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Analysis of Consumer Response to Automobile Regulation and Technological Change in Support of California Climate Change Rulemaking

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Executive Summary

Through Assembly Bill 1493 the State of California seeks to lower emissions of carbon dioxide (CO₂) by motor vehicles so as to limit climate change caused by the buildup of greenhouse gases in the atmosphere and thus ameliorate the negative impacts of such climate change on air quality in California. Reduction of CO₂ emissions from motor vehicle travel in California is not a simple proposition technically or socially. In light of the growing economy and population of California, achieving these reductions over the next few decades will require a comprehensive strategy that integrates and balances technical advances, regulatory action, and market forces. To make progress in any such strategy, Californians will be called on to act as both consumers to buy new products and citizens to support policy. In this report, we review research on past, current and future consumer behavior around vehicle purchases and citizen support that is relevant to potential policy avenues that might require alternative technologies or increase the cost of fuel or vehicles. We focus primarily on fuel efficiency as a CO₂ reduction strategy, recognizing there are a variety of other ways greenhouse gas emissions might be reduced in the transportation sector.

The terms “fuel economy” and “fuel efficiency” have important historical, legal, and technical distinctions and so we spend some effort in this report to explain how those terms are used in past research and in this report. The basic distinction we highlight is that the phrases “fuel efficiency” and “fuel economy” have specific meanings and therefore a specific relationship to each other in the minds of energy experts; the vehicle buying public does not in general share these definitions and distinctions. To (some) experts, efficiency is a narrow measure of the ratio of useful energy out of an engines crankshaft to the energy input; “fuel economy” is codified to mean miles per gallon. From this perspective, increased fuel economy is just one service that can flow from increased efficiency.

In this study, we focus upon—from narrow to broad—consumer response to reduced grams of CO₂ per mile, and therefore consumer response to improving the fuel efficiency of internal combustion engines and auxiliary systems, and thus reduced CO₂ produced in the course of the use of light-duty vehicles. Research on consumers and energy use comes from primarily three sources: federal regulators looking for ways to reduce fuel use, automakers and automotive marketing research companies wanting to know what motivates buyers, and a few academic, NGO, and foundation-sponsored researchers also interested in reducing fuel use. Additionally, there has been some research in recent decades related to green and social marketing of vehicles.

Very little past research is directly useful for our purposes; we must tease out bits and pieces of data and insight. We must often discuss past research that has focused narrowly on the issue of fuel cost savings and vehicle mile-per-gallon ratings, but not fuel efficiency, fuel economy, or greenhouse gas emissions. In some cases we must tease out insights from highly aggregated economic studies, which assume an overly rational model of car buyers. Also, questions have been asked in a way which makes sense to researchers for their purposes, such as probing consumers about “willingness to pay” or “payback periods” but not in a way which is relevant to car buyers decision processes or the structure of the market.

Past research at the Institute of Transportation Studies at UC Davis has focused on consumer response to alternative fueled vehicles, touching at times on the issue of consumers and fuel economy. But we are in the midst of completing more detailed work household interview work on consumers and fuel economy for the Energy Foundation and U.S. Department of Energy; we discuss preliminary results from that work in this review.

In general, this review covers the history of consumer response to fuel costs, fuel use, and the technical variables affecting fuel use and cost. Perhaps surprisingly, the real per mile cost of gasoline to drivers has remained stable over the past 100 years, while vehicles have become faster, bigger, and have added more fuel consumptive technologies over time such as automatic transmissions and four-wheel drive. Most importantly, consumers buy more cars and trucks per

household, and drive many more miles than in the past. Amidst these changes, gasoline is a less significant portion of household budgets and has dropped below automotive insurance and financing as an expense in most households. Over the time period of 1967 to 1992, consumers demonstrated they would pay considerably more for vehicles, both for “regulated” safety and emissions improvements, as well as for luxury, quality, reliability, performance, and size. The missing data for this analysis are comparable data for light-duty trucks. A complete accounting of the effects of safety and emissions regulations on car sales would have to address the degree to which the shift of the new vehicle market towards trucks was driven by more lenient safety, emissions, and efficiency regulatory treatment that allowed lower manufacturer costs.

Most, economic studies of consumer response to high gasoline prices date to the oil crisis of the 1970s and early 80s, and show that car owners in that period did not reduce their travel much in response to gasoline price rises (as opposed to actually gasoline supply disruptions and rationing), and that during that transition period, those buying new cars were able to reduce their fuel use, while used car buyers and non-buyers retained vehicles with worse fuel economy. These studies do not tell us however how consumers might respond to offerings in the market of advanced technologies with better fuel efficiency.

Research in household and automotive energy use shows that consumers do not have good information about their energy expenses, do not keep records of annual expenses, and do not have good energy instrumentation on most appliances and vehicles to keep them informed of energy or fuel use. There is a wide distribution of consumer fuel cost accounting behaviors, from those who are highly informed to those who keep no records and do no calculations of fuel economy; consumer consideration of fuel economy varies. When we ask car owners about fuel use and costs, most householders “confess” they probably should know, but that they have no idea. Perhaps the piece of knowledge about automotive fuel costs known by most drivers is the price of a gallon of gasoline or the cost to them of a recent tank of gasoline.

It has become common practice in the automobile marketing research industry to ask consumers to “rank” the relative importance of lists of aspects, features, or attributes of vehicles in their choices. Fuel economy ranked high in these studies in the early 1980s, but dropped very low in the 1990s, recovering a bit recently in the wake of higher fuel costs. Many studies of fuel economy choices have centered upon the tradeoffs between weight, power, size, and other energy consuming attributes of vehicles. And in fact, consumer demand for larger, more powerful vehicles has been a major feature of the market, along with demand for four-wheel drive, air conditioning, and other energy using devices. We review data from auto companies and other sources that show consumers want these things over fuel economy. On the other hand, advanced technologies, such as hybrid drive trains will offer fewer compromises than in the past and perhaps other amenities such as greater auxiliary energy, so research that characterizes fuel economy as a tradeoff is not an altogether accurate portrayal of the market situation.

It is of great interest to regulators and car makers to predict how much consumers will pay for technological advances that enhance fuel economy and efficiency, but buyers are not accustomed to paying more for better fuel economy, that is, for vehicles with lower fuel costs per mile. Consumers might respond to close-ended prompts (such as “would you pay \$500, \$1000, or \$1500 for better fuel efficiency?”) or even offer some dollar amount off the top of their head. But we are finding in our own work that lots of consumers are guessing, uninformed, overly optimistic, or in some cases answer with what they think such improvements *should* cost—not what they personally would be willing to pay. Based on issues discussed in the review below and results of recent interviews with car and truck buyers, we believe measuring willingness to pay for fuel economy technology is a problematic research direction. If a buyer thinks the hybrid vehicle is a good idea, they may want it regardless of such calculations. In this sense, marketing will have more impact on responses to questions about willingness to pay than calculated cost savings on fuel.

Few analysts outside economic traditions accept the plausibility of consumer calculation of payback periods, and in economics it is more of a normative position—how consumers ought to behave.

Ongoing research at ITS-Davis to understand household automotive purchases indicates that few buyers would engage in payback calculations; in fact we have found no household that thinks about fuel economy in terms of a payback period. When asked to do so, almost all participants are clearly unfamiliar and uneasy with the concept. A few grasp for familiar temporal anchors, e.g., their vehicle loan finance period, which are irrelevant to properly structured payback period calculations. Moreover, we have found that in many instances, consumers are overly optimistic about savings from better fuel economy. That consumers do not think of a pay-back period for fuel economy is not surprising when we compare fuel economy to most of the other things consumers want; ample speed, an attractive design, ample seating, and luxury options appear to have no economic payback aspect in consumer thinking about cars and trucks.

The history of light-duty diesel vehicle markets in the US in the 1980s and Europe in the 1990s offer some glimpses of consumer response to differences in vehicle and fuel costs, although not as clearly as we would hope. We also review studies of consumer choices for compressed natural gas in New Zealand in the 1980s as those also show the interaction of pump prices, fuel costs, and government incentives. Also, we discuss the emerging markets for hybrid vehicles in California and the US. Finally, we review recent work at ITS in which we study the issue of willingness to pay and payback explicitly with a variety of households in the region around Sacramento, CA.

This review points to two diverging viewpoints. On the one hand, if consumers were to think in terms of pay back periods (and the related metric, discount rates) then averages such as the “three year” figure that Greene (2002) provides by example are of little interest. Almost every study conducted of consumer payback periods related to energy conservation shows a wide variety of (generally implied) discount rates. This suggests the existence of a market that can be segmented according to how long people are willing to wait to be paid back. We should not be concerned initially with the “average” payback period, but with those people who are willing to wait longer. Still, even within a context where payback period calculations were imposed on consumers, those signals carried far more than price information. In the case of dual-fuel vehicles in New Zealand, payback periods—as an explicit element of government policy—came also to signify government commitment to alternative fuels. The payback calculation and government loans were part of an overall package of price supports and taxes, refueling station incentives, and other government support for alternative fuels. Across the board retrenchment on all these programs created uncertainty that may have had more to do with the continued decline and eventual end of New Zealand’s experiment with natural gas as a transportation fuel than did the actual effect on vehicle conversion and fuel prices. This experience speaks to the need for a long-term transition strategy, not simply a short-term “launch” strategy.

If on the other hand as we will argue here, consumers simply do not evaluate vehicle price and fuel economy in a rational economic framework, then we must penetrate the veil of modeling behavior “as if” consumers were rational to understand the real effects of various policies. Our recent interview work suggests that “fuel efficiency” is a more compelling message than “fuel economy.” It suggests that those who are buying hybrid vehicles are buying “whole bundles” of desired attributes; they are not buying what they consider to be economy cars.

As for consumer consideration of social and environmental value related to climate change, only in recent years have some consumers become aware of the role of transport fuel efficiency in global climate issues; the majority of consumers are relatively unaware or at least poorly informed of the role of fuel efficiency in the formation of greenhouse gases. Many of the initial buyers of hybrids and electrics are those who have made a decision to be pioneers of the new technologies for both cleaner air and to reduce their use of natural resources. It is still unknown how large this segment could become as knowledge of climate change improves and the role of fuel efficiency in climate change becomes more widely understood by the car-buying public. We supply an expanded discussion of polling data on Californian and American beliefs about policy on global warming in Appendix A.

1 Introduction: Reducing CO₂ from light-duty vehicles in light of present and future consumer behavior

Through Assembly Bill 1493 the State of California seeks to lower the emission of carbon dioxide (CO₂) by vehicles so as to limit climate change caused by buildup of greenhouse gases in the atmosphere and thus ameliorate the negative impacts of such climate change on air quality. Reducing CO₂ emissions from motor vehicle travel in California is not a simple proposition technically or socially. In light of the growing economy and population of California, achieving these reductions in the next few decades will require a comprehensive strategy that integrates and balances technical advances, regulatory action, and market forces. To make progress in any of these strategies, Californians will be called on to act as both consumers to buy new products and citizens to support policy. In this report, we review research on past, current and future consumer behavior around vehicle purchases and citizen support that is relevant to potential policy avenues that might require alternative technologies or increase the cost of fuel or vehicles.

Additionally, to develop effective policy and regulatory mechanisms, the State will need to understand current and potential consumer response to vehicles with reduced greenhouse emissions, including advanced fuel-efficient vehicles. Understanding consumer and citizen choices is not simple; consumers both complain about pump prices when gas prices go up yet appear to pay little attention to fuel costs in vehicle purchases or travel choices. Both automakers and energy researchers have patterned ways of thinking about consumer and fuel efficiency. Because fuel efficiency is so important to energy researchers, they tend to over-think consumer consideration of fuel-cost savings, when for their part consumers do not measure or calculate their fuel costs. On the other hand, because the market for high fuel economy vehicles has dropped in recent years with the low price of gasoline, and with the issue of greenhouse gases and green marketing so new to the automobile market, automakers have not been paying much attention to fuel efficiency in design, advertising or marketing until very recently with hybrid vehicles. In this report, we try to sort out research on past, current and future consumer behavior that is relevant to potential policy avenues, especially those that might require alternative technologies or increase the cost of fuel or vehicles.

CO₂ is a normal byproduct of internal combustion engines that burn carbon-based fuels such as diesel, gasoline, propane, ethanol, or natural gas. CO₂ from transportation is one of the main sources of anthropogenic greenhouse gases. Some strategies to limit CO₂ could include reducing the number of miles vehicles are driven in California through pricing, transit and other modes of travel, greatly improving the efficiency of internal combustion vehicles, shifting to bio-fuels that require returning carbon to living plant tissue for sustainable yields, or shifting to low and minimal carbon energy systems such as grid powered electric vehicles (recharged with non-carbon based energy sources such as wind or solar) and hydrogen fueled vehicles.

Reducing travel through pricing or transit has not kept down vehicle use in growing economies; even in Japan where transit is well developed and driving costs are exorbitant, personal vehicle travel is increasing. Alternative fuels and low carbon fuels are promising but more dependent on major changes in the refueling infrastructure. Relatively simple transitions to some alternative fuels, like methanol, have not been successful.

Of all the strategies listed above, the one that seems technologically closest at hand and most politically acceptable is to encourage advance technologies to improve the efficiency of vehicles powered by internal combustion engines. Still, these advance technologies are not easily implemented; advanced technologies usually cost more and may be unfamiliar to consumers. For example, hybrid electric drive trains are available only in a fraction of the 1000 or more make/models and makes of vehicles on the market. Not just new, but even some old technology, such as diesel engines, took several decades to gain a majority share in the European auto market, even with the encouragement of policy.

Nevertheless, we are in a period of the most radical transformation of vehicle technology since motor vehicles were invented, much of that change driven by environmental problems, advances in computer and other new technology, as well as increasingly and increasing global markets for automobiles and petroleum. Right now, the automobile industry and market is entering a period of rapid change in regards to these new technologies and new environmental goals, particularly in regards to global climate change concerns.

1.1 From fuel economy to fuel efficiency; a transformation of technology and values

The terms “fuel economy” and “fuel efficiency” have important historical and technical distinctions and so we spend some effort here to explain how those terms are used in this report. In this study, we focus upon—from narrow to broad—consumer response to reduced grams of CO₂ per mile, and therefore consumer response to improving the fuel efficiency of internal combustion engines and auxiliary systems, and thus reduced CO₂ produced in the course of the use of light-duty vehicles. However, the term *fuel economy* has a history in federal regulation related to fuel shortages in the 1970s, the potential security problems from declining oil reserves in the United States, and the subsequent regulation of fuel consumption through Corporate Average Fuel Economy standards, and the EPA fuel economy ratings. Additionally, consumer organizations and carmakers have also used these “economy” rating to identify and promote the vehicles with the higher fuel economy ratings. Additionally, some cars with the worst fuel economy ratings have been subject to gas-guzzler taxes. This historical use of the term “fuel economy,” while strictly defined as miles per gallon (see discussion in next sub-section), is about saving both fuel and money.

Energy and engineering experts, and automobile manufacturers in particular, stress the difference between fuel economy (MPG) and fuel efficiency. They wish to narrow the definition of fuel efficiency to its strictest technical measure—the ratio of useful energy out of an engine’s driveshaft to a unit of input energy (stored onboard the vehicle). With this definition of efficiency, things like increases in fuel economy, size, weight, luxury amenities, towing, four-wheel drive, and more are all services that can flow from increases in efficiency.

We may be moving from a past in which fuel economy was a primary component of a cost axis in the automobile market to a future in which fuel efficiency is a primary component of a value axis. Fuel economy is linked to a past in which many Americans had to budget their use of gasoline and fuel economy was associated primarily with reducing vehicle size, weight, and power; vehicle economy stood in contrast to luxury and power. To many consumers, fuel economy carries the notion of cheap vehicle. Along side this notion of economy, federal fuel economy provisions such as Corporate Average Fuel Economy standards were shaped by national security concerns stemming from the 1970s and 1980s oil costs. But with the low real price of gasoline in the past couple of decades compared to the escalating cost of other aspects of vehicle ownership—e.g., purchase price, financing, and insurance—fuel economy has been shrinking in importance in the vehicle market. Despite minor ups and downs in gasoline prices in the last few years, almost all growth in the automobile market has been towards larger, more powerful, and less economical vehicles. The economy segment of the market shrinks along with profits from that segment.

But as fuel economy has lost much of its market value, fuel efficiency, advanced technologies, and environmental values are an emerging value axis for consumers. Advanced technologies, such as hybrid vehicle systems, promise improved fuel economy without sacrificing luxury, size, weight, and power. And such new technologies offer cleaner air and reduced CO₂ emissions. We are studying consumers in a period of transition in technology, knowledge, and values. Given the history of fuel economy and its close relationship to fuel efficiency, we sometimes discuss research which is about consumer response to “fuel efficiency” of vehicles, and in some locations we discuss consumer response to cost savings from better “fuel economy” as those bear an indirect relation to consumer demand for vehicles that have reduced CO₂ emissions and better fuel efficiency.

1.1.1 Expert and legal uses of the terms fuel economy and fuel efficiency

The National Highway Traffic Safety Administration (NHTSA) officially defines fuel economy ratings as “the average mileage traveled by an automobile per gallon of gasoline (or equivalent amount of other fuel) consumed as measured, in accordance with the testing and evaluation protocol set forth by the EPA.” The Energy Policy Conservation Act (1975) added Title V: Improving Automotive Efficiency to The Motor Vehicle Information and Cost Savings Act of 1973.

The Alliance of Automobile Manufacturers (AAM) takes a more consumer oriented bent on their website, defining fuel economy as the dollars spent on fuel per mile and efficiency as the power available at the driveshaft per unit energy input. The AAM gives credit to automobile manufacturers for increasing the technical fuel efficiency of vehicles, but they claim consumer choices for more energy consuming vehicles is responsible for the declines in fuel economy. Increased output energy can be used to propel the vehicle further (per unit of energy input), it can drive increased auxiliary loads, it can drive a larger vehicle, or it can be dissipated in automatic transmissions and four-wheel drive systems. Improvements in efficiency can be used to increase fuel economy, or to increase the weight, power, or payload of a vehicle while maintaining the same economy rating.

1.1.2 Consumer uses of the terms fuel economy and fuel efficiency

Most consumers we have interviewed say fuel economy and fuel efficiency mean the same thing to them. If pressed for a distinction, many will say fuel economy is about money, and fuel efficiency is about how much gasoline is used. One respondent stated that fuel efficiency is a “classier” way to say fuel economy. When we ask what car comes to mind when we say “a car with good fuel economy,” many say “a small, economical vehicle; a Geo Metro.” When we ask about “a fuel efficient vehicle,” those respondents say “a Honda Civic, a Toyota Corolla” and note that these are higher quality vehicles than “economy cars.” A few respondents associate fuel efficiency with the new Prius or Honda Civic Hybrid, and even bring up the idea of “saving natural resources.” None mention greenhouse gas or CO₂ reductions, nor do they mention climate change in general. It seems clear to us from even a limited number of interviews that it is unlikely consumers in general make the distinction between fuel efficiency and fuel economy that experts do. The implications for this lack of shared understanding include the possibility of mistaken inferences and conclusions from surveys and other research on consumers.

2 Sources of research on consumers responses to improved fuel efficiency, global warming issues and other environmental factors in the vehicle market

Research on consumers and fuel efficiency comes from primarily three sources. These are federal regulators looking for ways to reduce fuel use, automakers and automotive marketing research companies wanting to know what motivates buyers, and a few academic, NGO, and foundation-sponsored researchers also interested in reducing fuel use, emissions of criteria pollutants or greenhouse gases. Additionally, there has been some research in recent decades related to green and social marketing of vehicles. Very little of this research is directly useful for our purposes; we must tease out bits and pieces of data. Most often, questions have been asked in a way which makes sense to researchers for their purposes, but not asked in a way which is relevant to car buyers decision process or the structure of the market.

2.1.1 Federal research on consumers and fuel efficiency

In the past, the federal government has conducted a limited amount of research on consumers and fuel efficiency. In recent years federal agencies have been limited in their ability to conduct research on US citizens. The primary cause is The Paperwork Reduction Act that requires federally supported research with more than nine respondents to gain Office of Management and Budget

approval prior to being implemented. Thus federally funded research has been limited to buying a few questions in others' polls, and focus group studies. Focus groups have been conducted by Oak Ridge National Laboratories on the topic of fuel economy. Also, the National Renewable Energy Laboratories, working with the Office of Transportation Technologies at DOE, periodically hires a few questions on national surveys by Opinion Research Corporation International (ORCI). These studies have been aimed at a number of topics related to fuel efficiency, including understanding how consumers consider fuel economy in their current purchases, respond to major improvements in fuel economy, and might respond to information about fuel economy, including websites and labels for new vehicles. We include a number of these federal studies in this review.¹

2.1.2 Automaker research on consumers and fuel efficiency

Automakers have sizable consumer research programs, which feed advertising, branding, pricing, marketing, and product design strategies. However fuel economy has not been a high-priority topic because consumers did not show much interest in fuel economy during the late 1980s and 90s when gasoline prices were low and declining in real terms. Moreover, most automotive market research is kept secret; when automakers find a research result that may provide a competitive edge, they keep it to themselves. What they do release is for strategic purposes, and in the case of fuel economy, the main purpose has been to avoid more stringent regulation. For example, the 13 member Alliance of Automobile Manufacturers (AAM) website devotes several pages to arguing that the growth of four-wheel drive, light-duty truck sales is driven by consumers' desires for safety, passenger room, cargo space, towing ability, and off-road capability. They quote Ward's Motor Vehicle Facts and Figures (2000, pg. 15) that the light-duty truck segment has grown from 22 percent in 1980 to 50 percent in 1999.

Similarly, in a 2001 presentation to the National Academy of Sciences, Mark Thibault, from General Motors (GM) represents well the view of the car manufacturers. He states that:

- Fuel economy is a secondary concern in all segments except low priced vehicles (13.9 percent of market) and the hybrid car segment (0.1 percent of market);
- Styling, price, quality, functionality, and safety are significantly more important in vehicle purchases;
- In general, the higher the price of the vehicle, the less important is fuel economy;
- Willingness to pay for fuel economy is low; and
- Consumers will not make tradeoffs for better fuel economy (MPG) unless fuel prices increase significantly or consumers fear a supply disruption.

He concludes that an automobile manufacturer could gain market share if they simultaneously meet all "primary" needs and were then still able to improve fuel economy.

Less oriented to arguments about CAFE standards are survey findings by major private research companies, such as J.D. Powers, Maritz, Dorhing, and AutoPacific. Most of these studies are for sale, but some findings are occasionally released for publicity purposes.

2.1.3 Economic studies of consumer demand for fuel economy and fuel efficiency

In reviewing the economic literature we see how the underlying reality of past vehicle options shapes expert analysis. That past reality is reflected by the most common description we have heard and read of vehicles that get good fuel economy, that such vehicles are small. This perceived diminutiveness often extends to performance, comfort, and safety. We hear this description in our

¹ We do not include a review of the CAFE review recently conducted by the National Academies of Science.

household interviews and we read it in the expert literature. This perception leads to the expectation that vehicles with higher fuel economy ratings ought to cost less than vehicles with lower ratings. Until quite recently, with the advent of hybrid electric vehicles, consumers have not faced the prospect of paying more for a more fuel economical vehicle. Experts have not had data to analyze on such revealed choices, except in such cases as we discuss below in which changes in fuel economy are accompanied by changes of fuel or propulsion technology.

The effects on expert analyses include the following: choice of problems to analyze—and importantly, the very incidence of any studies at all; assumptions that shape what are—or are not—“surprising” findings; and inferences drawn from models. We have characterized economics as an attempt to operationalize a fairly specific set of assumptions about consumption (and production) decisions within mathematical models, and to conduct experiments within those models (Kurani and Turrentine, 2000, p. 13.) Compared to other social sciences, economists share a far more singular core set of assumptions about human behavior. The cornerstone of economic thought is that firms, individuals, and households act in their own interest and make rational decisions when making choices. Consumers are assumed to have stable, ranked preferences for goods, or features of goods, and good information about all their options. Choices are constrained by budgets and consumer research is often framed around prices—how much will people pay for what amount of which products (ibid).

So, related to vehicle and fuel purchase and use decisions, economists have studied, for examples, household response to higher gasoline prices (see for example Kayser, 2000; Pitts, Willenborg, and Sherrell, 1981; Puller, and Greening, 1999), aggregate economic impacts of inaccurate EPA mileage estimates including impacts on consumer surplus (see for example Sennauer, Kinsey, and Roe, 1984), and competing effects (primarily fuel cost savings versus safety) of CAFE standards (see for example Yun, 2002).² Notably, we find no studies that directly analyze whether households will pay more to buy vehicles that have higher fuel economy—except in the alternative fuel and electric vehicle literature where lower per mile operating cost was a promised attribute of some alternative fuel and electric vehicles.

Regarding the incidence of analysis, long periods of quiescence in gasoline prices such as most of the period from the mid-1980s to the late-1990s have not attracted the attention of analysts. Even some very recent studies are re-analyses of data from the period of most concentrated historical change in gasoline prices and vehicle fuel economy—the early 1970s to early 1980s. See Kayser (2000) as one example of a recent study conducted on older data. Data from the 1981 Panel Study of Income Dynamics because “data from 1981 are the most recent data for one year in which gasoline prices were changing rather substantially.” While the data may allow for observation of consumer behavior under substantial changes in gasoline prices, it does invalidate some of Kayser’s inferences if we are looking forward rather than backward. Specifically, Kayser concludes, “It appears that higher income allows households to purchase newer cars that will on average be more fuel-efficient because cars in 1981 are subject to the corporate fuel efficiency standards.” Clearly the context has changed since 1981. New vehicles are not likely to be more fuel economical. CAFE standards have not been made more stringent, and new “cars” are now as likely to be less economical trucks. The question now is, will higher income households drive fleet average fuel economy up or down in an era when new vehicles may be either more economical, e.g., hybrids, or less economical, e.g., SUVs?

The impact on Pitts, Willenborg, and Sherrell’s (1981) analysis of the practical means through which consumers could obtain a more fuel economical vehicle during the time period of their analysis (1973 to 1979) is revealed in their statement that, “The consumer may be required to make major changes in lifestyle by driving less or *by exchanging comfort, safety, or other satisfactions*

² Studies of the magnitude (and existence) of a “rebound effect” in which changes (increases) in fuel economy feedback through vehicle use behavior (to consume some of the expected fuel use reductions by increasing the number of miles driven) are the subject of another study for CARB and are not reviewed here.

for smaller car fuel efficiency.” [Emphasis added.] They continue in this theme when explaining attitudinal variables they include in their analysis, “The comfortable-life variable was included in this study because, intuitively, many actions to downsize [household’s] automobile inventories would require purchasing smaller vehicles, and experiencing a corresponding increase in physical discomfort.”

Much of the analytical literature on vehicle and fuel choice from the mid-1980s to the present focused on alternative fuels, electric vehicles, and air quality. Inferences for our question—will households pay more for higher fuel economy—are confounded by the fact that any fuel cost savings of alternative fuels or EVs is due at least in part to the use of a fuel less expensive than gasoline (where prices are measured “at the pump,” not in a full fuel cycle analysis). Kurani and Sperling (1987) discuss how buyers of light-duty diesel vehicles in California during the late 1970s and early 1980s were seeking lower fuel costs through the higher efficiency and higher fuel economy of diesel engines *and* the lower pump price of diesel fuel. Owners of diesel vehicles felt disaffected when the pump price of diesel fuel surpassed that of gasoline. Natural gas and electric vehicles have been represented as cheaper to operate, due at least as much to lower unit fuel prices as any changes in efficiency or economy compared to gasoline vehicles.

The policy goals driving alternative fuel and electric vehicle research efforts affected whether and how the fuel economy of competing vehicle options were presented to respondents. For example, Golob et al (1995) presented fuel economy information about all the vehicle types, e.g., gasoline, methanol, natural gas, electric, within the context of refueling costs only, expressed as equivalent gasoline vehicle fuel economy. For example, the home refueling cost of a natural gas vehicle in one specific hypothetical choice example would have been represented as “4 cents per mile (25 MPG gasoline equivalent).” The general context then is one in which differences in fuel economy differences are presented, but they exist both within and across different fuel types, and are presented solely in terms of private costs per mile.

2.1.4 *Green and social marketing research*

For the most part, overall emissions of criteria pollutants and differences in such emissions from vehicles have been regulated during past decades. Notably, such differences have not been marketed, and therefore, automakers, federal and state governments have done little to educate vehicle buyers in a systematic or comprehensive way about differences in emissions between vehicles. This same relative lack of education and marketing is apparent with regard to the role of CO₂ in global warming and the role of fuel efficiency as a greenhouse gas reduction strategy. The salient effort that has been made is the labeling of vehicles according to their EPA MPG rating. However, little effort has been made to present differences in MPG as anything more than differences in fuel costs. (Efforts to do so include information on the US DOE’s fueleconomy.gov website and the Green Car Guide from the Association for an Energy Efficient Economy. However, each of these must currently be regarded as useful tactical devices awaiting an overall strategy.)

But a number of automobile advertisements in recent months have begun to promote fuel economy and the environmental benefits of vehicles. There is something of a brand race on to be the environmental leader in the auto industry; a sense among automobile companies that some consumers are more interested in fuel efficiency and environmental aspects of vehicles than in the past. This change may have been initiated or at least pushed along by the California ZEV mandate in the 1990s. Requirements to manufacture and market ZEVs raised the bar on vehicle cleanliness, bringing the first emission-free and near-zero emission vehicles to some fleet customers and a small number of California households. Automobile manufacturers approached this experiment with caution. They were uncertain of the potential consumer value placed on these attributes and worried that the technical limitations of battery electric vehicles and their higher costs were severe barriers to purchase for anyone but wealthy, committed environmentalist. This latter worry was echoed in their arguments against the ZEV mandate and resulted in very limited efforts to promote battery EVs.

The automobile manufacturers placed only a few very targeted advertisements in print media aimed at environmental groups.

Green marketing—the promotion of products based on environmentally superior (or at least environmentally less deleterious) attributes—of vehicles and brands has accelerated with the relative success of hybrid vehicles. Both Honda and Toyota have been airing prime time television advertisements featuring their entire line of vehicles, emphasizing their hybrid vehicles, as well as buying billboard and print space. The new-model 2004 Toyota Prius continues trends by garnering lots of attention, awards and larger than expected sales.

In addition to green marketing, a number of government and private groups interested in clean air and climate change issues have begun “social marketing” aiming to change the behavior of consumers. The best-known example of this is the promotion of hybrid vehicles by actors and celebrities. Some groups have also engaged in negative, anti-gas guzzler social marketing as well, including religious activists who started the “What would Jesus Drive?” campaign and political personality Ariana Huffington who have attacked SUVs. We have been surprised in ongoing household interview work we are doing on the topic of fuel economy at how much effect this “anti-SUV” sentiment might be having among some car and truck buyers. Although we do not initiate discussion of SUVs, many of our interview subjects bring up the “SUV issue.” Some of those with SUVs feel slightly defensive or sheepish about their SUVs, and some of our interview households express strong “anti-SUV” opinions. Perhaps as it is with political campaigns, negative campaigning works.

Green and social marketing are still relatively new to automobile companies. Until recently, most improvements in vehicle emissions and fuel efficiency have been achieved through regulation, not market mechanisms. “Green buyers” were not represented in any of the conventional market segmentation models. But in the last couple of decades, many marketing and consumer research firms have been developing green marketing techniques and re-segmenting their demographic models to include “green market segments” (for two recent models see NEETF/Roper 2001 and Zook *et al* 1999). SRI did pioneering work in the 1970s in this field with its Values and Lifestyles (VALS) model. Turrentine (1994) provides a history of green marketing and marketing of automobile innovations up to 1993. For more detailed discussion of social science approaches to green marketing and social marketing of vehicles see Kurani and Turrentine (2002).

The relationships between consumers, global climate change, and fuel efficiency are more incipient in green and social marketing than are clean air and clean water. In part, this is because the role of transportation emissions in global climate change is unknown to most Americans. However, polling data by Roper, Wirthlin Worldwide, and others have begun to measure changes in Americans knowledge and beliefs about climate change. While the connections between political beliefs and consumer behaviors are not well understood, we can expect that political belief and knowledge are probably necessary initial conditions for green and social marketing to succeed. We cover in some detail relevant knowledge, attitudes, and beliefs of Californians and Americans in Appendix A of this report. Such knowledge, attitudes, and beliefs are the leading edge of changes in the marketplace and are indicators of the will of citizens.

2.1.5 Recent consumer research at ITS Davis

We are in the midst of completing new research at ITS-Davis on fuel economy decisions by households. With support from the Department of Energy and the Energy Foundation we are investigating very fundamentally whether and how car and truck buyers consider fuel efficiency and fuel economy in their beliefs, behavior and decisions. In contrast to previous research, we are making few assumptions about the role of fuel economy and efficiency in purchases. Rather, we are interviewing households in a basic, open way about their beliefs, habits around use of fuel, and whether and how issues of fuel economy and efficiency shape their vehicle (and fuel) purchase decisions.

Most past research has assumed that consumers make decisions about fuel economy, know the MPG of their vehicles, and have a basic understanding of fuel costs. Our past work with alternative fuels and electric vehicles had raised questions for us about these assumptions. We had interviewed many consumers who seemed not to know the MPG of their vehicles or other vehicles and had not done any calculations of fuel costs. Most knew at most the current cost of a tank of fuel for their vehicles. We thought this was probably because gasoline was a second order expense for most households, lower in importance than, for examples, home ownership, vehicle purchase and financing, and schooling for children. Certainly, a marginal expense for gasoline, between vehicles with different MPG ratings is only a few dollars per week compared to escalating purchase, insurance, and finance costs. Additionally, we had heard anecdotally from automobile dealers that fuel economy was a post-purchase concern of vehicle buyers; some buyers were upset about fuel costs after making a vehicle purchase, but paid no attention to fuel economy before the purchase. Finally, some researchers, particularly from the automakers, have reported that consumers will want a specific payback period on increased costs from improved fuel efficiency.

We have therefore designed detailed household interviews. Our goal in these interviews is to examine in great detail consumer knowledge, beliefs and behaviors relative to fuel economy. We are completing two-hour household interviews; the final count will be between 57 and 60 households. Our sample includes households who recently purchased (or are considering to soon purchase) a new or used car or truck. Additionally, we have selected households from several “sectors”; including farmers and ranchers, graduating college students, computer hardware and software industry, state government resource agency personnel, off-road vehicle enthusiasts, outdoor recreation businesses, military personnel, and financial services. With each household, we review their full history of car buying and ownership, most recent purchase process, the role of fuel use in daily travel, habits, and budgets, and finally, the role of fuel efficiency against other considerations.

While this work still being completed, we have made two presentations on this research and cite these presentations. We will be reporting fully on this research in the coming months. We expect of have completed interviews by the end of April 2004.

3 Consumers, fuel use, and vehicle purchase behavior

In the following section, we review studies about consumers, fuel efficiency, and fuel economy. These studies have focused upon understanding and in particular measuring in some way the importance of fuel efficiency and economy to car buyers. Some studies have tried to estimate consumer willingness or lack of willingness to pay for fuel economy and the importance of fuel economy relative to other attributes of cars.

Researchers studying home energy use have been researching homeowners and their energy expenses far longer than vehicle energy researchers. One of the strongest findings from the study of home energy use is that consumers are ignorant of the issues and calculations surrounding energy use. In a review of consumer behavior around energy efficiency and economy for buildings, Lutzenhiser (1993) reviews numerous studies that show distortions across the population in understanding energy use. These distortions result in poorly informed decisions and maladaptive behaviors. For example, homeowners consistently overestimate potential energy savings from minor conservation behaviors, fail to know the relative amount of energy used by different appliances, and in general do not do any energy accounting. This lack of knowledge and accounting results in optimistic and unrealistic consumer estimates of payback periods for things like energy-efficient refrigerators, water heaters, and air conditioning.

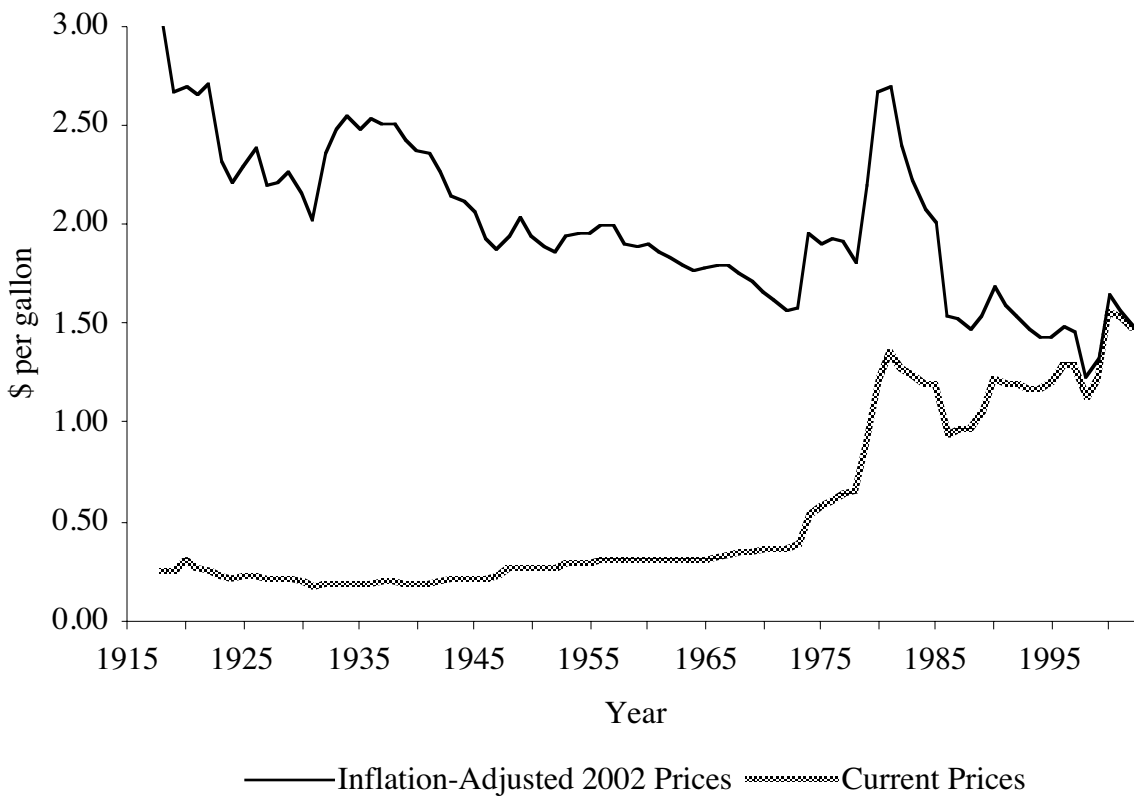
3.1 History of car and truck buyers and fuel costs

During the past 100 years, the cost of driving a mile relative to the cost of other goods has remained remarkably similar. In the mid-1920s, Americans prospered and many bought their first cars. Gasoline, in 2002 dollars, averaged \$2.23 per gallon. The Model T, an economical vehicle for its

time, got 20-25 miles to the gallon, had a 22.5 hp engine, weighed about 1,350 lbs., and cruised at 35-45 mph. American's didn't drive as much as they do now, or as fast, and roads were still mostly unpaved. And yet, the fuel cost to drive a mile then was similar to today, though perhaps a bit more expensive. While gasoline costs per mile have declined over the past 100 years, the average annual miles driven, cargo needs, and speed demands have grown tremendously. And as incomes have climbed, Americans have bought more vehicles per driver. Vehicles have gotten bigger, more powerful, more reliable, and have added sophisticated mechanical and electronic systems such as air conditioning and power steering that use energy. Perhaps the only instance of "downsizing" in vehicles in the U.S. came with the fuel shortages in the 1970's, followed by inflation and a higher real cost of gasoline, about \$2.29 per gallon in 1980 and 1981 (2002 dollars), a real cost not seen since 1939. The spike in real costs of fuel in 1980 can be seen in chart below, accounting for a real shift in fuel costs at that time.

Other nations have not always had the combination of low gasoline prices, growing incomes, expanding interstate highway system, and poor transit that resulted in so much automotive fuel use in the United States. In particular, in the post-WW II era European and Japanese automakers made small, economical vehicles for their working classes. Gasoline was taxed heavily in all these nations. When the oil shortage hit in the 1970s, small, economical vehicles from Asian automakers made big gains in the U.S. market, as US consumers responded to both actual shortages and higher prices. Fuel-efficient mid-sized sedans from Asia and Europe and diesel-powered Mercedes-Benz cars took market share from American luxury vehicles as well.

Figure 1: History of U.S. Retail Gasoline Prices, Current and Constant 2002 Dollars



Over the 1980s, the cost of gasoline per mile for an average light vehicle dropped from its high in 1980 of around 10 cents per mile back down to under 6 cents per mile in 1987, where it stayed throughout the 1990s (Davis, 2003). The price of gasoline has stayed low for many years while purchase price, depreciation, insurance, and maintenance costs have risen. Therefore fuel economy has not been as important to car buyers as it was in the 1970s and early 1980s. As gasoline prices dropped in the 1980s, American automakers responded by marketing larger vehicles with truck-like designs and bigger engines. The primary trends in US vehicle markets since the oil shortages of the 1970s have been the rapid growth of market share for minivans, SUVs, and pick-up trucks pushing sales of truck-based vehicles from less than 18 percent of the market in the late 1980s to over 50 percent by 2001. These larger, heavier, less aerodynamic, and often 4-wheel drive vehicles have lowered average fuel economy of the U.S. automobile fleet.

On average, depreciation of vehicles in the U.S. rose from 27 percent of the cost of owning and operating a vehicle to 47 percent between 1985 and 1999. In 1985, gasoline and oil were 23 percent of annual motor vehicle costs, and were the second biggest category of costs after depreciation. The cost of gasoline and oil have since dropped to 10 percent of annual costs (in 1999), and ranked fourth behind depreciation, insurance, and financing (Davis, 2002). Against this financial backdrop, marginal changes in fuel economy make less difference to the cost of owning and operating a motor vehicle.

Automakers have told regulators that there is little they can do to get consumers to buy more economical cars. They argue that because gasoline has been cheap, they have designed—and car buyers have chosen—larger, truck-like, and more powerful vehicles. And because fuel economy has not been that important, it has not received much attention until quite recently from automotive researchers looking at vehicle purchases. Yet despite seeming widespread consumer indifference to gasoline costs when purchasing a vehicle, consumers invariably complain whenever gasoline prices go up a few cents—enough so that television news stations send a reporter to the gas stations with every price jump to interview vehicle drivers refueling their vehicles. But for the most part, fuel costs have stayed low in comparison to other vehicle costs, and have not had a big impact on consumer purchases and travel behavior, except among the lowest income buyers. In the last three years, the price of gasoline has increased some, there are wars in the Middle East, and some of the public is aware of global warming concerns about fuel use. The launching of hybrid vehicles into the market may signal an interest in fuel efficiency, but it is early to be certain of the extent and impact of this interest.

3.1.1 *The history of consumers response to changes in vehicle prices due to regulatory changes*

The question of how consumers responded to changes in vehicle prices implies that regulations have raised the cost of vehicles, resulting in higher prices and further, that consumers have responded in some way to those price increases *due to regulation* as opposed to price increases due to other causes. Our main observation here is that the price increases due to emissions, safety and fuel economy regulations are overshadowed by other price variations in the market and the comparative relative *decline* in the costs of cars and trucks as compared to other goods and services. The question of how consumers respond to price increases caused by regulation makes sense only in an abstracted *ceteris paribus* way, but makes little sense in the real car-buying world, where all else has not been equal. The market has grown from several hundred to over 1,000 makes and models. Buyers are confronted by greater variation in prices between body styles, brands, trim packages, dealerships, rebates, financing options, options packages, warranties, yearly increases in prices and other options like four-wheel drive, etc. The question of how consumers respond to price increases caused by regulation makes little sense in a world where consumers don't evaluate vehicles by single attributes, but evaluate suites of attributes. Regulations designed to affect one vehicle attribute may affect consumers in unexpected ways, as consumers evaluate the suite of attributes to which the regulated attribute belongs. The question of how consumers respond to price

increases caused by regulation makes little sense in a world where prices convey more information than simply private cost.

Implicit in the question of how consumers respond to price increases caused by regulation is idea that the cost of vehicles to households has risen. This initial premise is at best arguable, if not demonstrably false when we ask “compared to what?” Expenditures on vehicles have declined as a share of aggregate consumer expenditures, while at the same time the number of vehicles sold has increased, the number of vehicles per household has increased, and the number of vehicles per household member has increased. In short, in comparative terms over time, Americans have been buying more vehicles and spending less of their income and time to do so. Over the time period of the analysis below, vehicles have also incorporated more safety equipment, more emissions controls, gone through periods of advancing and declining fuel economy, become more powerful, larger, heavier, incorporated more amenities such as air conditioning, improved reliability, and reduced maintenance requirements.

Data from the US Department of Commerce’s Bureau of Economic Activity demonstrates that on a current dollar basis, expenditures on new and used motor vehicles declined from 1959 to 2000 (Moran and McCully, 2001). In current 1959 dollars, purchases of new cars and trucks by households accounted for 4.2 percent of all *personal consumption expenditures*.³ The share for autos was 4.1 and for trucks, 0.1. By 2000, the overall share of personal consumption expenditures in current 2000 dollars had declined to 3.1 and the shares for autos (1.5) and trucks (1.6) were nearly equal. Shares for net purchases of used vehicles were similar in both years: 0.9 in 1959 and 1.1 in 2000.

The declining share of current personal consumption expenditure simply means that in aggregate consumers are spending comparatively less in aggregate on new and used cars and trucks than they are for other goods and services. Data on vehicle sales tells us this relative reduction is not because Americans are buying fewer vehicles. In 1959, Americans bought 7,065,000 new cars and trucks (AAMA, 1995). In 2000, they bought more than twice as many: 17,234,000 (Davis and Diegel, 2002; Tables 7.5 and 7.6) In fact, the year 2000 was the unprecedented fifth year in a row that combined sales of new cars and light-duty trucks topped 15 million units. This increase in the number of vehicles sold means that while aggregate expenditures for new and used cars and trucks declined as a share of total personal consumption expenditure, households bought more vehicles. The per capita number of vehicles in operation increased from 0.37 in 1960 to 0.78 in 2000 (Davis and Diegel, *ibid*, Table 11.2).

The implied high level of household vehicle ownership from such aggregate statistics is shown to be real by looking at more disaggregated data. For example, the share of US households who own more than three vehicles has increased from only 2.5 percent in 1960 to 18.3 percent in 2000. Despite the increase in quality, reliability, size, weight, performance, safety, efficiency, and emissions controls for cars and trucks, the total share of personal consumption expenditures for new and used cars and trucks declined over the forty-year analysis period.

3.1.2 *Historical data on safety and emissions costs from the 1980s and early 1990s*

Greene (1992) discusses data from the Bureau of Labor Statistics and additional data cited in the American Automobile Manufacturers Association’s (AAMA) *Motor Vehicle Facts and Figures 1991* for the years 1971-1989 on average household expenditure per new car and adjusted average expenditure per new car based on regulated safety, fuel economy, and emissions improvements to

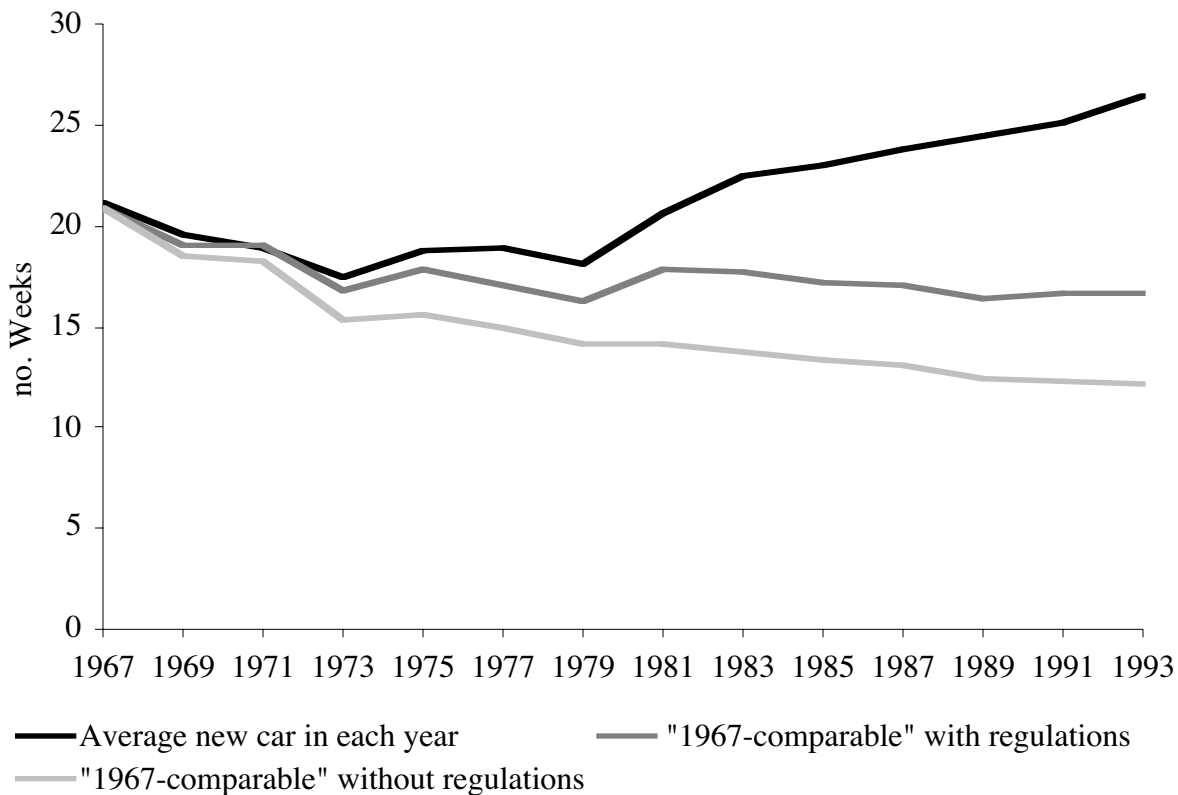
³ Personal consumption expenditure includes expenditures by US citizens abroad, including civilian and military personnel. It also includes imputed values for rents and services. While the Bureau of Labor Statistics consumer expenditure survey data (which excludes these things and more directly measures out-of-pocket expenses) might be preferable, we use the Bureau of Economic Analysis’ PCE because other data used by the American Automobile Manufacturers Association cited in this review are based on the PCE data.

vehicles. The conclusion he presented was that these regulations resulted in about a 20 percent increase in average expenditure per car in current dollars. (All dollar figures in this discussion are current dollars for the year in which the data are cited.) The data do not include trucks, which have not been subject to identical safety and environmental regulations over the time period he analyzed. Importantly though, truck sales have grown to more than half of the current market for new light duty vehicles. Maybe more importantly, the data are not specific to California, but are national.

But perhaps most important is that the average expenditure per new car has grown far more than the 20 percent attributed to safety and environmental regulations. The average buyer is buying much more luxurious, higher quality, more reliable, and more powerful cars and trucks than they did in 1967. (1967 is the base model year from which expenditure increases are calculated.)

We update slightly the data Greene (ibid) used using *Motor Vehicle Facts and Figures 1995* (AAMA, 1995, p. 60). The data on the number of weeks a household earning the median income in each year would have to work to pay for cars are plotted below. The average household expenditure in 1993 for a “comparable 1967” car without the regulated safety, emissions and fuel economy improvements would have been \$8,631. This would have required 12.2 weeks of median household income to buy. The average transaction price of a new “comparable 1967” car with regulated safety and environmental improvements would be \$11,806 and take 16.7 weeks of median household income to buy.

Figure 2: Number of Weeks a Household Earning the Median Income in each Year would have to Work to pay for the Average New Car.



The 1967 Comparable Car with Safety and Emissions Improvements, and the 1967 Comparable Car with out Safety and Emissions Improvements

This difference in average expenditure (\$3,175) was a considerable “price” increase, however it is nowhere near the whole story. The actual average household expenditure on a new car in 1993 was \$17,549, and required 26.5 weeks of work. This shows that consumers have on average upgraded their cars in many ways, i.e., they have chosen much more expensive vehicles than the average 1967 car. If you were to look also at trucks (including SUVs, vans, and minivans,) you would see even greater purchase power and flexibility in choosing what were luxuries in the 1960s, such as air conditioning, power accessories, elaborate sound (and now, video) systems, etc. The chart illustrates that two-thirds of the increase in the average expenditure for the price of a new car from 1967 to 1993 had nothing to do with regulated increases in safety and emissions control.

Our claim that the cost of automobiles declined from before the OPEC oil embargo of 1973 and well into the 1990s is bolstered by looking at the time it takes households to earn sufficient income to buy a new car. The analysis illustrated in Figure 1 indicates that even with safety and environmental regulations, the amount of time it would take a household earning the median income to buy the average new car declined from 1967 to 1993 by about one month. We note further that the “1967 car without regulated improvements” is an arbitrary datum and can in no way be interpreted as an ideal state that might have actually been perpetuated in the absence of government regulation.

The increase in the average expenditure for new cars was not accommodated entirely by proportionate increases in household incomes. Greene (*ibid*) cites evidence that in real terms household income increased little if at all over the period he analyzes. Increased expenditures on new cars were financed by longer-term loans. As Greene concludes, “Because of an increase in the maximum possible length of the term of the loan (from four to five years) in the early 1980s, the average monthly payment has not gone up as rapidly as new-car prices.” (Greene, *ibid*. p. 110). Data from the 1995 edition of the AAMA’s Facts and Figures show that the average term of a new car loan increased from less than four years (45.0 months) to four-and-one-half years (54.1 months) from 1980 to 1994. Greene’s reasons for why the term of loans have increased represent an optimistic view of the functioning of the market.

“The maximum loan period is market driven, that is, it is associated with the rate of depreciation for the automobile, which in turn is influenced in part by its lifetime, and durability and the demand for the automobile in the used car market.” (*Ibid*, p.110)

An alternative explanation is an intentional effort by the automobile industry to sell more expensive vehicles by offering longer term financing. This view is supported by our ongoing series of household interviews regarding vehicle purchases and by survey data. Many households shop for vehicles based primarily on the monthly payment they believe they can afford rather than the total purchase price. Kelley Blue Book (2003) reports that 20 percent of people shopping for a new vehicle “plan to negotiate based on the monthly payment.” A longer-term loan is one-way to sell a customer a more expensive vehicle while holding the monthly payment constant.

Over the time period of 1967 to 1992, consumers have clearly demonstrated they will pay considerably more for vehicles, both for “regulated” safety and emissions improvements, as well as for luxury, quality, reliability, performance, and size. The missing data for this analysis are comparable data for light-duty trucks. A complete accounting of the effects of safety and emissions regulations on car sales would have to address the degree to which the shift of the new vehicle market towards trucks was driven by more lenient safety, emissions, and efficiency regulatory treatment that allowed lower manufacturer costs.

3.1.3 *Econometric analysis of household response to higher gasoline prices*

The economic literature on household response to higher gasoline prices tends to focus on the issue of elasticities—how much does fuel consumption, vehicle miles of travel, or household fleet fuel economy change for a unit change in the price of gasoline? Pitts, Willenborg, and Sherrell (1981) set out to examine “how persons have reacted to the increasing price of gasoline in an environment of perceived shortages.” (The time period of their analysis is 1973 to 1979.) They state, “Economic principles lead us to believe that increasing prices of gasoline would decrease demand.” From this point they characterize the possible strategies for reducing fuel consumption in the face of higher gasoline prices, i.e., “...consumers could cut back on their driving, buy more efficient vehicles, seek the lowest-priced gasoline, increase relative usage of the more efficient vehicle(s) in multi-vehicle households, drive at reduced speeds, or do nothing at all.”

Pitts, Willenborg, and Sherrell (*ibid.*) group households into a two-by-two matrix according to whether or not they reduced or made no change to miles driven and reduced or made no change to the average number of engine cylinders in the household stock of vehicles during the period of analysis. (Number of engine cylinders is used as a proxy for fuel economy.) They conclude that membership in any particular group is determined by both demographic variables—such as race, household size, and years of formal education of the household head, values—such as desire for a comfortable life, an exciting life, and family security. Price sensitivity—measured as an attitudinal variable—did not explain adaptive behaviors in response to higher gasoline prices. More specifically, they conclude, “Generally, gasoline price increases do not discourage driving—except among specific segments whose financial condition will not accommodate the higher prices.”

This conclusion, that higher gasoline prices (at least within the range of price variations within the available data) do not result large reductions in travel, i.e., travel demand with respect to gasoline fuel prices is relatively inelastic, is repeated in other studies. Kayser (2000) concludes, “Higher gasoline prices will not lead to a substantial reduction in the amount of gasoline consumed by households in the short-run.” Puller and Greening (1999) conclude their analysis produces results “consistent with the literature and support the claim that gasoline demand is relatively inelastic in the year following a [gasoline] price change.” They decompose demand for gasoline into demand for travel and for the fuel economy of that travel. They find, ironically, that in the face of higher gasoline prices, households in the aggregate reduce *both* miles driven and the fuel economy of the remaining travel—on average, households travel fewer miles, but consume more gallons per mile for the remaining travel they do undertake. The authors offer the suggestion that households reduce higher economy highway travel more than they reduce lower economy local trips.

3.2 *Vehicle owners: knowledge and calculation of fuel economy*

Throughout this section we will explore the extent to which consumers may be plagued by similar mistakes and gaps in knowledge about fuel use in their vehicles as they are in their homes. In an on-going series of household interviews, we have found that consumers have limited knowledge of their vehicle’s fuel economy and monthly or annual fuel costs. When we ask these questions, most householders “confess” they probably should know, but have no idea. Perhaps the pieces of knowledge about fuel costs known by most drivers are the price of a gallon of gasoline and the price of a tank of gasoline. These are numbers they encounter weekly, and are shown plainly on pumps and signs, receipts and credit card statements. In a 1999 study for National Renewable Energy Laboratory study conducted by Opinion Research Corp. International (ORCI), out of 1,000 adult American car buyers asked about the fuel economy of their most recently purchased vehicle:

- 26 percent said “fuel economy was not an issue,”
 - 22 percent said they saw the fuel economy on the window sticker when they bought the car,
 - 12 percent saw the mpg in a dealer brochure,
 - 11 percent found the mpg in a magazine or consumer guide,
 - 5 percent heard the mpg by word of mouth,
 - 4 percent on the internet,
 - 2 percent on television,
 - 1 percent in a government fuel economy guide
 - 18 percent said they didn’t know or don’t own a vehicle.
- (Gurikova, 2002)

One reason for the lack of knowledge and perhaps indifference to fuel economy is that most vehicles have only primitive instrumentation for tracking fuel use, such as analog gasoline gauges, as well as odometers to measure distance driven. Only a few vehicles have instruments that show the driver real-time average or instantaneous MPG or have onboard computers to help drivers track fuel use over time.

In our most recent interview work, we are exploring the impact of these instruments on consumer awareness of fuel costs. Because of the general lack of accurate energy instrumentation, knowing a vehicle’s MPG requires reading the owner’s manual or doing some recording of fuel use and simple math. We have found that almost no one includes fuel costs in household budgets. However, some drivers who use petroleum company credit cards do see monthly and even annual summaries.

In previous detailed household interviews we did on markets for electric vehicles, we found only a minority of drivers knew the driving range and MPG of their conventional vehicles (Turrentine and Kurani 1995). These tended to be technically oriented consumers, such as engineers, who routinely calculate MPG. We found that few drivers know annual fuel costs, except those who are in business, and therefore keep track of expenses for reimbursement or tax purposes. Some of these also use the odometer to calculate when to refuel instead of their gasoline gauge. A few consumers we have interviewed calculate MPG on longer trips or if they have longer commutes.

The point here is that there is a wide distribution of consumer fuel cost accounting behaviors, from those who are highly informed to those who keep no records and do no calculations of fuel economy. This has a profound effect on consumer consideration of fuel economy.

Of all aspects of fuel economy, drivers are most aware of pump prices, the cost of a full tank of gasoline, and in some cases can offer estimates of average weekly or monthly fuel costs relative to how often they think they filled their tank in previous months. In part, pump price is also quite volatile, thus it gets lots of attention in the press. A rise in the price of gasoline of ten cents per gallon can get significant press, despite that such might result in only an increase of only a few dollars in weekly costs per vehicle. For this reason, pump costs and prices have a disproportionately large effect on consumers’ consideration of fuel economy.

Past studies have shown that, for example, decisions about purchases of light-duty diesel vehicles was most affected by pump price of fuel as opposed to annual fuel costs or any other cost measure (Kurani and Sperling, 1991). Marginal increases in gasoline prices have minimal impact on total consumer expenses, and yet get much attention from car owners, though as we have noted, that attention is seldom expressed as reductions in daily travel.

We are hypothesizing, based on preliminary results from on-going interviews with households regarding fuel economy and efficiency, that car and truck owners may overestimate how much they spend annually on gasoline, in part because their primary source of information about their fuel expenses is the pump price or the cost of a tank of fuel, and because they are more likely to notice and recall price increases than decreases. This hypothesis is in keeping with findings about home energy use. In summary, because of the decreasing cost of fuel in driver budgets, the overall increase in fixed costs of vehicles, and the lack of instrumentation, consumers do not manage

adequate information about fuel economy to make rational choices. Most importantly, few consumers know their annual fuel costs; they react mostly to pump prices and per tank costs. Even if car and truck buyers understood annual fuel costs, the low cost of gasoline might mean less interest in fuel economy.

3.3 Fuel economy and trends in consumer choice for new vehicle attributes

It has become common practice in the automobile marketing research industry to ask consumers to “rank” the relative importance of lists of aspects, features, or attributes of vehicles in their choices. Attribute ranking studies by major research groups such as Maritz, J.D. Powers, and Auto Pacific have often found their way into popular press, replacing past studies that focused on brand and model preferences. These ranking studies have featured prominently in the debate between vehicle makers and government regulators over CAFE standards. Perhaps most infamous is an oft-repeated quote about a study mentioned in the Los Angeles Times on March 29, 2000 reporting automobile shoppers ranked fuel economy lower than cup-holders. More recently attention has been on consumer rankings for safety, towing, four-wheel drive and other attributes of SUVs. Econometric analyses take this same individualized attribute approach—consumers buy vehicles essentially as amalgamations of individual attributes—and study the value consumers have for the particular combination and for individual attribute. Most significantly, safety and reliability have risen steadily in consumer purchase consideration over recent years.

In its discussion of fuel economy and consumers, the Alliance of Automobile Manufacturer’s website cites a 2000 Consumer Preference Research by Maritz Marketing that “ranks” a large list of vehicle attributes. Reliability is listed as number one, safety number six, power and acceleration number sixteen, quietness number nineteen, and fuel economy number twenty-five. Mark Thibault of GM discusses the ranking of fuel economy in his report to the National Academy of Sciences, noting that in a long list of questions asked at a consumer clinic, “I will purchase only a vehicle with good fuel economy” was number 65 on the list, and “Greater Fuel Economy/Less Performance” performance, dropped to number 99.

But simple attribute rankings overlook the different ways in which attributes of vehicles can impact consumer choice processes. Consumer choice processes may consist of a number of steps, including initial shopping behavior in which consumers form initial consideration sets of vehicles, but also a subsequent step in which options are narrowed. Along these lines a 2003 J. D. Powers “Escaped Shopper Study” asked, “for which reasons did car buyer reject a particular model.” That study reported that in 2003 gasoline mileage had moved up to 5th reason consumers rejected one model over another, up from 13th in their 2002 study (Daily Auto Insider, September 2003). Below is the list of top ten reasons from that study why people rejected a particular vehicle.

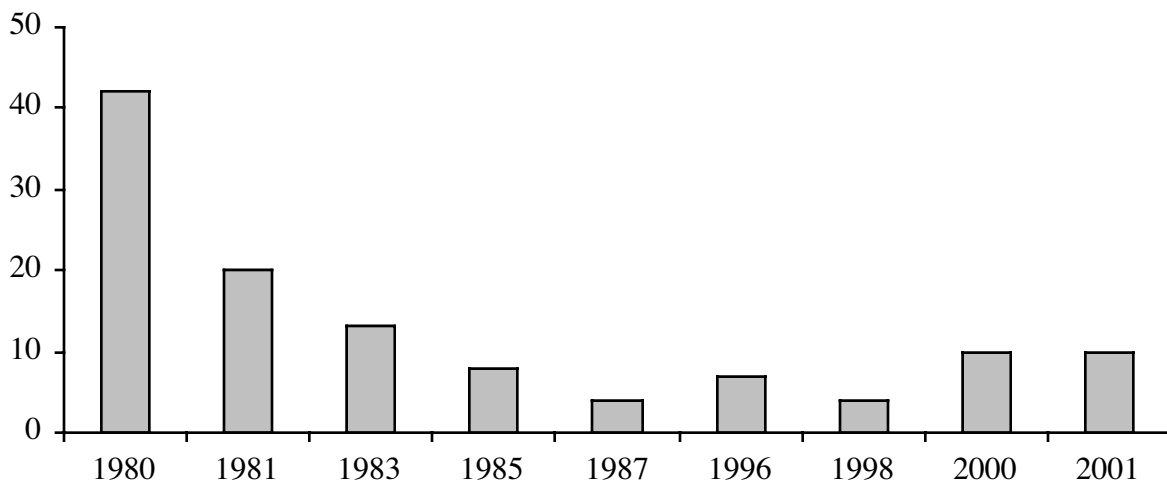
- 1-Total price too high,
- 2-Total monthly payment too high,
- 3-Didn’t like exterior design,
- 4-Didn’t have rebates or incentives that the ultimate choice did have,
- 5-Wanted better gas mileage,
- 6-Concerned about reliability,
- 7-Not available with low interest financing,
- 8-Didn’t like look/design of interior,
- 9-Salespeople didn’t act professionally,
- 10-Vehicle was too small.

Consumers go through a post-purchase “consumer satisfaction” phase as well, in which they evaluate how good a selection they made. In this phase they may shape their future choices and

influence other buyers. Automobile sales people have told us that good fuel economy does not “attract” buyers, but rather is a “post-purchase” attribute that shapes initial consumer satisfaction in the months after purchase.

Also, the ranking of fuel economy may be shifting in the last few years; the Maritz study cited above may have measured indifference to fuel economy at its height (or depth, depending on one’s perspective). A U.S. Department of Energy review of several 1980’s studies by J.D. Powers and later studies by Opinion Research Consumer Insights, shows how fuel economy was important in the early 1980s, dropped in the 1990s and has risen a bit in the last few years.

Figure 3: Americans who say they considered fuel economy in their last vehicle purchase, percent.



Source: Gurikova, 2002.

In a survey of 1,000 adult American car and truck buyers, an ORCI 1998 survey reported found the following “things” that would motivate buyers to purchase a more efficient vehicle in an open ended question “For your next vehicle purchase, what would motivated you to buy a more fuel efficient vehicle?” (cited in Gurikova, 2002).

- 428 said they would be motivated if there were cost savings (159 lower sticker price, 130 said lower costs in general, 121 said lower cost of fuel, 43 said other cost savings)
- 219 said they would be motivated by features and performance attributes (104 said less pollution and acceptable emissions, 33 said hp and speed, and 99 said other features/options)
- 167 said they would be motivated by the fuel efficiency/gas mileage
- 46 said they would be motivated by availability of the type of fuel needed
- 105 said “other”
- 74 said “not interested”
- 87 said “don’t know”

This open-ended question reveals a complicated set of responses. Only 74 persons rejected fuel economy outright, the majority of respondents were interested in some sort of cost savings, a smaller number in other features, and 167 who essentially echoed the question.

3.4 Willingness to pay for better fuel economy

It is of great interest to regulators and car makers to predict whether and how much consumers will pay for technological advances that enhance fuel economy and efficiency, technologies such as light weight materials, continuously variable transmissions, low rolling resistance tires, or more complex technologies such as hybrid electric drive trains.

Automobile buyers are not accustomed to paying more for higher fuel economy; higher fuel economy has until the advent of hybrid drive trains been a feature of lower—not higher—cost vehicles. If consumers wanted higher fuel economy, they bought less expensive four-cylinder engines rather than the six cylinder engines, or six rather than the eight. They bought smaller vehicles rather than larger ones. They bought manual transmissions rather than automatics. They bought two-wheel drive rather than four-wheel drive. Higher fuel economy has not been marketed as an attractive feature in many years. Except for recent hybrid vehicles and some diesel-powered models, the differences in fuel economy between most comparable gasoline-powered models are only a few miles per gallon. For example, according to the EPA estimates a Honda Accord gets three to four miles per gallon better fuel efficiency than a Ford Taurus—a direct competitor in the midsize sedan category. If consumers were to calculate their annual savings based on such a difference, it would be between one and two percent of the annual cost of owning and operating the vehicle. There are greater differences between vehicle types, such as between a midsize sport utility and a midsize sedan, which can approach three to four percent of the annual cost of ownership and operation, depending on the annual miles driven.

But, as we noted above, most consumers probably do not know their annual costs, per mile costs, or other measures of fuel costs. They *might* know the MPG of their different vehicles (our interviews reveal many don't) and might read the EPA labels when shopping (our interviews indicate few do). Moreover, obvious differences in upfront vehicle prices are likely to overshadow future fuel cost savings and maybe other concerns related to fuel consumption. Additionally, many of the options consumers seek, such as good acceleration, ability to tow, perceived safety, automatic transmissions, air conditioning, four-wheel drive, large cargo space and interior room decrease fuel economy, and thus conflict with and also overshadow marginal improvements in fuel economy.

However, based on the issues discussed above and results of our recent interviews with households, we believe measuring willingness to pay for fuel economy is currently a problematic research direction. Since they have not been faced with the reality of paying more for higher fuel economy, consumers might only have enough sensibilities about MPG to respond to close-ended prompts (such as “would you pay \$500, \$1000, or \$1500 for better fuel efficiency?”) or to offer some dollar amount off the top of their head. But their answers to such questions will not be based in how they behave when they purchase a vehicle; inferences from such questions should not be made in literal dollars and cents. For example, ORCI asked the following question was asked for NREL in a telephone survey of adult Americans: “How much more would you pay for a vehicle that gets 10 percent better fuel economy?” Responses from the 180 respondents are summarized below. The results might appear encouraging; nearly four of ten respondents indicate they would pay more than \$1,000 more for a vehicle with ten percent better fuel economy.

We are more cautious in our interpretation of such results. We ask a similar question in our current interview work and find that many of our respondents are not telling us how much they would be willing to pay. Rather, they are trying to estimate how much they thought such improvements might cost, or are trying to answer in a way that seems to them to be “reasonable.” In fact, most reveal they have no way of knowing how much they would be willing to pay.

Figure 4: “How much more would you pay for a vehicle that gets 10 percent better fuel economy?”

Dollar Amount	Percent
None	18
<\$500	7
\$500-1000	15
\$1001-2,500	17
\$2,501-5000	15
>\$5000	5
Don't know	23

N = 180.

Reported in (Gurikova, 2002)

Over the years, we have studied the potential market for electric vehicles and other automotive technologies, interviewing hundreds of Californians in their homes, and surveying additional thousands through telephone, Internet, and mail-back surveys. We have noted in several instances that responses by consumers gravitate to what we call “magic numbers” (Turrentine and Kurani 1995). For example, with electric vehicles we often found that a large percentage of our households, when asked how much range they wanted, would initially say “100 miles,” regardless of their needs. We had to dig deeper to find a more informed answer—100 miles was a simple, initial answer to a complex and novel question.

We see evidence of these “magic number” responses in other studies too. In household interviews or focus groups, large numbers of participants will routinely answer with a “magic number” such as “\$1,000” or “\$2,000” as an incremental amount they would be willing to pay for a new technology (and environmental benefit) they are being asked to consider. Also, focus group moderators and survey questions often prompt respondents with a range of big, round numbers, e.g., \$500, \$1000, \$2000, \$5000. Often the largest number of proffered response is \$1000 or sometimes \$2000. We see these ranges offered regardless of the technology being researched, whether it is a hybrid electric drive system, a battery electric vehicle, a CNG vehicle, or clean diesel.

We suspect these magic numbers are not measures of actual “willingness to pay” but rather are simpler, almost a yes/no response—high amounts are “yes” and zero or low amounts are “no.” When consumers are being asked to consider a new technology such as hybrid drive train, or improvement such as better fuel efficiency/economy, or a social benefit such as lower emissions of criteria pollutants or greenhouse gases, we argue a “willingness to pay \$1000” must be read by researchers as an agreement by the respondent that the technology seems beneficial, and there will be some willingness by the respondent to pay. Alternatively, they may be saying \$1,000 is a reasonable price increase for a new car incorporating the new technology—regardless of whether they would pay this amount. In general, we are finding in our own work that the distribution of answers in willingness to pay surveys—especially for novel services and technologies—are complex, and if you look in greater depth, you find many consumers are guessing, uninformed, overly optimistic, or in some cases answer with what they think is the right answer—not what they personally would be willing to pay. Still, they are likely signaling that they may favor the new idea, or at least are interested in more information.

3.5 Trade-offs of fuel economy with other attributes that may flow from increased fuel efficiency

Safety, four-wheel and all-wheel drive, and towing packages for trucks are three vehicle attributes or features that have grown in importance to consumers over the past two decades. The automobile industry has in particular made much of the issue of perceived and actual safety as a function of the size of vehicles. They have argued that CAFE standards will force reductions in size or weight, which will in turn compromise safety. They also argue that consumers value size as a safety attribute. A question asked by ORCI for NREL in 1999 found that 82 percent of the 1,000 adult Americans polled thought a lighter vehicle was not as safe as a heavier vehicle in a traffic accident. Four-wheel drive is another technology added to vehicles that is antagonistic to increased fuel economy. Another question asked by ORCI for NREL, this time in 1998, found that 47 percent of potential pickup truck buyers, 8 percent of potential minivan, 16 percent of potential standard van, and 43 percent of potential SUV buyers planned to use their vehicle off-road (Gurikova, 2002). The sampled consisted of 439 potential light duty truck buyers.

The AAM website cites a 1996 J.D. Powers “Appeal” study that states more than half of light duty truck owners report using their vehicles to tow a boat or trailer. The AAM also quotes the Coalition for Vehicle Choice saying the percentage of passenger cars that are capable of towing 2,100 lbs has dropped from 68 percent in 1978 to less than 6 percent in 2000. The 1998 ORCI study of 439 potential light duty truck buyers, (pg. 47 Gurikova, 2002) found that 52 percent of potential pickup truck buyers, 32 percent of potential minivan, 33 percent of potential standard van, and 51 percent of potential SUV buyers planned to buy a towing package.

Another trend in recent years has been greater power and acceleration, usually to the detriment of fuel economy. A number of studies have examined this trend. Thibault reports on a 1999 GM research clinic, i.e., a market research method in which participants answer a battery of questions, often with vehicles to drive, see, and touch. In the study buyers were offered a range of vehicles with increasing power and price and decreasing MPG. Buyers in the low-end coupe segment and the medium size sedan segment were offered the variety of vehicles summarized below, and asked to rate the vehicles desirability on a scale from one (least desired) to five (most desired).

Figure 5: GM research on consumer desire for power and MPG

Vehicle Description	Average Rating (1 to 5)
“Low-end coupe” market segment	
2.0L, 4 cyl., 125 hp., 28/38 mpg.	2.2
2.2L, 4 cyl., 140 hp, 25/36 mpg.	2.5
2.2L, 4 cyl., 160 hp, 25/36 mpg.	2.8
2.2L, 4 cyl., Turbo 175 hp, 25/35 mpg.	3.1
2.8L, V6, 170 hp, 21/30 mpg	3.5
3.0L, V6, 190 hp, 19/28 mpg.	3.7
“Medium size sedan” market segment	
4cyl., 137 hp, 22/31mpg.	2.6
4 cyl. Turbo, 175 hp, 20/28 mpg.	3.1
6 cyl. 222 hp, 20/29 mpg.	4.5

While it is difficult to interpret these results other than as a measure of “wants,” the low-end coupe buyers preferred the most powerful engine even at a higher price and with poorer fuel economy. In a medium-sized sedan segment clinic 0, the desire and willingness to pay for power over economy was even more pronounced.

In contrast to the study above, an NREL study by ORCI gave respondents an option to buy five vehicles contrasting in acceleration, weight, and MPG. Of these three variables, weight is an unconventional attribute, not usually considered a choice attribute, especially when represented as “10% lighter” or “10% heavier.” These numbers are probably meant to represent “smaller” and “bigger” and to elicit conventional consumer thinking that bigger is safer. The study showed a sizable group of respondents choosing a lighter, average acceleration, more efficient vehicle. And it is surprising that only 17% consumers would choose 1.5 seconds faster acceleration over \$4 a month savings. While unconventional in asking about weight, this study illustrates alternative wording might yield some new insights to consumer values.

Figure 6: ORCI study of consumer choice for power and MPG

Vehicle Description	Percent choosing this vehicle
0-60 in 10.5 seconds, 27.5 mpg	15
Same acceleration, 10% lighter, 2 mpg better (save \$4/mo.)	27
1.5 seconds faster, 10% lighter, same mpg,	17
1.5 seconds slower 10% heavier, same mpg	16
Same acceleration ,10% heavier, 2mpg worst (cost \$4/mo.)	5

3.6 What can we learn from the Case of Light-duty Diesel Vehicles?

Diesel engines provide somewhat improved fuel efficiency and can provide greater fuel economy than gasoline engines depending in part on whether the diesel vehicle also matches the gasoline-powered versions in power and acceleration. Whether improved efficiency and economy translates to lower fuel cost depends in part on relative fuel prices. Further, diesel engines have typically been offered by a limited number of manufacturers in a limited variety of body styles. Further, diesel fuel is available at only a small number of retail locations compared to gasoline. With these other difference in mind, we review consumer experience with diesel vehicles for clues as to whether people value diesel vehicles higher fuel efficiency and economy.

3.6.1 California, 1970s to early 1980s⁴

Diesel-powered light duty vehicles have long been available in the US, but their greatest popularity to date came during the late 1970s and early 1980s in response to gasoline price increases and supply disruptions. In contrast to the current case in Europe (see the following section), diesel fuel did not enjoy a consistent per gallon price advantage during this time period in the US. It was true that diesel vehicles consistently cost more to buy than comparable gasoline-powered cars and light-duty trucks. Despite a flip-flop in the relative prices of gasoline and diesel fuel, some diesel vehicle buyers could have expected to save on their private fuel costs because of the increased fuel

⁴ This section draws on a case study of diesel light-duty vehicle markets in California in the late 1970s and early 1980s conducted by Kurani and Sperling. We include here updated discussions. The original studies include Sperling and Kurani (1987) and Kurani and Sperling (1987).

efficiency of the diesel drive trains. Kurani and Sperling (1987) reviewed some specific cases. Those results are excerpted and updated below.

Based on data published by Oldsmobile engineers regarding the 1978 5.7 liter diesel engine, assuming vehicles are driven 15,000 miles per year, owners of 1979 model year Olds 88s and 98s could expect to wait 47 to 54 months for their fuel cost savings to pay back the additional cost of the diesel engine (Jones *et al*, 1978). A shortcoming of that analysis is the implicit assumption that consumers have a zero time value of money—that is, their implied discount rate for future fuel cost savings is zero.

An analysis of the difference between vehicle purchase price and annual fuel costs for the 1981 model year Volkswagen Rabbit and the Peugeot 505 is given in the table below. It is assumed that the vehicles were driven 13,000 miles per year, diesel fuel was prices 3.6 cents less [per gallon] than gasoline, and fuel price differences remained constant. The results are presented for a range of annual percentage rates (APR). The chosen APRs span a range of relevant values, from the zero percent value of Jones *et al*'s (ibid) analysis to a high value still well within the range estimated by Train (1985) and Greene (1983).

Figure 7: Consumer choice for diesel and gasoline

	VW Rabbit	Peugeot 505
Diesel model mpg	40	28
Gasoline model mpg	28	20
Increase in purchase price for diesel model	\$425	\$1,000
Difference in fuel cost per year (gasoline – diesel)	-\$230	-\$307
Months for fuel savings to pay back purchase price premium at:		
0 percent APR	22	39
6 percent	24	44
17 percent	27	58
30 percent	33	154

At zero percent APR, e.g., a simple payback calculation as assumed in the Oldsmobile analysis, it would have taken 22 months for the fuel cost savings to pay back the higher purchase price of the Volkswagen Rabbit and 39 months for the Peugeot 505. As future fuel cost savings are increasingly discounted by higher implied interest rates, the payback periods increase—dramatically so in the case of the Peugeot for which annual fuel cost savings were a smaller percentage of the difference in purchase price.

In summary, diesel fuel prices were less than gasoline prices [from 1977] through 1981, and fuel costs per mile were less with diesel fuel throughout the diesel car era [1977 to 1985]. However, by 1983 the full cost of owning and operating diesel cars had increased relative to gasoline cars so that annualized costs were similar for both types of cars. When, if ever, diesel cars' operating cost savings would pay back the higher vehicle purchase price was dependent on when the diesel vehicle was

purchased, relative fuel prices, the number of miles driven per year, the make and model purchased, the purchase price, and financing.

It was shown in further analysis that diesel car owners' satisfaction with their diesel vehicle and the likeliness they would buy another were correlated with their assessment of relative per gallon fuel *prices*. It did not appear they used economically rational analyses of vehicle and fuel *costs*. That is, diesel car owners appear to have used pump prices as an *indicator* of savings instead of calculating actual net savings (or net costs).

These results are germane to the current case of regulating GHG emissions for several reasons. First, the rise of diesel car sales in the US during the late 1970s and early 1980s appears to have been driven almost solely by a desire for reduced fuel costs (and at least hoped for reductions in maintenance costs). These fuel cost savings were the result of improved fuel economy and for at least some time, lower fuel prices. The combination of these resulted in lower fuel costs. In this diesel case study—in an era of high and uncertain gasoline and diesel fuel prices—some consumers were willing to pay more for a vehicle with better fuel economy than a comparably equipped gasoline vehicle.

However, the case study also highlights the difficulty of abstracting from historical examples. While it is true that diesel vehicles achieved higher fuel economy ratings, they did so by employing a fuel other than gasoline. This introduced the complication of refueling within a relatively less dense network of stations—a source of uncertainty that would not affect buyers of more efficient gasoline vehicles. Further, the diesel vehicles, while appointed with similar amenities, had lower performance in terms of acceleration, were noisier, and had visible, sooty emissions under hard acceleration.

Second, the payback analysis summarized above should not be interpreted as providing the payback periods desired by buyers of Oldsmobile, VW, or Peugeot diesel vehicles in the 1970s and early 1980s. The calculations are simply examples of what those payback periods would have been if people made them at different hypothetical interest rates. Still, the approximately 40 percent fuel cost savings provided by the nominally higher fuel economy of the diesel versions and assumed lower fuel prices could have paid back the higher initial purchase price of these two vehicles in about two or three years.⁵

Third, diesel car buyers appeared to use a simple indicator or heuristic to gauge whether or not they were saving money on fuel costs. This indicator was the per gallon fuel price at the pump. Satisfaction with pump prices—not fuel costs—was correlated with satisfaction with their diesel vehicle and the likeliness they would buy another. Taken together, these second and third points indicate that even under conditions of high fuel prices (and uncertain economic and political times)—conditions that make accurate information about vehicle operating costs especially valuable—consumers appear to have used simplified measures. Notably, as we are seeing now in interviews with households nearly twenty years after this diesel car case study, satisfaction—or more to the point, dissatisfaction with fuel cost—is determined by pump prices for fuel, less so by the fuel economy rating of the vehicle.

Fourth, the extremely wide variation in consumers' implicit discount rates for fuel savings can be interpreted in several ways. If we believed households actually understood these financial calculations, the range could represent a segmentation of beliefs across the population about the

⁵ By “nominal fuel economy” we mean that the fuel economy of the diesel-powered models cannot be directly compared to their gasoline-powered variants because of differences in other energy-consuming services, in particular power and torque.

time value of money (something that almost certainly exists in some form). Alternatively, if people don't understand these calculations, the range may indicate simple guessing.

3.6.2 More recent US Polling Data on Diesel Vehicles

In 1997 ORCI asked 1,010 adult Americans whether they would buy a diesel vehicle that got 40 percent better fuel economy and cost \$1,500 more than a comparable gasoline vehicle. Three-fourths said no, only one-fifth said yes. (Gurikova, 2002. pg. 64). In 1998 ORCI asked the following question about diesel vehicles, "How much would you be willing to pay for a diesel engine that gets 30 mpg compared to the gasoline version that gets 20 mpg?" This study was segmented by probable body style of next vehicle to be purchased. The segment with the most interest in this proposed vehicle was the probable pickup truck buyers; probable SUV buyers were also more interested than other body style segments. Across all vehicle types, less than half of respondents said they would buy a diesel engine under the stipulated conditions; *more* than half of probable pickup truck buyers said they would buy a diesel under the stipulated conditions. Across all body styles, 30 percent of respondents said they would pay up to \$5,000 dollars; among probably pickup truck buyers, 41 percent said they would pay up to \$5,000 for the diesel option.

Figure 8: Willingness to pay extra for a diesel engine that gets 30 miles per gallon over a gasoline engine that gets 20 miles per gallon

Dollar amount	Percent of Total Sample	Percent of probable Pickup Truck Buyers
< or =\$500	7	9
\$501-1000	8	11
\$1001-2000	8	7
\$2001-5000	7	14
\$>\$5000	2	3
none	55	47
don't know	12	10

Source: Gurikova (2002). Table 4.3.4.

A third set of poll data from ORCI in 2001 (Gurikova, 2001, Table 4.3.5) posed the following question:

"Assume that a new vehicle you want to buy has two engine options that are equally clean, dependable, powerful, odorless, and smooth running. One uses gasoline and the other uses diesel fuel and gets 40 percent more miles per gallon but costs \$2,000 more. Which engine option would you buy?"

Similar to the previous question, pickup truck/van and SUV buyers were more likely to be interested in the diesel option. Across all body styles, 27 percent of respondents indicated they would buy the diesel option (under the stipulated conditions). Among pickup truck/van and SUV buyers the proportions were 34 percent and 37 percent respectively. These are three of the body styles for which diesel engines are currently optional. (A small number of compact, mid-size, and luxury sedans from European manufacturers are available in the US.) People familiar with diesel engines would perceive that the question as asked by ORCI offers diesel engines that are more favorable than those engines in the real world, i.e., odorless, smooth running, and a 40 percent efficiency boost. Those who rejected the diesel option either did not judge the benefits to be worth the higher price, or were unable or unwilling to accept the premise of the question, i.e., that diesel

engines would be equally clean, dependable, powerful, odorless, and smooth running as gasoline engines.

3.6.3 Recent European experience with light-duty diesel vehicles

More recently Verboven (1999) has tested the assumption of implicit discount rates against diesel and gasoline vehicle markets in Europe—diesel vehicles get better fuel economy than gasoline vehicles but cost a bit more to buy. He finds a range of more reasonable implicit discount rates in his aggregate data, closer to real interest rates.

Still, Verboven *infers* these implicit discount rates and payback periods; he does not directly observe consumer decisions. He believes that in Europe, diesels have reached technical parity with gasoline vehicles, that uncertainty has been removed in the fuel market, and that consumers have good information about their engine options. European policy makers have in recent years used taxes to make diesel vehicles more attractive. Tax breaks and near-technical parity between gasoline and diesel engines (in terms of European emissions regulations) has resulted in increasing sales of diesels. In the first half of 2002, nearly 2 out of 5 new light-duty vehicles sold in Europe had a diesel engine. There is considerable variation across countries. In Sweden, only 6.7 percent of new light duty vehicle sales in the first half of 2002 had diesel engines; more than half those sold in Spain, France, Luxembourg, Belgium, and Austria had diesel engines.

3.7 The Case of Hybrids

Vehicles with hybrid gasoline-electric drive trains have been introduced to consumers in recent years. To date, all such vehicles have been small sedans or coupes, though automakers have promised to release a variety of compact and mid-size SUVs and full-size pickup trucks starting in the summer and fall of 2004. So far, these hybrid vehicles have been sold at a price of a few thousand dollars more than the price of a variety of comparably sized gasoline vehicles. The hybrid models are offered with several optional amenities, e.g., leather seats, multi-disc CD players, and GPS navigation systems, as well as services, e.g. roadside assistance, similar to those offered as standard on the top end of conventional models. Response to the hybrid vehicles has been good, with sales above manufacturers expectations and even manufacturing capacity. And as we have discussed above, Toyota, Honda, and Ford are trying to capitalize on the early popularity of hybrids, competing to identify the environmental benefits of hybrid vehicles with their own brand.

Anecdotal information indicates that used hybrids are currently commanding high prices in the used car market, and that relatively few are traded-in to dealers. Instead, most appear to be sold privately by the original owners and their family, friends, and acquaintances. A quick analysis of new and used vehicle prices indicates that used hybrids are also commanding premium prices compared to otherwise similar gasoline vehicles. A prospective vehicle buyer faced with the choice of buying a new or used vehicle will find themselves paying more, proportionally for a used hybrid than for a similar gasoline vehicle. Based on prices obtained from the web site www.edmunds.com, two-year old 2001 Toyota Priuses are selling for over 70 percent of the price of a new 2003 Prius. 2001 Toyota Echos and Corollas are selling for about 50 percent of the price of a new 2003 model.

The case of the introduction of hybrid vehicles suggests there is a market for a vehicle that costs more than a similar conventional vehicle—if that new vehicle facilitates a discrete step up in efficiency. The question is why people will pay this premium—apparently for both new and used hybrid vehicles? Is it due to fuel cost savings, environmental concerns, innovative technology or some mix of the three?

3.7.1 Hybrid vehicle sales and consumer valuation of "fuel efficiency" and "fuel economy"

There have been many studies in the past couple of decades about consumer willingness to pay for new automotive fuels and technologies, e.g., CNG and electric vehicles. Most relevant to our

discussion here is the willingness of consumers to pay for hybrid electric vehicles, which offer greater fuel efficiency. Hybrid vehicle sales provide a preview of the issues concerning upscale buyers and willingness to pay for fuel efficiency.

For more environmentally oriented, affluent car and truck buyers, fuel efficiency may be a more desired attribute than fuel economy. More affluent buyers may be, or become, motivated if the technology used to accomplish higher efficiency is interesting or tied to social benefits like reduced greenhouse gas emissions and fuel security. In this instance, fuel economy, i.e., saving money, is a secondary benefit rather than the primary benefit.

If consumers were more interested in fuel efficiency than fuel economy, this would diminish and possibly even negate any rebound effect (in which lowering the cost of travel through higher fuel economy results in more travel). One of our interviews with a hybrid buyer revealed that the vehicle prompted searches for additional energy saving and travel reducing—not increasing—behaviors. They have begun to walk to market and are investigating transit schedules for commuting. Consumer interest in fuel efficiency might also counter arguments that the added cost to OEMs of new fuel economy technology will slow the overall turnover in the fleet, resulting in older vehicles being used longer, thus slowing improvements overall. In the case of reduced fleet turnover, it might be that consumers pick better efficiency, not for the few dollars it saves but in the same way they pick other added values.

3.8 Payback period / discount rates

Recent studies, especially those of automotive companies, have claimed that car and truck buyers will, on average, want to get back any increased purchase price due to new, improved fuel economy technology within three years (see Greene, 2003 for an example). The idea behind a payback period is that consumers will respond in a rational way to price increases. Few vehicle attributes are viewed in this way; for example consumers do not expect financial payback on leather seats, acceleration, or safety. (In the case of safety, people arguably are paying more for technologies they hope never payback; it all depends on how they view the probability of being in an accident severe enough that the additional safety technologies make a positive difference in protection and survival.) In the case of fuel economy, the assumption is that the consumer makes a simple calculation to estimate a payback period. For example, the consumer may estimate that a more efficient vehicle will cost \$600 more to buy, but that he or she will save \$200 per year in fuel, thus get a payback in three years. A more complicated approach uses what is called the *implicit inter-temporal discount rate*. In this case a consumer must make a calculation based upon both the annual fuel cost saving of \$200 but also the annual interest value of the money on the \$600 depending on the investment opportunities for the consumer. In this hypothetical case, the payback would be longer than three years as future savings are discounted.

While this makes some sense from the standpoint of implicit discount rates assumed by economists in a theory of consumer behavior, the idea that consumers actually use discount rates in making decisions is not accepted outside of economics. (The point is not whether they should, but whether they do.) Even the idea of payback calculations is seldom observed in household decision-making. Consumer researchers, particularly those looking at energy-using appliances, have argued that such interest calculations are beyond most consumer decision capabilities (Stern, 1992), cultural models (Kempton, 1995), and raw ability to calculate (Chater et al, 2003). A wide set of studies in the 1980s and 90s found that consumers were relatively risk averse, inferring consumers had discount rates as high as 70 percent for some energy-intensive appliances such as air conditioners (Sanstad and Howarth 1995). Risk-aversion in this case translates into consumers who prefer to pay less now for a more energy consuming product, than risk not getting back an initial up-front “investment” in a less energy consuming product. Such aversion is consistent with steeply discounted future savings.

Within the economics literature, various analyses in the 1980s concluded that consumers use implicit interest rates ranging from 4 to 40 percent in valuing energy savings associated with automobile purchases (Train, 1985; Greene, 1983). In Calfee’s (1985) analysis of hypothetical

choices of electric vehicles he calculated implicit discount rates for future fuel cost savings ranging from essentially zero to 92 percent. The evidence also suggests discount rates vary with income; on average higher income households appear to use lower discount rates than do lower income households. This is the equivalent of saying that, all else equal, higher income households should be willing to wait longer for a given investment in improved fuel economy to be paid back.

3.8.1 Use of Payback as an Explicit Policy Tool: Case of CNG in New Zealand⁶

There is at least one example of a case where payback period has demonstrably been important to consumers' decisions whether to adopt a comparatively expensive automotive technology. As a precondition of qualifying for a government-subsidized loan to pay for the cost of converting a light-duty vehicle to dual-fuel gasoline-natural gas (or gasoline-propane) applicants in New Zealand had to demonstrate a payback period of 24 months or less. Government-subsidized loans were available from 1983 to 1987. In 1985, terms of these loans were made less favorable; down payments were required, interest rates were increased, and the total number of available loans was limited.

The consumer experience in New Zealand involved a visit with a loan officer to make the simple payback period calculation. It is not surprising then that Kurani's (1992) analysis showed that payback period was an important part of consumer decision-making regarding vehicle conversions. It is equally clear that a 24-month payback period was not a result of consumer decision-making, but a cause of decision-making imposed by policy. In fact, as with buyers of light-duty diesel vehicles in California during the late 1970s and early 1980s, Kurani found that buyers of CNG (and LPG) conversions in New Zealand used unit fuel prices as measures of their satisfaction with their choice. The following discussion is excerpted from Kurani (1992).

Only the simple cost indicator, fuel price, corresponds to changes in kit sales. But recall that a person deciding whether to convert a vehicle in 1985 doesn't know that the fuel price advantage of new fuels is going to continue to decline. What she knows is that after five years of an increasing fuel price advantage for CNG, there has now been a one-year decline. What is the only possible assumption about future fuel prices? Only this, that they are uncertain—more so because the government has stepped back from strong statements in favor of maintaining the fuel price advantage and has begun to discuss deregulating the price of gasoline. (In the case of payback calculations I have implicitly assumed no relative change in fuel prices over time. This is the simplest assumption and the one used in loan qualification calculations.)

3.8.2 Detailed Household Examinations of Automotive Purchases and Fuel Economy

Early findings from the work we are still conducting indicates that it might be misleading to ask car and truck buyers about payback periods or discount rates. In the 54 detailed interviews we have completed to-date with California households, we have not encountered a single household or individual who have employed "payback period" concepts in their decisions about automobile purchases—either used or new. When questioned about payback periods, only a few understand the idea in the context of a car purchase, especially the idea of a payback period for fuel efficiency technology. Those who fully grasp payback periods or discount rates are those employed in financial careers, engineers, and others who are accustomed to making calculations.

Many aspects of vehicle purchases are not amenable to "payback" concepts—consumers might think leather seats increase the resale value, but don't expect to be "paid back" for their aesthetic appeal. Perhaps the one area in which payback concepts are used by several of our respondents is reliability of the vehicle, and therefore costs of maintenance. Here we do encounter some sensibilities by consumers about payback, but not in terms of calculating a specific payback period.

⁶ This section is based on a case study of dual fuel light-duty vehicles in New Zealand conducted by Kurani. We include here updated discussions. The original study is detailed in Kurani (1992).

Consumers are more concerned with identifying a reliable brand of car, than in calculating payback periods on hoped for reductions in maintenance and repair costs.

When pressed to state a payback period related to higher fuel economy, many households have been unable to estimate or even imagine one. Most commented that they had never thought about payback periods, and imagined that they would have to “do some math.” One financial analyst responded to our questions about the possible role of fuel savings in his household’s vehicle purchases, saying, “Oh, you mean the payback period. I never thought about it that way.”

What is clear is that no household, not even those who understand the calculations to find a payback period, ever actually made such calculations including fuel costs for their automotive purchases. If they do offer a payback period, they arrive at a number in one of a number of ways, including the following:

1. The length of time they financed a recent vehicle (typically three to five years)
2. The length of a lease of a current vehicle (often five years)
3. The length of ownership of a vehicle (depends on household and vehicle)
4. Some are optimistic, imagining they spend much more on fuel per year than they really spend and that paybacks are possible within one or two years.

None mention discount rates for future fuel savings.

4 Conclusions

We believe the meanings of important terms like “fuel economy” and “fuel efficiency” are 1) not shared by energy experts and lay consumers, and 2) may be evolving from their current meanings. The term *fuel economy*, while defined in federal law as “miles per gallon” (under specified test conditions), has historical usages linked to saving both fuel and money. In addition to these historical, political, and marketing meanings, experts and lay people distinguish “fuel economy” from “fuel efficiency” differently.

Energy and engineering experts tend to narrow the definition of *fuel efficiency* to its strictest technical measure—the ratio of useful energy out of an engine’s driveshaft to a unit of input energy. With this definition of efficiency, things like increases in fuel economy, size, weight, luxury amenities, towing, four-wheel drive, and more are all services that can flow from increases in efficiency.

Most consumers we have interviewed say fuel economy and fuel efficiency mean the same thing to them. If pressed for a distinction, many will say fuel economy is about money, and fuel efficiency is about how much gasoline is used. One respondent stated that fuel efficiency is a “classier” way to say fuel economy. A few respondents associate fuel efficiency with the new hybrid electric vehicles from Toyota or Honda. These respondents may characterize efficiency in terms of “saving natural resources,” but none mention greenhouse gas or CO₂ reductions or climate change in general.

It seems clear to us from even a limited number of interviews that it is unlikely consumers in general make the distinction between fuel efficiency and fuel economy that experts do. The implications for this lack of shared understanding include the possibility of mistaken inferences and conclusions from surveys and other research on consumers.

We may be moving from a past in which fuel economy was a primary component of a cost axis in the automobile market to a future in which fuel efficiency is a primary component of a value axis. Fuel economy is linked to a past in which many Americans had to budget their use of gasoline and fuel economy was associated primarily with reducing vehicle size, weight, and power; vehicle economy stood in contrast to luxury and power. To many consumers, fuel economy carries the notion of cheap vehicle. Along side this notion of economy, federal fuel economy provisions such as Corporate Average Fuel Economy standards were shaped by national security concerns

stemming from the 1970s and 1980s oil costs and growing imports. But with the low real price of gasoline in the past couple of decades compared to the escalating cost of other aspects of vehicle ownership—e.g., purchase price, financing, and insurance—fuel economy has been shrinking in importance in the vehicle market. Despite minor ups and downs in gasoline prices in the last few years, almost all growth in the automobile market has been towards larger, more powerful, and less economical vehicles. The economy segment of the market shrinks along with profits from that segment.

In effect, over the past several decades, consumers have complained about gasoline prices as if they see (which in fact they do) the current prices shown in Figure 1. However, they have made vehicle purchases (and other fuel-use determining decisions) as if the impact of the unit price of gasoline on them is shown by the constant dollar price curve. Current prices are cause for complaint, but over the longer term the generally declining generalized unit cost of gasoline has facilitated more energy consuming behavior.

The existing econometric literature offers little insight into this specific issue or to the central questions posed for this review—how will consumers respond to more economical vehicles that cost more to buy than less economical, but otherwise comparable, vehicles? Much of the literature is from a time when such choices simply were not available to consumers—thus there is no revealed data to analyze. Literature on revealed and stated choices for alternative fuel and electric vehicles does address the question of whether people will pay more for vehicles with lower operating costs, but in these analyses any changes in operating costs are confounded with changes in fuel type and therefore price, as well as fuel availability and refueling location. The most nearly relevant literature is on household response to higher gasoline prices. This literature indicates that household travel is relatively unchanging in the face of increases in gasoline prices in the short term; that households can make counter-productive changes, e.g., reducing miles of travel but shifting remaining travel to less efficient vehicles.

Additionally, there is the more specific question of how consumers have responded to regulation induce costs, such as air bags or catalytic converters. As we note in the review, consumer response these regulated costs are probably not discernable because they are not advertised to buyers and are buried among bigger price increases overall in the market in the past three decades as buyers have shifted to SUVs and other higher priced vehicles packages.

There may be lessons from past experiences with alternative fuels. The rise of diesel car sales in the US during the late 1970s and early 1980s appears to have been driven almost solely by a desire for reduced fuel costs (and at least hoped for reductions in maintenance costs). These fuel cost savings were the result of improved fuel economy and for at least some time, lower fuel prices. The combination of these resulted in lower fuel costs. In this diesel case study—in an era of high and uncertain gasoline and diesel fuel prices—some consumers were willing to pay more for a vehicle with better fuel economy than a comparably equipped gasoline vehicle.

However, the case study also highlights the difficulty of abstracting from historical examples. While it is true that diesel vehicles had higher fuel economy, they did so by using a fuel other than gasoline. This introduced the complication of refueling within a relatively less dense network of stations—a source of uncertainty that would not affect buyers of more efficient gasoline vehicles. Further, the diesel vehicles, while appointed with similar amenities, had lower performance in terms of acceleration, were noisier, and had visible, sooty emissions under hard acceleration. These differences though all point to people paying a higher generalized cost—in terms of money, performance, and convenience—than strictly the upfront monetary cost, for fuel cost savings (and perhaps longer driving range per tank-full). They did so however in an era of not merely increasing fuel prices, but actual gasoline supply disruptions.

From both the case of diesel cars in California and CNG vehicle conversions in New Zealand we learn that buyers appeared to use a simple indicator or heuristic to gauge whether or not they were saving money on fuel costs. This indicator was the unit fuel price at the pump. Satisfaction with unit pump prices—not fuel costs—was correlated with satisfaction with their diesel vehicle or CNG

conversion and the likeliness they would buy another. Even under conditions of high fuel prices (and uncertain economic and political times)—conditions that make accurate information about vehicle operating costs especially valuable—consumers appear to have used simplified measures. Notably, as we are still seeing now in interviews with households, satisfaction—or more to the point, dissatisfaction with fuel cost—is determined far more by pump prices for fuel, and less so by the fuel economy rating of the vehicle.

But as fuel economy has lost much of its market value, fuel efficiency, advanced technologies, and environmental values are an emerging value axis for consumers. Advanced technologies, such as hybrid vehicle systems, promise improved fuel economy without sacrificing luxury, size, weight, and power. And such new technologies offer cleaner air and reduced CO₂ emissions. Consumers are in a period of transition in technology, knowledge, and values.

The current introduction of hybrid vehicles in some ways expands on earlier episodes when consumers were offered non-incremental improvements in fuel economy. Based on historical data reviewed in Section 3 on average household expenditures for new vehicles, we find little reason to believe that in any aggregate sense safety and emissions regulations have stymied new car sales because of associated price increases. By the mid-1990s households were spending less of their income, in the aggregate, for new cars than they had in the late 1970s. It appears as if no more than one-third of the increase in average expenditure for a new car is associated with regulated safety and emissions improvements. The choices of some consumers to spend several hundred more dollars to buy diesel passenger cars also shows a willingness to make non-incremental changes under specific conditions.

It should not be inferred that “regulated” is synonymous with “not desired by consumers.” The question comes back to market segmentation and the ability to craft regulatory language that facilitates and makes the most of differences in consumer willingness to pay. Such segmentation is not based on inherent and unchanging preferences. The relevance of GHG reductions is subject to change based on information, education, culture, and opportunity.

We are interpreting our initial findings from our household interviews to mean that payback periods are probably a misleading concept as they have been applied in previous surveys. Minimally, surveys should establish first whether or not a consumer has ever employed a payback concept in a vehicle purchase, and whether the consumer would consider it applicable or practical for them to consider payback calculations related to fuel efficiency technologies. Consumers could be educated about payback periods. We are hypothesizing that some households might be convinced to accept longer payback periods given the social value of fuel efficiency combined with the savings from fuel economy; however others may require shorter payback periods if they see the declining role of fuel costs in their overall cost of vehicle ownership.

This review points to two diverging viewpoints. On the one hand, if consumers were to think in terms of pay back periods (and the related, more sophisticated, metric of net present value) then averages such as the “three year” figure cited by way of example by Greene (2002) could be meaningfully interpreted (though knowing the distribution of payback periods would be more useful). Almost every study conducted of consumer payback periods related to energy conservation shows a wide variety of *implied* discount rates. (That is, these studies don’t directly examine individual household expenditures, but infer discount rates from statistical models based on the assumption that the rate exists in the first place.) Never the less, a distribution of rates across households would suggest the existence of a market that can be segmented according to how long people are willing to wait to be paid back. We should not be concerned initially with the “average” payback period, but with those people who are willing to wait longer. Still, even within a context where payback period calculations were imposed on consumers, those signals carried far more than price information. In the case of dual-fuel vehicles in New Zealand, payback periods—as an explicit element of government policy—came also to signify government commitment to alternative fuels. The payback calculation and government loans were part of a package of price supports and taxes, refueling station incentives, and other government support for alternative fuels. Across the board

retrenchment on all these programs created uncertainty that may have had more to do with the continued decline and eventual end of New Zealand's experiment with natural gas as a transportation fuel than did the actual effect on vehicle conversion and fuel prices.

On the other hand, few analysts outside economic traditions accept the plausibility of consumer calculation of payback periods. Our ongoing work to study household automotive purchases supports this contention. We have found no household that thinks about fuel economy in terms of payback period. When asked to do so, households are clearly unfamiliar and uneasy with the concept. They grasp for familiar temporal anchors, e.g., their finance period, how long they expect to own the vehicle that are irrelevant to structured payback period calculations. Under these conditions, it is vital to pose questions about payback periods to households in an interactive context that allows the researcher to assess the "quality" of the response. Did the respondent understand the question? Have they ever actually thought about it before? Are they constructing an answer to a novel question on the spot or are they referring to a mental library to retrieve an answer from a question they have previously answered for themselves? In this view, the wide variation in consumers' implicit discount rates for fuel savings may indicate differences in understanding the question (of valuing energy savings over time) and its associated concepts, different heuristic answers, e.g., the temporal anchors of finance periods and expected time of ownership, and simple guessing.

To return to one of our basic questions—will consumers pay more for a more fuel economical vehicle? —We see indications they will under conditions of rising fuel prices, fuel scarcity, and vehicle-fuel options that appear to offer non-marginal options. Higher fuel prices alone—at least those experienced over the past few years—do not appear to prompt the purchase of vehicles with higher fuel economy ratings. More telling though, we find little evidence that consumers have the basic tools to construct meaningful answers to questions that have been posed to them about this issue. Our in-depth—and admittedly still preliminary work—research with households indicates the following.

First, assistance with payback or net present value calculations may simply reveal to most households that they will save less money, or wait longer to be paid back, than they guess.

Second, estimates of consumers' purported payback periods for fuel cost savings are likely too deeply flawed to form the basis of any policy. Many studies draw inferences based on the assumption that consumers act, or will act, *as if* they make decisions based on payback concepts. It is important to penetrate this assumption to understand how consumers actually make decisions.

Third, new—non-marginal—options matter. We see evidence that hybrid electric vehicles—which offer a non-marginal improvement in fuel efficiency and fuel economy—are subtly re-defining concepts like "fuel efficiency" to incorporate images of advance engineering and high quality.

Four, differences between expert and lay understandings of the basic terminology of the debate must be made clear and incorporated into future research. The possible cost of continued mis-communication includes mistaken inferences and therefore mis-designed policies to reduce greenhouse gas emissions and the risk poorer air quality.

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6 Appendix A

This Appendix summarizes polling data relevant to the underlying goal of reducing greenhouse gas emissions from the transportation sector. It includes primarily citizen response to political polls, as opposed to consumer responses to new products and technologies.

6.1 *Consumers and the larger context of collective benefits of reduced greenhouse gas emissions*

Government policy is one mechanism through which collective decisions are enacted in democratic societies. Regardless of their level of factual knowledge, citizens of those societies are asked repeatedly for their opinions of various policy measures. And more recently, as efforts to implement “market based solutions” to a number of social problems have been promoted, people are being asked to act as consumers, again regardless of their level of knowledge.

6.1.1 *Understanding polling data on consumers, climate change, and fuel efficiency*

We will interpret polling data and other studies of how people respond to specific strategies to reduce CO₂ emissions. These strategies include, but are not limited to, what it appears people will pay for reductions in greenhouse gas emissions from their personal travel. Rarely is the question asked as such. Much more commonly, and therefore a much greater part of this review, questions have been asked about greenhouse gas reduction strategies such as increasing fuel economy and switching to lower carbon fuels. We note that results of public polling in this topic area (as is true of all polling) are subject to large contextual effects. In fact, the very incidence of relevant polling tends to be driven by related policy events rather than an ongoing effort to monitor citizen/consumers. For example, numerous polls were undertaken leading up to the climate negotiations in Kyoto in 1997. Another round of polls accompanied the Bush administration’s announcement in the spring of 2001 that the US would not ratify the Kyoto Treaty on climate change. Conversely, Wirthlin Worldwide dropped a line of questioning on the public’s perception of the environment in the fall of 2001. Wirthlin had established a more than decade-long series of data, but in response to the terrorist attacks on September 11, 2001 they dropped these questions from what would have been their expected spot in a national survey done in early October of that year. (As we will discuss, the question was asked in a CBS/New York Times poll in the fall of 2002.)

Several events may have changed the context in which people evaluate the potential threats of global climate change, greenhouse gas emissions, and strategies to reduce them. The election of George W. Bush may have marked change in Americans’ assessment of environmental threats and their solutions. The terrorist attacks on the U.S. on September 11, 2001 may have done the same. The recent event with arguably the most direct effect on Americans and their vehicle purchase and use behavior was the initiation of a war in Iraq during the spring of 2003. The war created at least short-term uncertainty about petroleum prices and supplies. It also created clashing images of war protesters demanding (among other things) an end to what they claimed was a “war for oil” and war supporters and Hummer H2 drivers proudly identifying with real-time images from the war showing the military-version Humvee in action.⁷ In California, it is also possible that the political battle over the passage of AB 1493 during 2003 permeated public discourse to the extent that that discourse itself has shaped citizen/consumer awareness, knowledge, and consideration of global climate change and its possible solutions.

Before we examine citizen/consumer response to specific policy strategies and market conditions, we examine the larger policy context. Before addressing whether consumers will pay more for

⁷ For reporting on the impressions of some Hummer H2 drivers, see for example Hakim, D. (2003a).

products that reduce greenhouse gas emissions from transportation, we address whether citizens support the larger policy context in which governments propose to do “something” about greenhouse gas emissions. Polls driven by events such as those mentioned in the previous paragraph are typically designed to provide specific input to support arguments in favor of, or in opposition to, some outcome of the events. It is especially important to deconstruct such polls—to understand the sample, to have access to the full questions, to be able to compare question wording to other polls.

Another shortcoming of event-driven and policy-driven polling is that long-term, consistent sets of questions, asked of either a repeated cross-section sample or a panel, rarely exist. We show such long-term data series where we are able. As we have before, we recommend a multi-sponsor project to design and conduct a long-term tracking study to assess in a consistent manner over time citizen/consumer awareness, knowledge, and consideration of issues related to fuel economy, climate change, and clean air. Finally, studies and polls are infrequently conducted for California alone. Much of the data we present is drawn from national studies; we present studies and data specific to California on topics for which we have discovered them.

Efforts to shape public behavior through information campaigns and even marketing, are predicated on the idea that if people correctly understand a problem, and are offered a means to solve that problem, they will choose to adopt the solution rather than perpetuate behaviors that cause the problem. This premise shapes our analysis of political behaviors such as voting and participating in public meetings and consumption decisions about where to live and what products to buy. It also shapes responses to polls. Questions such as those that ask people whether they are willing to support tax increases to solve a particular problem can confound the problem with the solution—especially if the problem is not well understood by the respondent. That is, people may respond to the notion of higher taxes separate from their assessment of the problem simply because they don’t understand the problem well enough to have formed an assessment. The pollster thinks the respondent is addressing the problem/solution combination, while the respondent is communicating only their opinion of the proposed solution.

6.1.2 *What do consumer/citizens know? What do they support?*

So what do Americans know about environmental issues, and in particular, those related to global climate change? The results from three studies over the period from 1997 to August 2002 suggest that Americans lack basic knowledge about the environment to make informed choices about proposed solutions to a host of problems.

The National Environmental Education and Training Foundation commissions the survey firm Roper Starch Worldwide to conduct a *NEETF/Roper National Report Card on Environmental Attitudes, Knowledge, and Behaviors in America*. In 1997, the survey included a battery of 12 factual questions; the 1501 adult (age 18 or older) American respondents were graded according to how many they could correctly answer. The same battery of questions was repeated to a sample of 1505 adult Americans in the year 2000 study.⁸ The headline of the press release announcing the 1997 results was titled “Two out of Three Adults Flunk Simple Test on Environmental Knowledge.” Following the 2000 survey, the conclusion was that two out of three adults *still* flunk the same test. The NEETF’s gave the following general assessment in the second study:

“...Americans lack the basic knowledge and are unprepared to respond to the major environmental challenges we face in the 21st century.”

⁸ According to information on NEETF’s web site (<http://www.neetf.org/roper/roper.shtml>), the series was initiated by the Times Mirror Magazines in 1992 in collaboration with Roper Starch. The NEETF took over the survey in 1995. NEETF represents that their survey provides “...the only longitudinal data available on what Americans know and think about important environmental issues.”

In 2002, NEETF and Roper ASW concentrated on energy topics in their 10th Annual National Report Card.⁹ As with previous studies, NEETF reports that Americans know little about their energy, and worryingly, know less than they think they do. Only 12 percent of the sample earned a passing grade on the energy-specific environmental test; approximately three-fourths say they have “a lot” or “a fair amount” of knowledge of energy.

On the topic of the fuel economy of the cars and trucks they drive, most Americans think automotive fuel economy is getting higher. Only 17 percent of respondents knew (or guessed) that on-road measures of miles per gallon declined over the past several years. Only one-third knew that transportation is the largest user of petroleum in this country. On questions related to energy production and global warming, Americans were also uninformed. Just as many Americans mistakenly believed that most of our electricity comes from hydroelectric projects as correctly knew that most of our electricity comes from burning coal, oil, and natural gas.

6.2 General Public Support for Environmental Policy

We see two phenomena in polling data that are of interest to this review. First, there are efforts to characterize people as either more or less in favor of action by government to achieve environmental goals. Second, there are efforts to shape the answers to these questions by manipulating the context in which the questions are answered. These efforts to lead respondents may use question wording, question order, or some other element of the survey instrument.

We raise these issues to highlight the fact that the only survey results we have found in which high percentages of respondents have opposed government policy to address greenhouse gas emissions or strategic policies to achieve GHG emission reductions are studies in which respondents were clearly lead to oppose such actions. Examples include a poll by Wirthlin (2001) and a Competitive Enterprise Institute report on CAFE and safety (2002)¹⁰.

⁹ Roper also conducted this survey. Again, the sample was adult (age 18 or older) Americans contacted by telephone. The sample size was 1503. The study was conducted in August and September 2001. Though specific dates are not provided in the summary available to us, we surmise the study was completed prior to the terrorist attacks of September 11, 2001.

¹⁰ In the aftermath of the terrorist attacks of September 11, 2001, Wirthlin Worldwide constructed a series of questions in which respondent’s that chose to object to drilling the Arctic National Wildlife Reserve had to identify themselves as environmentalists in league with Saddam Hussein. The questions and responses are as follows:

“As you may or may not know, the U.S. Congress is presently debating whether or not to allow oil and natural gas production in the Arctic National Wildlife Refuge in Alaska, also know as ANWR. I am going to read you some statements regarding the ANWR. After I read each one, please tell me if you agree or disagree with each statement.”

Increasing our dependence on foreign oil will make the “Saddam Husseins” of the world more powerful and America more vulnerable.	
70 percent	Total Agree
50	Strongly Agree
19	Somewhat Agree
29	Total Disagree
14	Somewhat Disagree
15	Strongly Disagree
1	Don't Know/Refused

Most studies conducted over the past few years reveal that most Americans—in spite of or because of their relative ignorance of energy and environmental issues—support further efforts by government to solve environmental problems; differences do exist in levels of support across different, more specific, environmental problems. In the series of NEETF/Roper studies cited in the previous section, a plurality of Americans consistently believes regulations have “not gone far enough” to address environmental problems and issues. Even in 2001, after the current Bush administration came to power, a plurality of respondents (44 percent) to the NEETF/Roper poll said regulation had “not gone far enough.” This was more than double the percentage of those who thought that “current regulations go too far” (21 percent). Most of the remaining believed the then current laws “struck about the right balance.”

For many of the past years, Wirthlin Worldwide has asked the following question of adult Americans:

“Do you agree or disagree with the following statement? Protecting the environment is so important that requirements and standards cannot be too high, and continuing environmental improvements must be made regardless of cost.”

Though the allowed answers are a four-point scale from “strongly agree” to “strongly disagree,” Wirthlin Worldwide typically reports the data only as “agree” or “disagree.” (The question responses do allow for “don’t know,” but there is no mid-point to the response scale indicating a neutral response.) Wirthlin Worldwide dropped this question from their immediate post-September 11, 2001 poll (in order to focus on America’s response to the attacks). The question was included in a CBS News/New York Times Poll conducted in late-November, 2002.¹¹

For the past two decades a majority of Americans have claimed to be willing to pay very high costs to improve environmental quality. And even if there was a decline from the last year of the Clinton administration to the second year of George W. Bush’s administration, still a majority of Americans agreed with this statement.

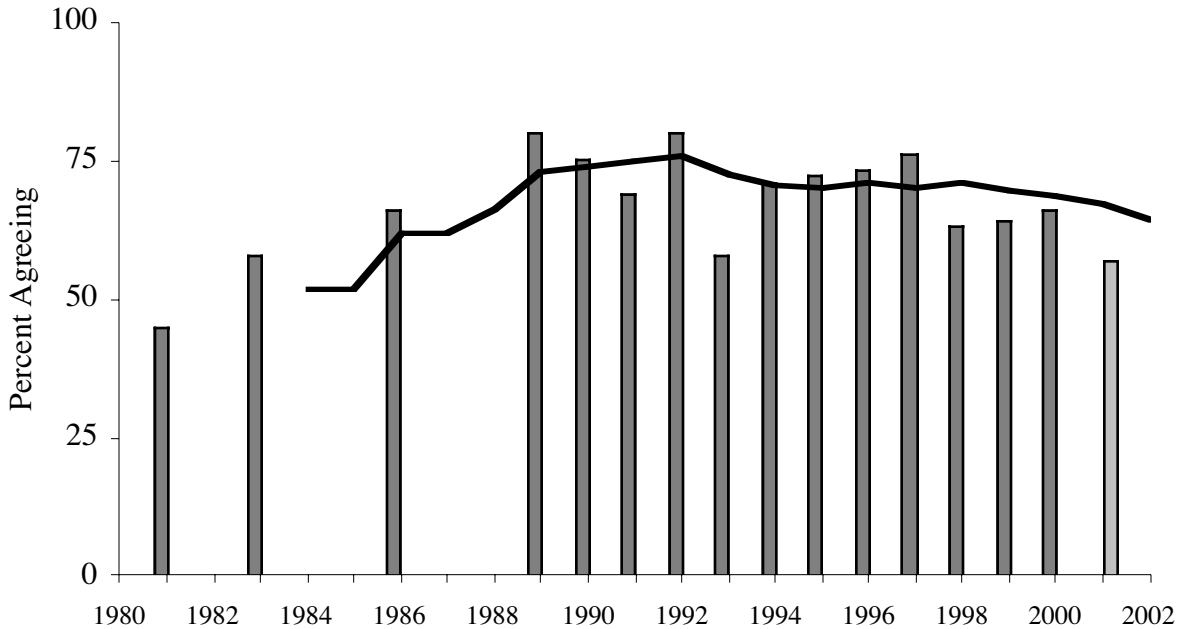
Environmentalists say we should preserve America’s last pristine wilderness in Alaska even if it limits our national security.	
34 percent	Total Agree
16	Strongly Agree
18	Somewhat Agree
64	Total Disagree
28	Somewhat Disagree
36	Strongly Disagree
1	Don't Know/Refused

The Competitive Enterprise Institute (2002) constructs a series of questions in which support for CAFE standards erodes as they “explain” its adverse effects on safety. Nowhere do they acknowledge the uncertainty and disagreement among experts about the information presented to respondents.

¹¹ In general, this question has been asked in a telephone survey. The samples in most years have been made up of about 1,000 adult Americans.

Figure A1: Importance of protecting environment

"Protecting the environment is so important that requirements and standards cannot be too high and continuing environmental improvements must be made regardless of the cost."



Note: The trend line is a five-year moving average.
 Sources: 1981 to 2000: Wirthlin Worldwide, 2000
 2002: CBS News/New York Times Poll, November 2002

Another question in the same CBS News/New York Times poll directly poses the question of whether respondents believe government—and the Bush administration in particular—should be doing more or less to protect the environment. The question and responses are summarized in the following table.

Figure A2: CBS News/New York Times poll “When it comes to regulating the environment and safety practices of business, do you think the federal government is doing enough, should it do more, or should it do less?”

Percent	All	Republicans	Democrats	Independents
“Should do more”	62	46	72	67
“Doing enough”	25	38	20	21
“Should do less”	7	12	4	6
“Don’t know”	6	4	4	6

Note: The CBS News/New York Times poll was conducted between November 20 and 24, 2002. The sample was a national sample of 996 adults. Sampling error is reported to be ± 3 percentage points.

The role of government in protecting the environment is one specific question that follows from the more general relationship between business and government in the area of environmental protection. The following question asks for the respondents' opinions of whether or not business can be trusted to "take care of the nation's resources," or whether "strong government rules and regulations" are required to protect the environment from businesses. In this case, there is more clear-cut evidence that Americans in general and Californians in particular believe that strong environmental regulations and enforcement are required to protect the environment. The margin of those who believe in the need for environmental regulation to those who believe businesses can be trusted is almost two-to one in California, and is more than that nationally.

Figure A3: LA Times Poll on business and environmental stewardship

Which of the following statements comes closer to your view: "Many businesses can be trusted to take good care of the nation's natural resources, and the government should intervene only in the worst cases," or "Many businesses will cut corners and damage the environment unless strong government rules and regulations are in place"?		
Percent	National	California
Businesses can be trusted	27	33
Businesses will cut corners	65	63
Don't know	8	4

Source: Los Angeles Times (2001)

6.2.1 Can we say anything more specific about Californian's perceptions of the role of government in environmental issues?

As describe in the preceding paragraphs, some survey questions asked specifically of Californians support the conclusion that Californians continue to support a strong role for government—federal, state, and local—in promulgating and enforcing stricter environmental laws. Studies done by the Public Policy Institute of California (PPIC) probes this in greater detail. The PPIC focused on environmental issues in their June 2000 (Baldassare, 2000) and June 2002 (Baldassare, 2002) Statewide Surveys.

Responses to additional questions lend credence to the interpretation that Californians believe government has a role to play in addressing environmental issues. The proportion of Californians who believe that stricter environmental laws and regulations are worth the cost rose from the survey taken prior to the 2000 general presidential election to the one in June 2002; rising to the point that more than twice as many Californians believe it as believe stricter environmental laws and regulations hurt the economy.

Figure A4: Change in number of Californians wanting more environmental regulations

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right.		
(1) Stricter environmental laws and regulations are worth the cost;		
(2) Stricter environmental laws and regulations cost too many jobs and hurt the economy.		
Percent	2000	2002
1) Worth the cost	57	64
2) Hurt the economy	37	31
Don't know	6	5

Sources: 2000; Baldassare (2000). 2002; Baldassare (2002)

More Californians opposed offshore oil drilling—even if it means higher gasoline prices—in 2002 than did in 2000. The shift is not as dramatic as in the previous question. Still, what was a majority position in 2000 became even stronger by 2002 when nearly six in ten Californians said they were willing to see an (unspecified) increase in gasoline prices rather than see the California coast opened to oil drilling.

Figure A5: Californians and off shore drilling

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right.		
(1) Policymakers should not allow more oil drilling off the California coast, even if this means higher gas prices for California drivers.		
(2) Policymakers should allow more oil drilling off the California coast if this means lower gasoline prices for California drivers		
Percent	2000	2002
1) No more drilling	54	59
2) More Drilling	43	36
Don't know	3	5

Sources: 2000; Baldassare (2000). 2002; Baldassare (2002)

Nearly two-thirds of Californians believe that protecting the environment is more important even if it means restricting energy production, than believe that energy production is more important. Those believing the environment is a higher priority than energy production outnumber those believing energy production is a priority by more than two-to-one.

Figure A6: Californians and energy policy, 2002

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right.	
(1) Protection of the environment should be given priority, even at the risk of limiting the amount of energy supplies—such as oil, gas, and coal—which the U.S. produces.	
(2) Development of U.S. energy supplies—such as oil, gas, and coal—should be given priority, even if the environment suffers to some extent.	
Percent	Percent
1) Environment is the priority	65
2) Energy is the priority	29
Don't know/other answer	6

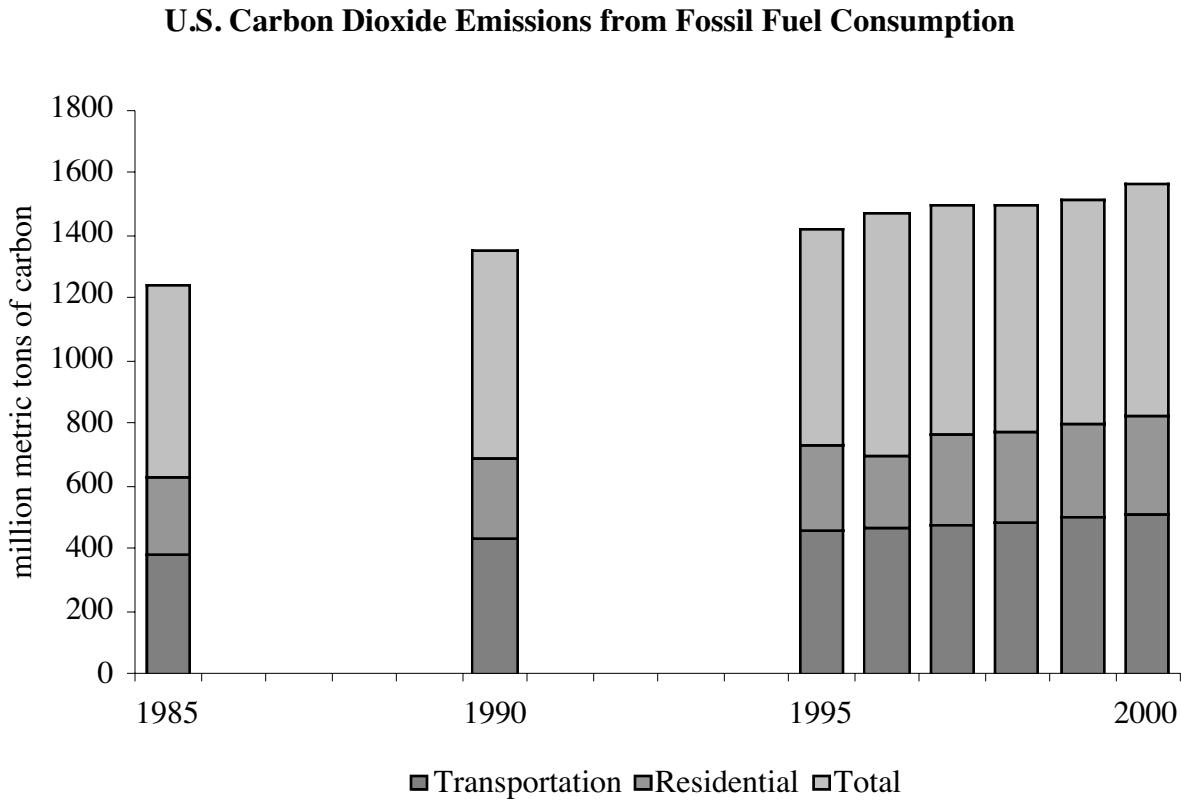
Sources: Baldassare (2002)

6.3 Consumers, Global Warming, and Fuel Economy

6.3.1 Basic Greenhouse Gas and Global Warming Information

There is certain information about global climate change and greenhouse gas emissions that it would be useful if citizen/consumers knew. These include the sources of greenhouse gas emissions and the relative sizes of those sources, the strategies for reducing those sources, the implications of global climate change, and ideally, the private and public costs and benefits of each of those strategies. As some of these (in particular the last) are relatively uncertain even to specialists, we can forgive the lay public for not having a complete picture of how to reduce the risks associated with global climate change. The figure below illustrates CO₂ emissions created by the consumption of fossil fuels in the U.S. over the period from 1985 to 2000. Emissions are divided the transportation sector, the residential sector, and all other sectors. First, are the total emissions for the U.S. large? Using world emissions of carbon as the standard, the answer is yes. In 1990, the U.S. created 23 percent of the world's carbon emissions; this rose to 25 percent in 1999. Within the U.S., how large are the emissions from transportation? They have risen slightly from about 30 percent of the total carbon emissions from fossil fuels in 1980, to about 33 percent in 2000. Further, more CO₂ emissions are created by the use of fossil fuels in the transportation sector than by the use of energy in residences homes.

Figure A7: Global warming and transport sources of CO2



Source: Davis, S.C. and S.W. Diegel (2002), Table 3.4

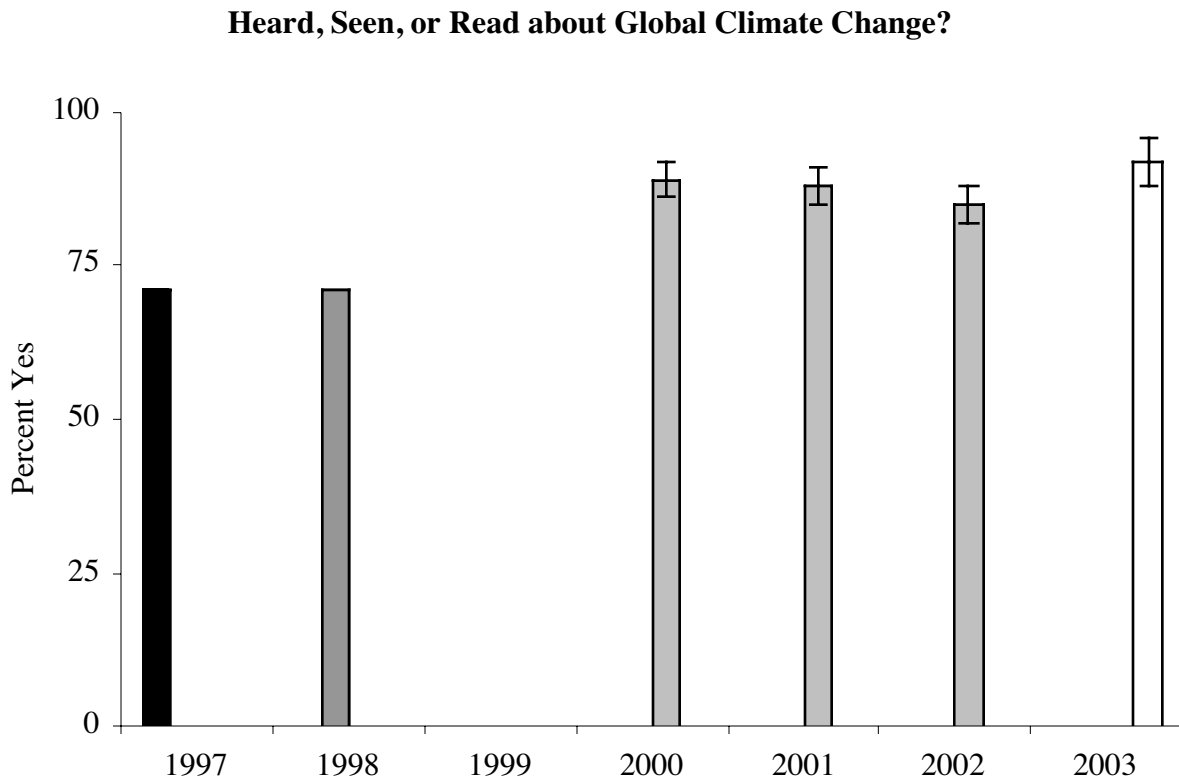
Several studies of citizen/consumer response to global warming are organized around a sequence of questions. The sequence moves from basic awareness of global climate change, through (usually self-reported) measures of knowledge, and on to support for various initiatives to reduce greenhouse gas emissions. As international negotiations of climate change treaties often spark polls of citizens, questions regarding specific international meetings, e.g., Kyoto in 1998 and Bonn in 2001 are often included. We will follow this same general outline in this section.

Data from numerous polls indicate that Americans have heard of the phenomena of global climate change. As the data in the next figure illustrate, by the turn of the 21st century, nine of ten Americans had heard, see, or read about global climate change.

6.3.1.1 Do people think that global climate change is a real problem?

Most Americans and most Californians have heard of global climate change; most believe the problem is real and that something should be done about it. Baldassare (2000) cites original and secondary sources to conclude, “A solid majority (57 percent) of Californians believe that there is evidence to warrant either immediate action (22 percent) or some action (35 percent) to address global warming.” Two years later, he cites responses from a new poll that show the percentage of Californians who believe global climate change is a real problem requiring action increased to 62 percent (Baldassare, 2002). The difference between the years 2000 and 2002 is within the sampling error of both surveys, so any representation of an increase should be made cautiously.

Figure A8: Have people heard of global climate change?



Sources: 1997: World Wildlife Fund National Survey. August 14. Cited in Gurikova (2002).
1998: Program on International Policy Attitudes. October 22-27. Cited in Gurikova (2002).
2000 to 20001: Harris Interactive (2002). Sampling error is reported as ± 3 percentage points.
2003: Leiserowitz, A. (2003). Sampling error is reported as ± 4 percentage points.

Notably, there are strong differences in responses in the 2002 survey according to political affiliation. A majority of Democrats, independents, and those respondents not registered as members of any political party at least believe there is enough evidence and we need to take some action to address global warming; only amongst registered Republicans do a majority believe either that more research is required before we do anything or that concern about global climate change is unwarranted.

We note that links between fuel economy and global climate change are not solely the purview of radical environmentalists. Two groups have gained national notoriety over the past year—one asking, “What would Jesus drive,” and the other linking poor fuel economy to support for terrorism. Even mainstream consumer information sources such as The CarConnection.com have counseled visitors about the link between fuel economy and global climate change. In an online article posted on October 1, 2001 (only weeks after the attacks of September 11) reporter Carol Traeger wrote:

“If a wallop to your wallet isn’t enough to get you to rethink your own family transportation, maybe you should consider the environmental consequences...One of the most important things you can do to reduce your contribution to global warming is to buy a vehicle with higher fuel economy...By cutting back on your

fuel usage, not only will you save money and help protect the environment, you'll help reduce our country's dependence on oil imports (a patriotic issue right now) and conserve resources for future generations. Plus, you and your kids can enjoy more stops at the yogurt store and fewer stops at the dumb old gas station.” (Traeger, 2001).

She goes on to highlight the most efficient vehicles in a number of vehicle classes and to provide links to government and NGO web sites that have more information. She has woven together several benefits of fuel economy that are in addition to the private fuel costs faced by drivers. This context is largely missing from the economic-based literature, which tends to focus only on what people will pay up front for increased efficiency to save money on fuel costs over time. Those benefits include reducing CO₂ emissions, reducing the nation's dependence on oil (with a specific if oblique reference to Middle East), conserving resources for the future, and the day-to-day convenience of fewer stops at gas stations.

Now, we can take issue with some of these. Within the context of buying a new car, most new cars (with the exceptions of hybrids) have about the same range per tank—less efficient vehicles tend to have larger tanks. So only by buying a hybrid (at this point in time) can you actually “buy” fewer stops at gas stations. And many economists argue that increases in efficiency aren't the best way to allocate resources, either across contemporaneous uses or across time; they argue for “right pricing.” There are notable difficulties with such proposals, not the least of which is their political unpopularity. (See Delucchi, 2000 for a discussion of both theoretical and empirical difficulties of such proposals.)

But the primary difficulty with information such as that presented by Ms. Traeger is the lack of specific follow-up to ascertain the effect of her article. This is not a specific complaint against her or CarConnection.com; the problem is much more general. We know that information linking global climate change to vehicle choices is available from a wide variety of mainstream and not-so-mainstream sources. Rarely however is the provision of information linked specifically to research on the effectiveness of the combined message and media.

6.3.1.2 Policy support in California

We are now poised to ask whether or not there is support amongst Californians for the state to take action on fuel economy and global climate change. Again, the Public Policy Institute of California has asked this question of Californians (Baldassare, 2002). Their question and the survey responses are reproduced below. A vast majority of Californians supports the state taking action to reduce greenhouse gas emissions from new cars. Even among those who profess to believe that more research is required before taking action a “veto-proof” two-thirds majority favor this action.

These results are repeated in yet another survey by the PPIC in the summer of 2003. A large majority of Californians (68 percent) believes greenhouse gas emissions, if unchecked, will lead to global warming. Even more people (73 percent) state that steps to curb greenhouse gas emissions need to be taken immediately, despite the fact that only a minority (45 percent) believes that global climate change will pose a serious threat to them in their lifetimes. And again, 80 percent of Californians support the state of California taking action to limit greenhouse gas emissions from new cars.

Figure A9: PPIC poll, “Do you favor or oppose a state law requiring all automakers to further reduce the emissions of greenhouse gases from new cars in California by 2009?”

“Do you favor or oppose a state law requiring all automakers to further reduce the emissions of greenhouse gases from new cars in California by 2009?”			
	All adults	Belief about Global Warming	
		Change is real/Action needed	More research needed/Concern is unwarranted
Favor	81%	90%	67%
Oppose	16	9	29
Don't know	3	1	4

Source: Baldassare (2002)