section on lifestyles and use environments.

Our sample of EV owners typically chooses to use their EV for a particular trip for a combination of practical and symbolic reasons. Reasons for choosing the EV or the gasoline vehicle are shown in Table 3. The most important reasons to use the EV for any particular trip include: to help the environment and to save on gas. The choice of the gasoline car is dominated by the need to travel out of EV range or carry passengers or cargo. Only a few trips are ever taken in the gasoline car because the EV is not sufficiently charged.

Table 4 shows differences in the types of trips for which EVs and gasoline vehicles are chosen. Commutes to work, local errands, leisure and shopping trips tend to be made in the EV. Only vacation travel is overwhelmingly assigned to the gasoline vehicle.

Table 3: Reasons to Choose a Vehicle for a Particular Trip

Electric Vehicle	Number
To help the environment	61
To save on gasoline	31
Because it is fun to drive	26
Because it is quiet	15
To show EV to other people	15
Because it is my favorite car	8
Gasoline Vehicle	
Trip is out of EV range	73
To carry more cargo	20
For added power	17
To carry more passengers	15
Because EV was not charged	9

Note: Answers for each vehicle type sum to more than 100 because multiple answers are allowed.

Table 4: Trip Type by Vehicle Type

Trip Type	Electric Vehicle	Gasoline Vehicle
Personal Errands	80	17
Leisure	53	29
EV rallies	50	0
Commute to Work	41	15
Travel for Business	35	27
Shopping	40	11
Vacation Travel	0	60

Note: Answers for each vehicle type sum to more than 100 because multiple answers are allowed.

Lifestyle and use environment

We asked if the EV owners believed they had to adjust their lifestyle or the location of common activities to accommodate owning an EV. Fifty-nine owners said they made no adjustments, 36 indicated they had made some changes. The most often mentioned change was the need to plan

which vehicle to use for certain days or certain trips. For ten people this involved an active decision process; for eleven others it involved a simple trip-by-trip decision rule -- if the trip is within the EV range, the EV is used. Four owners indicated driving the EV had changed their driving habits. They drove more slowly and constantly monitored their energy use. Four others said that they now shopped closer to home or planned shopping trips to stores or malls with outlets at which they could recharge. Lastly, not all lifestyle changes are regarded as negative or as additional planning tasks. Six EV owners indicated that the lifestyle changes were positive. One of these stated that in fact he had built his EV to match his lifestyle.

The mundane nature of these changes is one explanation why EV performance and range characteristics do not affect gasoline vehicle use. For most EV owners, their activity space appears to be disjointed. The part of their activity space which can be accessed by the EV, is; activities outside the EV range are accessed by the gasoline vehicle. Since EV and gasoline vehicle travel are independent, activities within the range of the EV are independent of activities outside the EV range. And among those who now plan activities, over half plan activity access with a rule which reinforces this conclusion -- the simple "if in range, use EV" rule. Recall too from Table 3 that the single most frequent reason for choosing the gasoline vehicle for a particular trip is because it is out of EV range.

The limited lifestyle changes required to adapt to EVs is reflected in the owners perceptions of their communities. Overwhelmingly, EV owners judged their communities to be convenient use environments for EVs. 84 said their community was convenient and only 10 said their community was not convenient for EVs. 33 of the 84 stated that the topography of their community was suitable to EVs and 26 others said the close proximity their workplace and stores made their communities a convenient place to use their EVs.

How the vehicle is recharged

Forty-eight owners said their vehicles have an on-board charger, 8 others indicated the charger was portable and could either be carried on-board

the vehicle or left behind. Sixty-seven of the chargers incorporated an automatic shutoff feature at the end of the recharging cycle. Fifty-eight of the vehicles recharge on 110 volt circuits, 18 charge on 220 volts, 23 owners charge at either 110 or 220 volts, or at some other, unspecified voltage. Seventy-one respondents had modified the wiring in their house to accommodate recharging their EV. However, all but 16 of these reported zero costs for the changes. Of the sixteen who reported a non-zero cost, the median cost was $20, the high cost was $200.

The majority of EV owners strive to prevent deep discharges of their batteries. 72 respondents "top-off" the battery pack all the time. That is, they recharge the vehicle at every available opportunity, whether the trip ends at, or away from, home. 12 do not "top-off" and 14 do sometimes, but not always. Among the reasons to top off: 38 owners said it is good for the batteries; 23 top-off to maximize driving range; and 7 owners said they top-off because it is easy to do. Topping-off appears to be a frequent adaptation to extend both driving range and the life of expensive batteries.

Opportunity recharging

We define opportunity recharging as any recharging done away from home. Approximately half of our sample of EV owners regularly recharge their vehicles at an away-from-home location. Sixteen recharge at friends or family; eighteen at work; seventeen at other locations. The median length of time of this opportunity recharge was three hours. The median distance from home of the recharging site is fifteen miles. Only three people said they had ever paid for an opportunity charge.

We asked respondents to report on specific trips made in their EV during the week prior to the interview. Of the 82 reported trips, the EV was recharged after 57. 51 of those 57 trips were made in EVs which had on-board or portable chargers. 40 of these 51 trips involved recharging at an away-from-home location. That is, among the reported trips made in a vehicle which could be recharged away-from-home, 78 percent of those trips involved away-from-home recharging.

Distance to this regular opportunity recharge location from home is positively correlated with increased vehcile range. Simply put, vehicles which can be driven farther, are. The distance to this regular away-from-home recharging site is one measure of the spatial dimension of the EV owners activity space. Given the modest lifestyle changes reported by EV owners, we know residence, work and shopping locations are not changed to accommodate the EV range. Rather, people purchased or built an EV with sufficient driving range to allow them to access their activity space.

Costs

Fifty-nine owners said they kept track of cost comparisons between their electric and gasoline vehicles. Twenty respondents compared gasoline and electricity costs, 14 kept track of maintenance costs. The median cost per mile for recharging our sample of EVs was 4 cents. In spite of the fact that many of them keep records of costs, not enough EV owners could provide enough details for us to construct any definitive statements as to whether their EVs are more or less expensive than their gasoline vehicles on a life-cycle basis.

For consumers and EV researchers attempting to assess the viability of EVs, battery replacement is one of the major unknown components of the life-cycle costs of battery electric vehicles. This cost is driven both by battery price and frequency of replacement. Within our sample, all which use lead-acid batteries, the median replacement frequency is 3 years. 4 people replace their vehicles batteries every year; 25 people replace the batteries every 2 to 3 years; 20 people replace them every 3-5 years; and 11 people replace their batteries only every 5-7 years. The average cost of replacing the battery pack for vehicles of less than 96 volts is $627. The average cost of battery packs of 96 volts or greater is $819. The difference is statistically significant ($\alpha = 0.05$). Additionally, most of the reported EV maintenance problems, which contribute to increased costs, are related to the batteries. 35 owners reported problems with maintaining water levels, terminals and general battery condition.

Battery leasing has been suggested as one means to offset the uncertainty of battery replacement costs and the high purchase price of EVs. 50 owners said they would be interested in leasing batteries. For those owners who provided enough data to estimate both battery replacement costs and an "interested in leasing" price, their lease prices are very close to the prices they are already paying to replace batteries. The median price they said they would be willing to pay per year to lease batteries is $180 dollars, their median expected annual battery replacement cost is $198.

Lifecycle costs are also affected by fees and taxes. 13 owners reported receiving some tax advantages because of their EV purchase. 73 percent said their vehicles are registered as an EV, and thus are exempt from smog inspections. This saves them both the cost and inconvenience of smog inspections.

Are Today's EV Owners Likely to Purchase OEM EVs in the Future?

We are interested in how this early group of EV owners might relate to the coming mass market for EVs. Are they in fact an advance guard of this market? We speculated that, given their hobbyist approach toward EVs, existing owners would not express a desire for mass manufactured EVs. Yet 60 respondents said they would buy a mass produced EV; only 19 said they would not. We did not expect this relationship, thus it deserves further investigation. We do find interesting correspondence between these EV owners and the EV target market characteristics we found in previous research (11,12). Based on this study and our previous work, we are becoming convinced that a household's activity space is the primary determinant of purchase intentions. The activity space is defined by the household's choice of activities, timing of those activities, their location, mode of access and the linkages to other activities and other household members. The EV owners in this sample provide evidence regarding the importance of activity space which corroborates our findings in our interactive stated-preference experiments (PIREG) (11,12).

We analyzed the effects of activity space, personal motivations and socio-demographic characteristics of EV owners on their response to the question of whether they would buy a mass produced EV at a price equal to a comparable gasoline vehicle. Based on initial bivariate analyses we chose the following explanatory variables:

Size of activity space -- distance to away-from-home recharging site;
Distribution of activity location in the activity space -- convenience of community to EVs, EV trip purposes;
Motivations for driving an EV -- to save gas, because EV is fun, to protect environment.

The following constructs were also tested, but showed no statistically significant relationship to the dependent variable:

Years respondent had owned EVs;
Top speed of existing EV;
Range of existing EV;
Reasons they drove an EV rather than a gasoline vehicle --
EV is their favorite car, Other cars in household in use, EV is quiet;
Types of trips made in the EV --
Commute, Leisure, Travel for work, Shopping;
Characteristics of Respondent --
Handy, Age, Education, Income, Own or rent residence; and Miles driven per year in EV.

We estimate a log-linear model which includes the following explanatory variables: three reasons to drive an EV rather than a gasoline vehicle; two trip purposes for which the EV is used; and the assessment of whether the respondent's home community is a convenient place to own an EV. Parameter estimates are shown in Table 5. The model explains about 32 percent of the variation in choice whether to buy a mass produced EV. (Note that models of categorical dependent variables rarely exhibit high R-square values -- the 0.32 value is quite acceptable.) The model correctly predicts 84 percent of responses.