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# CLEAN AIR FOREVER? A LONGITUDINAL ANALYSIS OF OPINIONS ABOUT AIR POLLUTION AND ELECTRIC VEHICLES

by

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and  
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## Abstract

Many current initiatives to develop the electric vehicle depend upon public perception that electric vehicles (EVs) are good for the environment. This study investigates how people acquire information about the environment and EVs, and whether their opinions about environmental efficacy change over time and experience levels. These issues are explored across two data sets. The first data set is a panel survey of California households (n=1718) and environmental opinions are tracked over two waves of survey. A decline in the environmental ethos is associated with several factors, including interpersonal communications and exposure to more specialized media. A sample of households from the panel study were subsequently chosen, among others, to participate in a two-week long trial of EVs (n=69). Opinions about environmental efficacy are studied as users gain first hand knowledge of an EV. Opinions about the environmental efficacy of the EV show improvement, but trial users become less likely to cite the environmental benefit as a reason for choosing the technology, and they do not change their opinions about providing policy incentives.

## INTRODUCTION

An issue posed by battery electric vehicles (EVs) being developed for the personal (household) vehicle market is that the regulatory process, in addition to the market forces, is being utilised to realise the highly valued goal of clean air. The environmental objective is being pursued by mandated technological progress and institutional developments that might one day increase the range of EVs and possibly eliminate the need for lengthy overnight recharging. Until then, EV demand largely depends upon consumers adopting a new ethic towards range and refuelling opportunities in response to a common good.

This paper seeks to contribute to the body of knowledge through an analysis of two sets of data collected from the same respondents. The first is a panel survey of California households conducted as part of a alternative-fuel vehicle demand forecasting study. These data allows us to examine attitudes towards the environment and EVs at two points in time, 1993 and 1994. In the second dataset, a small subsample of the panel respondents were selected for participation in a trial of a pre-production EV. This latter dataset introduces the dimension of actual experience with the technology. These two related datasets allow us to explore and contrast:

1. changes in environmental attitudes towards electric vehicles over time in the general population, with
2. changes in environmental attitudes amongst highly-involved EV users.

We begin with a general consideration of issues raised by the promotion of environmental benefits through transportation policies and the questions that this poses for transportation analysts. We then review literature related to understanding potential demand for EVs. The results presented from our analysis are then discussed in the context of consumer perceptions of transportation and the environment.

## ELECTRIC VEHICLES AND ENVIRONMENTAL BENEFIT

Environmental benefits appear, almost by definition, to be synonymous with EVs. Other potential benefits of the technology, such as a quiet motor or low maintenance costs are typically secondary considerations. The term 'zero emission' which is used in both legislation and by the press, reinforces the expectation that EVs are good for the environment.

The advocacy of EVs on environmental grounds has tended to be distinct from the consideration of other vehicular characteristics like range between refuelling and energy source, but these are interrelated. For example, with overnight recharging, EVs cannot be driven as far as gasoline vehicles can, but there are indications that households with more than one vehicle would still want to use the vehicles for many local trips (Golob, *et al.*, 1997; Kurani *et al.*, 1996; Nesbitt, *et al.*, 1992). In a hypothetical two-vehicle household with one EV and one conventional gasoline (or diesel) vehicle, households might increase use of their gasoline vehicle for longer trips, thus increasing demand for petroleum. On the other hand, the household might switch some short trips from the gasoline vehicle to the EV for reasons related to potentially lower operating cost and perceived environmental benefits. Use of an EV for short trips could bring significant environmental benefit, since it is well known that higher vehicle emissions are associated with gasoline vehicle cold starts, due to the inefficiency of current emissions control systems when operating with cold catalysts and rich fuel-air mixtures (Ross, 1994).

EV environmental factors are also related to concerns about energy use and petroleum source, although these concerns are often subordinate to vehicle emissions. In a gasoline vehicle, the overall vehicle energy conversion efficiency is estimated to be between 15% and 20%. EVs exhibit similar efficiency when the electric generation facility is included (Kreith, *et al.*, 1995). Gasoline, unlike other fuels, has a high energy density so that it is easy to store for long distance transport, and technology for relatively safe and easy handling is well developed. Greene (1994) notes that these favourable characteristics of gasoline have tended to be inherent barriers to the growth of EVs and alternative fuels, such as compressed natural gas. Some of the proposed environmental goals of the electric vehicle might be reached through advancements in conventional automotive technology instead. Ferris and Wiederkehr (1995) and DeCisso and Ross (1996) discuss near-term advancements in gasoline vehicles that may offer opportunities for reducing motor fuel consumption and greenhouse gas emissions.

In the early 1970's there was a surge of interest in EVs, in response to the energy crisis and concerns about national oil dependency. The environmental benefit of EV technology was later rediscovered as a key dimension with the passage of the 1977 Clean Air Act amendments and related legislation. At that time the Environmental Protection Agency (EPA) set standards for six major pollutants: ozone (O<sub>3</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), lead (Pb), suspended particulates, and sulphur dioxide (SO<sub>2</sub>). Observers believe that regulation helped to reduce vehicle emissions by 80 to 90% from pre-control levels, and car fuel economy standards more than doubled (Deakin, 1990). Still, a number of urban areas could not meet

the federal air-quality standards, and in California, this spurred a new interest in clean fuels.

In 1990, the California Air Resources Board (CARB) adopted a ZEV mandate as part of a comprehensive low emissions vehicle (LEV) program. This required that 2% of all new light-duty vehicles sold in the state by the largest auto manufacturers be ZEVs, increasing to 5% in 2001 and 10 % in 2003 (light-duty vehicles being defined as cars, pickup trucks, vans and sport utility vehicles). Only battery (pure) electric EVs meet the ZEV definition at the current state of on-road technology. The original California regulations were endorsed by twelve north-eastern states and the District of Columbia. In 1996, CARB reached an compromise agreement with auto manufacturers and rescinded the mandated sales levels for the first two years, 1998 and 2001. In return, auto manufacturers have agreed to test market EVs for demonstration and development purposes and to market California-style LEVs throughout the U.S. by 2001, three years earlier than mandated by the 1990 Clean Air Act. As of June 1997, the 2003 mandated ZEV sales level still stands in California, and the California-style mandates adopted in states such as Massachusetts and New York are currently under reconsideration.

Although EVs have zero-emissions at the tailpipe there is considerable discussion about their other environmental impacts. Discussion takes place across four main issues: (1) comparative impacts with gasoline emissions (2) environmental impact of electrical generation (3) life-cycle emissions and (4) environment and noise. The last issue is not particularly controversial, since there is general agreement that EVs are quieter than gasoline vehicles. However, this is not of unequivocal benefit, since pedestrians and drivers may rely upon audio cues for information about oncoming vehicles.

Emissions from mobile sources and electric generation have been reported more extensively, and studies of air quality assessments have been made by Sperling and Deluchi (1989), Wang and Santini (1993), Wang, *et al.* (1990), and synthesised in reports by Kreith, *et al.* (1995) and Michaelis (1995). When compared with gasoline vehicles on a per-mile basis, EVs using the current (U.S.) electric generating fuel-mix, would appear to reduce emissions from hydrocarbons (HC) and carbon monoxide (CO) by almost 100% (Kreith, *et al.*, 1995; Wang, *et al.*, 1990). This benefit in favour of EVs is reinforced if the analyses take in the total emissions costs of gasoline production and distribution (DeLuchi, 1993).

Today, transport accounts for nearly 90% of total emissions of CO and between 40 and 50% of HC are thought to be transport related (Table 1) (also, Barde and Button, 1990). CO is associated with severe health problems and can also indirectly contribute to "greenhouse gases" and the threat of global warming. HC together

with exhaust emissions of nitrogen oxides (NO<sub>x</sub>), are known to be the principal causes of urban smog and ozone pollution. Currently the transport sector produces only about one-half of the emissions of nitrogen oxides, but new demand for electricity could lead to an increase in this emission (NO<sub>x</sub>), and in emissions of Sulphur Oxides (SO<sub>x</sub>).

Table 1: Percentage of Emissions Attributable to Various End Use Sectors

Sector	Nitrogen Oxide (NO <sub>x</sub> )	Carbon Monoxide (CO)	Carbon dioxide (CO <sub>2</sub> )	Sulphur Dioxide (SO <sub>2</sub> )
Transport	54%	89	28	6
Industry	22	1	34	65
Other	24	10	38	29

Source: OECD and International Energy Association. US GAO (1994).

Estimates of both mobile source emissions and stationery (power plant) emissions depend upon the fuel sources. If vehicles are powered by fuels like compressed natural gas, or reformulated gasoline, there are some reductions in certain types of pollutants, but increases in others. For example, compressed natural gas slightly increases the level of NO<sub>x</sub> but there are large reductions in carbon monoxide. In the case of power generation sources, emissions of NO<sub>x</sub> and SO<sub>x</sub> are improved (they are lower), but only when fuels like hydroelectric power or nuclear energy are used. Sperling and Deluchi (1989) (see also Kurani *et al.*, 1996) consider the net difference from mobile source and electric generation pollution. They conclude that, regardless of the feedstock used, the large decrease in HC, CO, and NO<sub>x</sub> from vehicles would have a greater impact on ambient air quality than a moderate increase in SO<sub>x</sub> emissions from new electricity production. However, the impact on greenhouse gas emissions is more sensitive to the electricity feedstock, and, using 1985 as a baseline year, they estimate that on a per mile basis, the quantity of greenhouse gases would be about the same as that emitted (in 1985) by vehicles.

The third issue, life cycle emission costs, has also received only some attention. Deluchi, *et al.* (1989) has noted that chemicals used in the manufacture of EV batteries could have an environmental impact on local solid waste disposal and water quality levels. Wide scale disposal of lead acid and nickel-cadmium batteries is a related concern, since recycling may increase soil and water contamination. Environmental hazards from disposal of lead-acid batteries are discussed by Lave, *et al.* (1995) and Lave, *et al.* (1996), but Socolow (1995) points out that Lave *et al.*

fail to compare the EV lead problem within the context of the 100 million lead-acid ignition batteries to be found in today's internal combustion vehicles, and Sperling (1995) points out that EV technology is advancing beyond lead-acid batteries to new battery technologies and even to other electricity storage devices such as flywheels and fuel cells.

The life-cycle costs of alternative fuels are a further consideration. Increased electrical energy is needed to compress natural gas and there are new waste disposal issues from a higher demand for power from nuclear energy. In some areas like California, much of the electrical power generation takes place at a geographical distance from urban areas with pollution. This factor, and the ability to 'scrub' emissions at a single point, underpin assertions that stationery source emissions be contained more effectively than mobile source ones.

The issue of EV versus gasoline vehicle emissions is scientifically complex, and the outcomes are highly dependent upon assumptions made about how and where electricity is generated, as well as normative expectations of gasoline vehicle use. Most consumers probably know very little about the detail, and are unlikely to care much about it either. From a research perspective, it is interesting to examine what types of questions have been put to consumers about EVs and environmental choices.

## **CONSUMER MARKET STUDIES**

Despite the legislative intent of The California Air Resources Board, there does not appear to be an outpouring of consumer interest for this environmental policy. Marketing studies in the US have shown that consumers are sceptical of many products promoted with environmental claims (Roberts, 1996) and they are often unlikely to pay a premium for 'green' products (Pearce, 1990). On the other hand, there is a growing environmental awareness and ethos (Kempton et al, 1995) and the development of social values and public opinion is not a short-term process.

Consumers studies involving EVs and environmental benefits can be grouped into three main types, with the general caveat that many projects involve a combination of all three methods: attitudinal surveys, experiments or quasi-experiments, and consumer preference studies.



Attitudinal surveys, like one by Kirchman (1993) have been undertaken for diverse reasons, like assessing customer response to new utility demonstrations, or establishing possible market segments. These studies cannot easily be generalised because they are based on cross-sectional surveys, and the issue of environment is a 'social good' so 'top-of-the-mind' responses tend to be very favourable. While a good research design can address these, the most problematic issue is that many people have no familiarity with the technology, and do not have a basis for understanding the questions.

Experimental and quasi-experimental studies are more helpful in this regard. Shortly after the CARB legislation, Turrentine *et al* (1992) sampled 236 drivers, who participated in alternative fuel vehicle test- drives. They measured opinions using several methods including pre- and post test surveys, focus groups, and structured interviews. It was found that people who belonged to environmental organisations (e.g. Greenpeace) did not express higher purchase intentions for clean fuel vehicles. However, a strong relationship was found between clean fuel purchase intentions and the idea of "moral choosing." "Moral choosers" tended to be younger, and chose the EV over other clean fuels. In this same research, focus groups were also used. They helped to pinpoint a 'social response' dimension. Drivers voiced the opinion that there could be no personal responsibility for vehicular air pollution as long as they saw worse violators than themselves. As a prerequisite for accepting personal responsibility, drivers wanted flagrant violators to be dealt with first.

In an extension of this research with a new sample, Turrentine and Kurani (1995) discuss environmental implications. Although there was little evidence that car buyers would pay more for an environmental vehicle, they believed that longer term support for environmental issues was increasing. For example, there is a latent negative perception about the smell and toxicity of gasoline. They suggest that over time, it could become a stigmatised smell, like tobacco. More recent published results suggest that environmental awareness may not itself lead to choice of an EV, but that environmental factors will play a role in the future search for new vehicles (Kurani *et al*, 1996).

Another quasi-experimental study, by Urban *et al* (1996), used a different technique. A multimedia workshop was used to virtually simulate information available to a consumer making a new vehicle purchase. Unfortunately, sampling was based on several preconditions, and one was that respondents accepted the idea of an environmentally friendly vehicle. During the multimedia workshop (called an information accelerator), respondents had opportunities to learn more about EVs, and hear or read about their environmental impact. Concerns about the environment were the lowest rated issue, based on a perceptual rating of eight different scales:

EV construction, quality, value, appearance, safety, performance, comfort, cargo space, and environment. This result, and other data, supported the conclusion that consumers did not want to give up other car attributes to get environmental benefits, although they did perceive them to be moderately important.

Preference studies are another technique that have been used to explore the association between EVs and environmental values. These studies typically use closely-related methods such as conjoint analysis, stated preference modelling and stated choice modelling. Although they attempt to describe the technology in some depth, one criticism, at large, is that consumers do not have preferences about technologies they have not directly experienced (Greene, 1985 and Kurani *et al.*, 1996). Greene (1985) suggests that these studies should be best interpreted qualitatively as indicating what is, and is not a priority to consumers.

Several studies have looked at the market for EVs as a distinct market segment. Beggs and Cardell (1980) and Beggs, *et al.* (1981) studied the potential demand for EVs by applying discrete choice models to stated preference (SP) data in which individuals provided rank orderings for hypothetical vehicle descriptions. Reanalysing data collected in an earlier study (Morton, 1978), Beggs and Cardell concluded that consumers are sensitive to limited vehicle range, but there was an unexplained preference for EVs. In contrast, Nesbitt, *et al.* (1992) conclude that reducing EV cost is more important than increasing driving range in attempting to increase potential market share, because households may have to adapt their driving patterns to the characteristics of EVs. In another early study, Hensher (1982) calculated demand elasticities for EVs in terms of operating cost, purchase price, and the range of the EV. His results indicate that higher future gasoline prices could be an important factor in EV demand.

Calfee (1985) studied the potential demand for EVs as small cars, where the vehicles are described in terms of price, operating cost, capacity in adult passengers, EV range and top speed. Calfee also estimates a positive coefficient for the EV dummy variable, which he interprets to mean that respondents "tended to choose electric cars even when, according to their own revealed evaluations of attributes, the conventional car was more desirable." He attributes possible reasons for a positive choice-specific dummy variable for EVs to: (1) an environmental factor, (2) worry about future gasoline price and availability, or (3) a bias toward the new and, perhaps, trendy technology.

Bunch *et al.* (1993) and Golob, *et al.* (1993) employ multinomial logit models applied to SP vehicle-choice data for a large sample of households in California. The vehicle attributes manipulated in the SP experimental design include purchase price, fuel cost, range, fuel availability, performance and vehicle emissions. They

conclude that consumers would be willing to pay more for vehicles with reduced emission levels, *ceteris paribus*, perhaps on average as much as \$9,000 for reductions of up to 90%. These data were used by Fulton (1994) to develop forecasting models for EVs and alternative-fuel vehicles.

Segal (1995) used conjoint analysis as a forecasting methodology and identifies the dominance of purchase price and re-charging convenience as being the only factors for the prediction of market share; emissions reduction is not included as an attribute, as it is in most other preference studies. Segal concludes that the necessary educational and promotional effort needed to create an EV market is probably beyond the resources of either the utility or auto industry.

Finally, Brownstone, *et al.* (1996) developed a model of vehicle transactions choice based on SP data conditional on current household vehicle holdings. They found that emissions reduction was valued more highly by households with children than by households without children. Their results indicate the highest premium for reduction in emissions is likely to be paid by two-vehicle households with children under 21 years of age. Bunch *et al.* (1996) developed a microsimulation forecasting model for EVs and alternative-fuel vehicles based on the Brownstone, *et al.* (1996) vehicle choice model and the Golob *et al.* (1997) vehicle usage models.

It is noteworthy that most of the EV market research cited here is based on samples drawn from California. On the one hand this is defensible, since the initial roll out of EVs today has taken place there. However, there is likely to be heightened awareness of vehicular emissions in California because of local conditions and press attention, state programs that require semi-annual vehicle emission checks (Glazer, *et al.*, 1995) and a requirement that all new cars sold in-state are equipped, at added cost, with California emissions packages. What does emerge from almost all of these studies is that even in California, where many people feel that the environment is valuable and that motor vehicles degrade it, there is not a strong conviction towards the EV on environmental values alone.

## OBJECTIVES

In this study we explore initial public opinion and try to establish a baseline of information about the association between EVs and the environment. We are interested in *how* people acquire information so we examine sources that influence knowledge and opinions about the EV. We also examine changes in opinions about EVs and the environment over time.

We extend our baseline by following the development of environmental opinions, once people gain personal experience with an EV. We have a sample of fifty-three households that participated in a two week long EV trial using manufacturer's prototype vehicles. We compare environmental opinions when these people have no direct information, with those expressed opinions before and after the trial.

Using these two data sets, we explore whether (1) environmental attitudes towards the EV vary over time in the general population and whether (2) environmental attitudes differ among highly involved users. Is environment a key dimension, if people have direct opportunity to experience an EV, or do people place more weight on conventional vehicle factors, like cost and performance?

## RESULTS

### *The Panel Survey*

In the first study, we examine attitudes towards the environment and EVs over time, using panel data from California households. The first wave had 4747 households and was collected in late 1993. The second wave, in 1995, had a total of 2258 households, of which 76 % ( n=1718) are common. We report here on respondents who participated in both waves. Comparison with US Census data verified that the sample is representative on age and income, but slightly skewed towards those with higher education. Since we are using the data for exploratory purposes, we did not re-weight the data.

A series of environmental questions were asked over the telephone, as part of call-back interviews. In each wave, respondents were asked to rate the environmental benefit of electric and natural gas vehicles. On a five-point scale respondents indicated whether electric vehicles (natural gas vehicles) were a key to solving air pollution in California. The specific wording was "I am now going to read a series of statements. Please tell me if you strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with these statements: a) Electric vehicles are a key solution to solving air pollution in California, and b) Natural gas vehicles are a key solution to solving air pollution in California." There was a 'no answer' (NA) category for respondents who had no opinion, or did not know what natural gas and EVs were.

At face value, the survey items ask directly about environmental perceptions. They were scaled with other survey items about the environment and found to have a high inter-item reliability. Similar wording has been used in other studies about clean fuel vehicles (Turrentine *et al.*, 1992). The item about natural gas vehicles was as an internal control. Most respondents seemed to associate the study with EVs. We expected that a socially desirable answer about clean fuels would be more likely for EVs, and less likely for natural gas.

The items were rated on a 1 to 5 scale, where 5 means “strongly agree.” It can be seen (Table 2) that respondents always gave a higher rating to EVs than natural gas ones. Put another way, when first surveyed, 72% indicated the EV was a key solution for solving air pollution, and 58% said natural gas vehicles were key. However, at the second wave about 18 months later, people were more sceptical of the environmental benefit, and the mean scores are lower.

Table 2. Environmental Belief in the Panel Data

<b>EV is Key</b>	% who agree or strongly agree	$\mu$	$\sigma$	<b>NGV is Key</b>	% who agree or strongly agree	$\mu$	$\sigma$
Wave I	78%	3.98	1.18	Wave I	74%	3.78	1.10
Wave II	70%	3.69	1.00	Wave II	59%	3.46	.93
	$t=9.49$ ( $p<.001$ )				$t= 9.94$ ( $p<.001$ )		

As we hypothesised, people initially perceive that the EV is a good technology for improving air quality. If asked to give an ‘off the top of the head’ opinion about EVs, environmental benefits seem plausible. It is noteworthy that favourable ratings were also given about natural gas vehicles but they are lower than electric, and they also trend downward in the second wave.

These results suggest caution in the interpretation of attitudes found in cross-sectional data. Our further analysis identifies trends *within* the panel data. We were particularly interested in people who changed their opinion about the clean-air efficacy of EVs over the course of the panel survey. The direction of change is two tailed- some will change their opinion relative to their initial response, and believe that the EV provides greater environmental benefit. Others will grow more disbelieving. The off-diagonals in Table 3 track those who gave a different opinion

in the two waves of the panel survey. The sample size here is 1592, since cases with missing values on other variables had to be excluded for testing in a structural equations model. We explore the antecedents of change, and look at the role of communications as a key explanatory variable.

Most people do not have direct experience with EVs, and are probably not aware of the scientific debate over their environmental consequences. Thus, their 'off top of the head' opinion is likely to be formed by what people read or see in the general media and by hearsay. Media channels play an important role since people do not have direct opportunity to see an EV, nor can they test the claims about air-quality. The literature on the diffusion of innovation identifies that both interpersonal discussion and the mass media are vital channels in the early stage of an innovation (Rogers, 1986).

Table 3: Change in the Environmental Belief

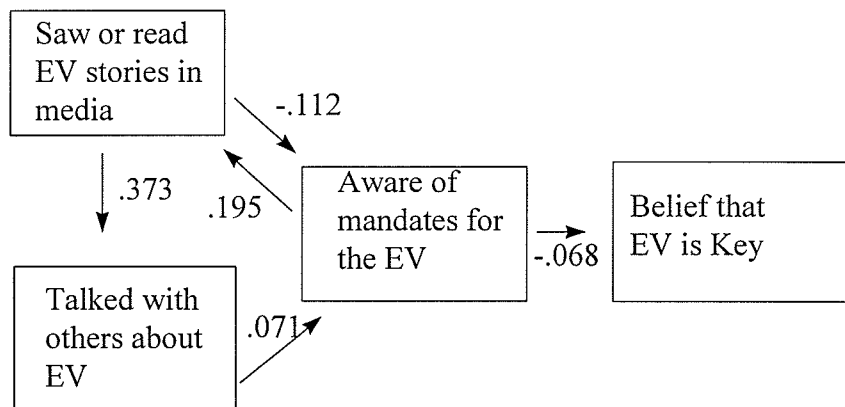
Wave 2 (rows) Wave 1 (columns)	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
Strongly Disagree	16 (= 0)	8 (= +1)	4 (= +1)	7 (= +2)	4 (= +2)
Disagree	34 (= -1)	49 (= 0)	15 (= +1)	86 (= +2)	38 (= +2)
Neither Agree nor Disagree	10 (= -1)	27 (= -1)	22 (= 0)	86 (= +1)	44 (= +1)
Agree	25 (= -2)	65 (= -2)	29 (= -1)	353 (= 0)	381 (+1)
Strongly Agree	4 (= -2)	14 (= -2)	4 (= -1)	76 (= -1)	191 (= 0)

Measures of mass media exposure were developed specifically for this study, based upon a news comprehension, processing and recall model (Graber, 1984; see also McQuail and Windhahl, 1993). This model assumes that public attention to the media is voluntary, that it is guided by a wide range of motives, and that information is 'perishable' and changes from day to day. It was judged to be a useful model for studying public opinion about EVs, because while most people have had passing exposure to news stories about the technology, the majority will not be interested, or will not recall specific details. The model assumes that a schemata or interpretative framework is a precondition for attention and recall. In the study, survey items probed general exposure levels as well as specific recall of stories.

To assess the probability of general exposure to relevant stories we recorded which newspapers and magazines each respondent read, and subsequently did a computerized content analysis of the publications to assess coverage rates about clean fuel topics (Torous, 1994). Other media variables were recall of media stories about clean fuels, knowledge of the 1998 California legislation, and interpersonal conversation (having talked with some one about EVs). The first two items probe the extent of media recall. First, respondents were asked if “they had seen or heard any specific information about EVs or NGV powered ones,” and to describe the stories briefly. Then, another question asked, “if they were aware of any legislation that would require automobile manufacturers to sell alternative fuel or electric vehicles in California.” If they answered affirmatively, respondents also named the approximate year they thought the legislation took effect. We also expected that the 1998 mandate would increase public attention over time. We included the item about the 1998 legislation, because we expected that temporal proximity to 1998 would increase news coverage, and factual information about the California regulation would change in response to higher levels of media attention.

Several different structural feedback relationships were tested with the data. The best fitting model is shown in Figure 1. It has with 30 degrees of freedom, and a  $\chi^2$  value of 40.67. The significance level of  $P=.09$  is above the rejection level of .05.

Figure 1: Predictors of Change in the Belief that EV is Key



In this model, the strongest association is between selective attention to the message and conversation (.37). People who remembered something in the mass media about EVs were more likely to talk with others about it. The process is also

dynamic: those who learned more about the regulation, also paid more attention to news stories. However, as hypothesised, as people learned more about the regulation, they were less prone to view EVs as a key solution.

Belief that EVs were a key solution was associated with several exogenous variables, with an overall  $R^2$  of .09. Females, and age groups 16-25, 35-45, and 55-65 were more likely to think that EVs were key. However, the most significant predictors were exposure to business magazines, auto magazines, and newspapers. Reading a newspaper was positively associated with the belief that EVs were a key to solving air pollution, while there was a negative association with reading the other types of publications. Not surprisingly, the business press and automobile magazines were likely to be more critical of the information about EV environmental efficacy. This may give some clue as to why environmental opinions declined with greater media exposure.

The combined panel study results suggest caution in interpreting environmental opinions about EVs. Opinions measured from a cross-sectional study are likely to be superficial. An 'off the top of the head' judgement is that EVs are good, and this opinion is probably derived from hearsay and stories in the general mass media. More controversial, or conflicting information, may be found in the specialised press. The latter information is acquired as people become more knowledgeable about the issue. Thus, we see some evidence about 'negative' word of mouth, or contradictory information, as people learn more about the technology they become more doubting of its environmental benefit. We can speculate that people begin to consider other environmental consequences, like the source where electrical energy is produced, or lead-acid battery recycling. Taken as a whole, these results lead to an inference about future diffusion: since vehicle choice is a high involvement decision for consumers, actual EV buyers are likely to be exposed to contradictory or complex communications about the environmental benefit of the technology. Our next analysis provides closer examination of this, as we study a population which used EVs over a two week trial period.

### *The Vehicle Trials*

The second study consists of 69 households, who participated in a two-week long EV trial in California. The vehicles used in the trial were prototypes, developed by a major auto manufacturer. These EVs incorporated a number of new and advanced components, and recharged fully in approximately 6 hours using a 240 volt, 30 amp circuit. Most drivers were selected from the previously mentioned panel study (n=53), but to increase the sample, an additional 16 people were chosen from their participation in a different transport survey. All of the households had to reside



within 40 miles of an EV service centre. Other selection criteria were an outstanding driving record, and access to an overnight garage or carport with a 240 volt circuit. The trial does not purport to have been based on pure random selection, but importantly, neither daily driving distance or commute length were used as screening variables. More detail on the sample is given in Table 4. It can be seen that the sample is well educated, it favors men, and is skewed towards middle- age groups. The trial sample is not an accurate representation of potential vehicle buyers, and this potential bias should be considered as we test for the probable role of attitudes and preferences.

Table 4: Respondent Characteristics in Vehicle Trials

Attribute	Breakdown	
Gender		
male	60%	
female	40%	
Education		
high school	10.3%	
some college	29.0%	
college	29.8%	
post-college	31.0%	
% of HH with children	32%	
% of HH with 1 car	26%	
	$\mu$	$\sigma$
Age	45.54	10.97
VMT- first HH veh. *	13,704	6,226
VMT- second HH .*	12,784	11,163

\*annual mileage per vehicle, estimated by respondent

Three different methods were used to collect data: an in-board travel logger, for recording vehicle miles of travel (VMT) and recharging information; a fill-in travel diary; and pre-trial and post-trial attitudinal questionnaires. The pre- and post-trial questionnaires had items which asked about vehicle operations and recharging activity, multiple attitudinal measures, and behavioural intentions. They incorporated the same question wording as the panel survey: “are electric and natural gas vehicles a key solution for air pollution.”

By keeping the question wording constant, we were able to track environmental opinions as respondents migrated *from* the panel *to* the trials. In Table 5 we examine results for 53 respondents, while cautioning about generalizations from such a small sample. Trial experience is associated with an increase in belief that

the EVs provide air pollution benefit. By the end of the trial, users more highly rated EVs as a key to solving air pollution. It may be coincidental, but scores are similar to those observed at the first wave of survey (when people first were surveyed and gave 'off the top of the head' answers).

This result refutes the hypothesis that as people learn more about the EV, they become more doubting of its environmental benefit. This also contrasts conditions described by the structural equation model described above, where people developed more negative evaluations as they acquired information *indirectly*. Unlike the panel, trials users acquired information from *direct* experience. Although they could not realistically test the claims about air pollution efficacy, they seemingly gained faith in its validity. Further support that direct experience with EVs made a difference is found in the result that there was no change in the 'control' condition: attitudes towards about air pollution and natural gas vehicles did not improve over the course of the trial (Table 6).

Table 5: Opinion that Electric Vehicles are a Key to Solving Air Pollution Problem

	Mean	Std. Dev.	Difference with mean of previous period	
			t-statistic	Significance
Panel Wave 1	4.00	1.16		
Panel Wave 2	3.58	.98	2.051	.047
Pre-trial	3.77	.78	-.829	.535
Post-trial	4.04	.89	2.30	.027

Table 6: Opinion that Natural Gas Vehicles are a Key to Solving Air Pollution Problem

	Mean	Std. Dev.	Difference with mean of previous period	
			t-statistic	Significance
Panel Wave 1	3.88	1.12		
Panel Wave 2	3.65	.81	1.349	.186
Pre-trial	3.45	.71	-.329	.744
Post-trial	3.44	.82	.625	.535

If the experience of driving an EV is associated with belief that it can help reduce air pollution, is it also a persuasive belief, in terms of vehicle choice? Before and after the trial, drivers rank-ordered six statements about the EV. Respondents were first asked to rank, in order of importance, their reasons *for* buying an EV. Subsequently, they were then presented with a different task, and asked to rank their reasons for *not* buying an EV.

In the pre-trial, 47% said that their first (primary) reason for selecting an EV was for clean air benefits. An additional 31% of respondents said that their first reason was to have a vehicle that was cheaper to operate than gas. Importantly, selecting an EV on the basis of the environmental benefit declined with trial experience. Post-trial, the most frequently selected reason was having a vehicle that was cheaper to operate (35%), and only 34% still cited clean air as their first reason, representing a decline of 13%.

When asked their primary reason for *not* acquiring an EV, just 3% of the respondents in the pre-test mentioned that EVs also had environmental detriments. No one cited this after the trial. The major post-trial concerns were the lack of range (50%) and vehicle costs (49%).

We can now overlay these results with the attitudinal data that showed an improvement in environmental efficacy. Although opinions about the technology improved, this was not construed as a criteria for vehicle selection. When people evaluated whether to acquire a vehicle, factors that also apply to the purchase of a conventional gasoline vehicle (such as range and cost) seemed to matter first.

To explore this further, we present brief evidence from post-test purchase intentions. With issues of confidentiality in mind, we do not reveal the actual level of purchase intention or show the results from a multivariate analysis. Instead, we look at the relationship between purchase intention and citing (in the pre-test) that environmental benefits were a key reason for selecting the vehicle. It will be recalled that 47% of the pre-test respondents mentioned an environmental reason for acquiring it. A cross-tabulation of purchase intention with this belief found that those expressing environmental concern were not more likely to choose the EV (chi-square = 1.93,  $p = .39$ ).

Finally, since previous research had suggested that the perceived environmental efficacy of EVs will rest upon actions taken by others, and by society at large, we explored issues of 'social responsibility.' Did trial users modify their belief towards mandates for the EV, and towards public policy to encourage clean air technology? Survey items used to assess this were: "a) the government should subsidise clean

fuel vehicles if they cost more the purchase; b) gas vehicles that pollute more should be taxed more; c) auto manufacturers should be mandated to produce clean fuel vehicles, and d) the government should provide funding for research and development of clean fuel technologies.” A composite scale, with these four items, had a coefficient alpha of 0.62 and factor analysis confirmed there was only one underlying dimension.

Table 7: Opinions About the Role of Public Policy and Mandates

	Mean	Std. Dev.	t-statistic for difference in means
Before Trial	9.77	3.48	
After Trial	10.22	3.25	.84

It was found that support for public policy intervention was high, both before and after the trial. However, participation in the trial was not associated with change either for or against the public policy measures. Perhaps these opinions about the role of public policy/ government intervention seem to be more stable, and are anchored in strong political points of view. We can juxtapose the lack of change on this dimension, with change in both environmental attitudes, and motivations for purchasing the vehicle.

## CONCLUSIONS

It is of interest to policy makers, transportation planners, and automobile manufacturers alike to understand more about consumer perceptions of transportation and the environment. There is currently legislation in California and elsewhere to mandate clean fuel vehicles, and a limited number of clean fuel vehicles are available for lease. The uptake of clean fuel vehicles will depend upon many issues, such as their convenience, price, range, and so forth. Perceived environmental efficacy could be an aspect of the consideration set.

This is a relatively novel concern, for as we suggested in the introduction, environment is a new dimension of vehicle choice by consumers. There is an issue that may have sensitised them to this, however. The oil crisis of the 1970's introduced a different set of issues. Prior to intervention by the then EPA

(Environmental Protection Agency), most consumers probably gave low weight to energy efficiency (miles per gallon) in their vehicle- purchase evaluations. Public concern about energy helped incite new policy, and lead to different types of vehicle choices. Driving smaller cars was one way the public responded, and between 1979 and 1989 survey data indicates the percentage driving full-size cars dropped by 14 percentage points ( Farhar,1994). In a similar vein, strongly held attitudes about air pollution *could* stimulate policy intervention, and a movement towards new vehicle types.

In current terms, the absence of strong public dissent may have made easier the 1996 roll-back of zero emissions legislation in California. Viewed from an aggregate, a weakening of public opinion towards the EV could also derail future policy making. A previous study examines how seat-belt legislation was instituted in the US despite early opposition by the automobile industry, shows a groundswell of support that oscillates between public opinion and the mass media (Walker, 1977).

There is some empirical evidence from our current research that opinions towards the EV weaken over time. The analysis uncovered that, as people acquired more indirect information about EVs from the mass media or from conversation, they also became less favourable about the clean fuel benefits. We speculate that this decline could be related to negative information in the media about vehicle range, or to stories about electricity generation and fuel source. A decline in public opinion is not favourable towards maintaining and generating support for new clean-fuel mandates.

On the other hand, results from the vehicle trials are somewhat more encouraging. After driving an EV over two weeks people expressed higher opinions about the environmental efficacy. Respondents are unlikely to gain more 'knowledge' about the clean fuel benefits, since it is a scientifically complex issue. However, by using the vehicle, they might gain 'faith' that the technology is good for the environment. Perhaps people like the vehicle and thus make favourable attributions about it, or perhaps they feel compelled after a vehicle trial to give more 'supportive' answers. But if the latter was a full explanation, then pre-test scores should also have been high. The EV trials are associated with more positive opinions about the environmental benefit of EVs.

If there were more EVs on the road, perhaps as a result of fleet initiatives or more widespread trials, would public support be garnered for EVs? There are some factors identified by this research that that need to be considered, alongside putting demonstration vehicles on the road.

In the trials we found that as people gained experience with the vehicles, they were more likely to cite factors *other* than air pollution for acquiring one. On the one hand, this is a favourable result because new qualities of the EV seem to enter a decision set. Perhaps the EV might be admired for its quiet ride or low maintenance costs. On the other hand, evaluations are also likely to be made in terms of other features, and the current generation of EVs may not compete, when direct comparisons are made on range, purchase price, and convenience of use, among general buyers. (For a discussion of decision making about the novel attributes see Kurani, *et al.*, 1996.)

The second concern is a methodological one. Throughout this research, we have cautioned that cross-sectional survey results can be unreliable, and we highlighted the benefits of longitudinal data. Trial data provide a rich base for interpretation, but trials impose their own limitations. In particular, there is the issue of small samples, and the notoriety of participating in an EV trial is likely to produce upward biased estimates of interest in EVs. Fewer people are likely to buy EVs than express purchase intention, for there are no repercussions for overstating its appeal. However, based on purchase intentions expressed in earlier studies, a trial with a sample of more women, or different age representations could produce even greater support than shown here.

A final factor to consider has to do with the social 'externalities' of air pollution. A solo electric car user cannot perceive an environmental benefit unless many other drivers do the same. While the overall level of support for EV use was high among the trial users, participation in the trial did not sensitize them towards more public policy initiatives to improve mobile air quality.

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