04A0091
WGM-5001-41

Alternative Vehicles

An Interactive Qualifying Project Report
Submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science
By

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August 30, 2004

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Project Number: WGM-5001

Acknowledgements

I would like to thank Fred Hutsen for facilitating many of the interviews and providing continued support and input throughout this project. I would like to thank Professor Ed Clarke for his continued consultation and support, and for his invaluable time and information on the research of the various forms of alternative vehicles. Special thanks to Gille Labelle of Westboro Toyota for his expertise and references. My sincere appreciation to Stephen Loring for his generous invitation to attend a Rotary Club Luncheon. Thanks to Professor Datta for his input, support and references. And special thanks to my advisors Professor McGimpsey and Professor MacDonald for organizational direction and encouragement.

ABSTRACT

The purpose of this IQP is to research and discuss the various forms of alternative energy powered motor vehicles currently under development and to obtain information pertinent to automobile manufactures via surveys to that will provide insight into the publics perceptions of such vehicles. This insight will aid in the development of a representation of how drivers are using their automobiles as well as a set of standards/criteria such alternative vehicles would have to meet in order to make them commercially viable.

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1. Introduction

This project is designed to explore and to assess the practical and environmental concerns of internal combustion engine alternatives which are currently being manufactured for both current and prospective commercial use. Through researching the current technology of how internal combustion alternatives operate and how they are manufactured, important environmental issues regarding the energy and effort that is required to produce them, as well as how they are disposed of will be addressed. In addition, consideration will be given to where the energy to supply the various types of alternative vehicles comes from and whether it is both efficient and environmentally sound. Current and prospective combustion engine alternatives that will be discussed include: electric, fuel cell, flex-fuel, bi-fuel, and compressed natural gas. After determining the environmental concerns regarding each of the considered types of vehicles; governmental and data obtained from dealerships, current owners and statistical data obtained from previously related studies will be used to determine the efficiency, reliability and practicality associated with each of the currently employed alternative vehicles. Information made available through public sources and dealerships will be used to evaluate and estimate the cost of owning, maintaining and disposing of each of the currently and potentially available alternative vehicles. Issues pertaining to the employment of these vehicles will be explored through researching the accessibility to the public (rural and city) as well as public and corporate fleets. An evaluation of the public's

knowledge, concerns and opinions of the various alternative vehicles will be conducted through two surveys. Both surveys will elicit information regarding how people use their current vehicles and what they would want from their prospective future vehicles that is pertinent to automobile manufactures. Taking all of the above information into consideration, this project will determine from a primarily environmental standpoint which of the currently produced alternatively powered vehicles is most suited for public use, and will also suggest which appear to be most promising for commercial use within the next five years.

2. Research

Rising environmental concerns and escalating costs have driven society to begin developing alternatives to one of the most integral parts of our lives; the automobile. With increasing emissions currently being released from conventional automobiles and dwindling resources to supply them, technology is now forced to address the automobile as a central cause of pollution and an approaching energy crisis.

2.1 Electric Vehicles

Prior to the 1830's, steam was the first powered means of public transportation, using electricity as the means of electromechanical energy conversion. (Hussain, 3) Led by Faraday's invention of the direct current (DC) motor in 1831, developments of the electric car progressed up until the 1900's when 38% of all vehicles were electric, 40% steam and 22% gasoline powered. It was not until the invention of the starter motor in 1911 which gave internal combustion engines the advantage of convenience, that the country began to evolve toward its current dependence on gasoline powered vehicles. The concept of electric vehicles as an alternative to the combustion engine was not revisited until the 1960's when gasoline powered vehicles where recognized as a source of environmental concerns leading major manufactures such as General Motors and Ford to begin investing in research and development of alternatively powered vehicles. Although the acceleration of the electric vehicle was comparable to gas powered vehicles, the slow top speeds attained and the heavy, expensive, and inefficient silver-zinc battery were indications that the level

of technology was not yet commercially acceptable. Research by the government was not employed until the 1970's when gasoline prices soared and independence from foreign oil was a goal of the government. In 1976, Congress enacted Public Law 94-413, the electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976, which authorized a federal program to promote the technologies of electric and hybrid vehicles. (Husain, 5) Since then, dramatic technological improvements to the electric vehicle have been made. Improvements such as: high-power, high-frequency semiconductor switches, improved microprocessors and improved power converters, have been design to drive the motors more efficiently. (Chan, 19) Increased legislation by the California Resources Board in 1990 determined that by 1998 2% of all vehicles should be zero-emission, 5% by 2001, and 10% by 2003. Due to impossibly high standards, the mandate was revised to require that 4% of all vehicles sold by 2003 be zero emissions. .

The energy required to power a purely electric vehicle comes from two sources: applied and stored power. Applied power being the electricity generated from raw materials (whether it is from a nuclear, hydro or fossil fuel plant) that is used to charge the battery, and the stored power being actual power delivered to the vehicle by the battery. In order to determine the overall efficacy of a vehicle, the vehicles efficiency must be evaluated as the product of each of its component stages that involve an input and output of energy from the conversion of energy at the plant to the deliverance of energy from the drive shaft to the wheels. Since the transmission of chemical energy stored in the battery of

an EV that is used to generate energy for the vehicles propulsion, much of the vehicle's efficiency lies in the capability of its battery. Unfortunately it is the battery aspect of the EV which is the primary hindrance in preventing it from reaching a mass market. Although extensive research on EV batteries has been done over the past 30 years, many feel that there is still currently no battery that can deliver an acceptable combination of power, energy, and life cycle that is needed to make a commercially viable vehicle.

Early models of electric vehicles relied upon power generated from primary DC batteries which only allowed the flow of electrons to travel one way, making them capable of only a single discharge. Secondary batteries are now employed which allow the electrons to move back and forth in cycles and thus are capable of regeneration and recharging. Of the numerous types of secondary batteries used in prototypes, the most common include: lead-acid, nickel-cadmium, nickel-metal-hydride, lithium-ion, lithium-polymer, sodium-sulfur and zinc-air. The general design of an EV battery consists of a positive and negative electrode immersed in an electrolyte and partitioned by a separator. Oxidation and reduction reactions take place continuously between the two electrodes upon connection of their circuit to discharge electrical energy. The connection of the circuit between the two electrodes allows electrons to flow from the negative electrode through the electrolyte to the positive electrode. The flow of current is then directed to an electric motor, turning the drive shaft and then the vehicle's wheels. The electrolyte must have a high and selective conductivity for the ions that take part in the electrode reactions, while also being able to act as a non-

conductor for electrons in order to avoid self-discharge of batteries. (Hussain, 45) The pieces acting as a separator (usually a polymer) between the two sides of different charge must be both permeable and stabilizing to the traveling electrons. Unfortunately, a process known as self-discharge does occur, allowing some current to flow regardless of whether the circuit connecting the electrodes is not completed; causing the battery to gradually discharge itself and thereby decreasing its longevity. Until engineers are able to overcome or significantly reduce the process of self-discharge EVs will not be capable of long distance travel.

The lead-acid battery, as a result of its low cost (readily available materials and inexpensive to manufacture), safety, reliability and ability to generate considerable power, is the current battery of choice for today's EVs. A lead-acid battery consists of a negative electrode made of solid lead (Pb) and a positive solid lead-oxide (PbO2) electrode which depletes to form lead-sulfate and water. During recharging, the supplied current from an external source forces current through the positive electrode to restore the created lead-sulfate back into its original reactant states of lead and lead-oxide. To counter the accumulation of oxygen in the positive region of the battery cell, considerably porous separators are used to ensure even dispersion. Although the technology of the lead-acid battery continues to progress, their unreliability in cold temperatures and short life cycle contribute to the factors preventing EV commercialization.

The nickel-cadmium batteries use an alkaline electrolyte in a reaction between metal and oxygen. Compared to the lead-acid batteries, the nickel-

cadmium batteries have a longer life cycle, greater reliability and enhanced performance capability in low temperatures. It is cadmium toxicity that makes their safe usage and effective environmental disposal a work in progress. To eliminate the toxic concerns associated with cadmium, the nickel-metal-hydride battery was developed and is now used in some EV and many HEVs. Their drawbacks include: high cost, elevated self-discharge rate and poor performance at higher environment temperatures. The lithium-ion batteries present an opportunity for a productive EV and HEV future with their excellent power ratings, low self-discharge rate, good temperature performance and easy of recycling. The listed lithium-polymer, sodium-sulfur and zinc-air are among many prototypes of batteries currently being engineered for suitable application to EV and HEV vehicles.

Many people are under the impression that EVs have a limited maximum highway speed; however, recent developments in EV technology have made EV conversion more efficient and performance more acceptable. The maximum speed of a typical EV ranges between 60 and 80 mph, depending on the volt conversion of the battery pack voltage and how much it is charged. The common 96-volt conversion of a small EV has an average expected speed of 65 mph, while the more powerful 120 volt battery of a sports EV such as the Porsche 914 can reach top speeds around 85 mph. A single straight terrain highway conversion draws energy from about16-20 six volt batteries. The range of the typical EV using a lead-acid battery is about 50 miles, while the use of a nickel-metal-hydride or lithium ion battery can enable them to travel 180 miles. The

maximum ranges are negated, however, by the use of air conditioning and power draining sound systems and the maximum ranges assuming good driving habits.

In order to facilitate current EV users and encourage potential customers, organizations such as the Electric Auto Association is working with the public and current EV owners to develop a reliable and effective charging infrastructure. Seeking agreements with public property owners of facilities such as malls, municipal parking lots, hotels, and other public areas to install electric vehicle chargers is one of the many steps the EAA is taking to help integrate the electric vehicle into society. The EAA has also gone as far as establishing a system of providing service to EV customers traveling out of the range of public recharging stations. Through establishing a network of current EV owners, the EAA has made it possible for EV vehicle owners to access a list of EV owners and their addresses whom have opened their home charging systems to other EV travelers. EAA members also share the responsibility of making frequent checks on establishments offering recharging services to EVs to regulate and monitor their reliability in terms of both working service and enforcement of “EV only” parking spaces. EV owners are encouraged to report any vehicles violating “EV only” parking slots as there are considerable fines. It is networks such as the EAA that have enabled the use of EVs, and help secure them a future in society.

Recharging of an EV can be done at both public and private stations. Installing an EV recharger entails simply plugging the device into any regular 120

volt outlet and selecting the desired charging current. Home charging usually takes between 6 and 8 hrs (overnight). Public facilities usually offer stations with 208 to 240 volt chargers, enabling a complete charge in two to six hours. However, one manufacture claims to have recently developed a 59 kW battery than is said to recharge in a matter of minutes. The battery of an EV does not have to be fully charged in one sitting, but can be recharged in spurts, leaving the final overall charge to be completed at night.

The life expectancy of a lead-acid battery is about three years depending upon how it is maintained. "Lead-acid wet cell batteries need to have distilled water added monthly, it can be a 15 min chore if one uses a dedicated plastic garden sprayer with the sprayer removed. A 20 battery pack might need a gallon of water per month. A gallon of distilled water at the grocery store is about $1."(GMEV.com) A new lead acid battery pack typically costs $1,000-$1,200. (eaaev., 3) Although more expensive, Nickel metal hydride batteries are designed to last the lifetime of the vehicle.

For a 94 volt lead acid battery the average costs of electricity per mile is about $ 0.05, depending on your location. Most public charging stations are free. However, economic issues regarding on and off-peak time periods and the adverse effects on the power grid of using a high voltage quick charging system poses a significant level of inconvenience. In contrast to domestic recharging, it is much more difficult to develop a public charging system because there are many factors such as electrical safety, ergonomics, weather conditions, variation of EVs and availability of areas for charging stations that need to be taken into

account. (Chan, 256)

The recharging of EV can have both positive and negative effects on power systems. Off-peak usage can even out the demand on power system facilities, while usage during normal periods can generate additional encumbrances on existing power systems.

When considering the prospect of replacing many of the internal combustion engine that now exist with EVs or HEVs vital issues arise, such as: the availability and convenience of re-charging stations, the management of clean and efficient charging and the overall evaluation of environmental impacts from the vehicles themselves and the power plants they utilize power from. According to the EAA: an electric car is 37%-97% cleaner than a comparable gasoline powered car, even including the pollution generated by the electric power plant. (U.S. Dept of Energy) The 37% pertains when more polluting sources of energy such as coal are used and the 97% pertains to when the more desirable hydro, wind and solar energy are utilized. However, statistics as of December, 2003 released by the US Department of Energy indicate that compared to the 37% coal that is used to produce our electricity, virtually no wind and solar is used, while 4% nuclear, 3% hydro are used. The type of electricity that would be used to power ones electricity is dependant upon where in the country you live. Just as the type of alternative vehicle you drive will be dependant upon the accessibility of the fuel in your area; for example, recharging facilities are only currently available in half of the states. If you live in California and recharge your EV

primarily at night then your vehicles is essentially emission free because electricity purchased during night time hours id drawn from hydro-electric energy sources in Washington and Oregon. Battery packs comprised of lead-acid are 95 % recyclable, and are both cheap and clean to recycle.

For a time electric vehicles appeared to be the solution to emission problems, however due to the overall low mileage and performance capability, car companies like Toyota and GM produced models that never made it to the mass production lines. However the remarkable progress made in the development of EV's paved the way for the innovation of powering up the performance of an HEV with the high powered electronics made possible by the work on electric engine.

2.2 Hybrid Electric Vehicles

The hybrid electric car was developed in response to both growing environmental concerns associated with the conventional internal combustion engine and to compensate for the electric vehicle's lack of performance capabilities. Toyota, currently the leading manufacturer in hybrid technology began its research in gas electric vehicles in the early 70's. By 1995, Toyota had completed it first version of the current Prius and in several years was made available to the Japanese public. By not being available in the US until 2000, Toyota manufactures were given ample time to equip the Prius model with performance capabilities required for American highways. The basic hybrid operation can be described as follows: Through utilizing both an internal combustion engine and the stored electrical energy available from a regenerative braking system that can be periodically fed to an electric motor, the power system of a hybrid vehicle is able to deliver better mileage than the standard internal combustion engines and provide better range than any electric vehicle currently available. "Vehicle design complexity increases significantly with hybrid vehicles because controls and support systems are needed for a thermal engine and an electric machine in addition to the components needed for controlled blending of power coming from the two sources". (Hussain, 243) Hybrids rely on more than one energy source for power for their propulsion. The generator/starter initially engages the internal combustion engine, and then as soon as the internal combustion engine is warmed up or after your first stop or "idle stop", depending upon the make and model of the hybrid, the ICE shuts off

automatically, allowing the electric motor to take over. Taking advantage of the energy normally wasted during idling, the HEV recharges it battery until the accelerator is pressed. The electricity stored in the battery pack is used by the electric motor to propel the vehicle traveling at low speeds, up hills, and during acceleration, where gas engines are least efficient and most polluting. For the duration of driving time, a computer system will be engaging and disengaging the ICE by monitoring the amount of energy being required. The electric motor and the internal combustion engine exchange power through a set of nickel-metal-hydride batteries. When the vehicle comes to a stop its computer directs the system to store the excess energy from the brakes into batteries to be used later by the electric motor. The computerized system then passes power stored in the batteries (by the use of smaller capacitors) to the electric motor for acceleration. The computer must also continuously monitor the amount of charge in the batteries, making sure that they never charge over 70% and never under 30% of their capacity, thus ensuring that the batteries will last a couple of hundred-thousand miles.

Due to the intermittent aid from the electric motor, the gasoline engine can achieve better gas mileage while maintaining basically the same operation of a conventional car despite its smaller, more efficient size. However, the addition of a regenerative braking system requires the implementation of a complex computerized system which has proven to be not too convenient to manufacture and maintain.

Although companies such as Honda, GM and Chrysler are competing in the Hybrid market, Toyota still produces the most powerful hybrid yet, the 2004 Prius, which accelerates better than a four-cylinder Camry but gets twice the mileage. Experts estimate that hybrid-electric vehicles will play a significant role in the auto industry's future despite the promise that the hydrogen fuel cell vehicle may eventually power an even more satisfactory alternatively powered vehicle. Since fuel cells currently lack in technology and infrastructure, hybrid vehicles offer a significant improvement in emissions. "Even bumping up the average gas mileage of US vehicles to a modest 40 miles per gallon by 2012 would mean the United States could trim its oil consumption by three million barrels per day—more than its imports from all the Persian Gulf countries. And although buyers may have to pay more initially for gas-electric hybrids, they could save, on average, $5,000 at the gas pump over a 15 year life of the vehicle."(MIT mag)

2.3 Hydrogen Fuel Cells

First used by NASA in the 1960's as a source of electrical power, hydrogen powered fuel cells are now being aggressively researched as an answer to our domestic dependence on electricity. A fuel cell is a device in which a chemical reaction occurs to produces electricity with a continuous source of fuel provided, unlike batteries which must be periodically recharged. The fuel supplied to a fuel cell consists of hydrogen and oxygen, and like a battery, a fuel cell consists of an anode and a cathode. Inside the fuel cell, hydrogen molecules are broken apart at the anode into hydrogen ions and electrons, which allows for the remaining protons to travel through the electrolyte, reaching the cathode and thereby completing the circuit. Oxygen must be passed over the cathode so the oxygen atoms can break apart and join the free hydrogen electrons from the anode. The result is the production of water and electricity. Since the hydrogen gas does not burn at any stage in the process, there is no thermal to mechanical conversion, removing any risk of fire. Although many types of fuel cells exist, it is the alkaline fuel cell which has been most applied to the propulsion of vehicles. Alkaline fuel cells require pure hydrogen, low temperatures and can deliver electrical efficiencies of up to 60%. The storage of pure hydrogen is also a crucial issue when determining the viability of hydrogen powered vehicles. Providing a vehicle with pure hydrogen requires the hydrogen to be compressed or liquefied, which necessitates a considerable amount of energy. Metal hydrides and carbon-nanotubes are currently being used to reduce the large pressure requirements and to maximize the amount of hydrogen that is able to

be stored in a single tank. Further research regarding safe and efficient storage is underway and automobile manufactures estimate that future hydrogen fuel cell models will be safer than the internal combustion engine vehicles driven today. Methanol is currently available as a commercial fuel in fuel cells, as it helps to reduce but not eliminate emissions.

"Currently hydrogen is four times as expensive to produce as gasoline (when produced from its most affordable source, compressed gas), and ten times more expensive than internal combustion engines." (US Dept. Energy, freedom car) Although GM is participating in the hybrid sector of the auto industry, it decided this year to invest millions of dollars in fuel cell technology and promises to have a commercially viable and mass produced model by 2010. However the problem of refueling and mass producing pure hydrogen leave the industry to contend with issues of infrastructure. Producing pure hydrogen and compressing it into tanks is costly and requires a significant amount of energy, thus making the reality of hydrogen powered vehicles about 15-20 years into the future.

2.4 Liquefied Petroleum Gas

Liquid petroleum gas or LPG automobiles are bi-fuel vehicles that contain two separate fuel systems: one for gasoline or diesel, the other for propane or compressed natural gas. (http://www.fueleconomy.gov/feg/bifueltech.shtml) LPG vehicles primarily run on propane, propylene, butane, and butylenes in various mixtures, which are a derivative of crude oil distillation. The propane used to power an LPG is stored in a pressurized tank to keep it in liquid form. This tank is about the size of a spare tire. The liquid petroleum flows through a safety valve that is controlled by an rpm sensor into the converter where it is changed from liquid to gas. It is then mixed into the appropriate air/fuel ratio for the needed operating conditions of the engine. (US Dept Energy) A LPG powered automobile emits a smaller quantity of reactive organic compounds, less nitrogen oxide, and less carbon monoxide than a comparable gasoline-powered automobile.

LPG has been used in vehicles since the 1920s, and currently has refueling facilities in each state. LPG vehicles can be outfitted with either dedicated fueling systems, which are designed to utilize only LPG, or bi-fuel fueling system that facilitates fueling with either LPG or gasoline. This is the most widely available alternative transportation fuel at present. According to the U.S. Department of Energy, there are more than 350,000 propane vehicles in the United Sates and about four million internationally which consist of cars, pickup trucks, and vans also encompassing medium- and heavy-duty vehicles such as

transit buses, shuttles, trolleys, delivery trucks, and school buses. LPG is also utilized in a number of off-road and indoor vehicles, such as forklifts and loaders, where its clean burning properties are especially desired to preserve indoor air quality.

2.5 Compressed Natural Gas

Compressed natural gas (CNG) vehicles come either in a bi-fuel design or run solely on natural gas. Similar to the LPG gas design, the bi-fuel model for CNG has two fuel tanks and runs partly on conventional gasoline. The dedicated CNG vehicles only have one gas tank and so have a higher capacity. Their reduced emissions combined with large carrying capacity have made them ideal vehicles for fleets. "Approximately one out of every five new transit buses in the United States is powered by natural gas."(ttp://www.eere.energy.gov/ cleancities/afdc/afv/gas_vehicles.html) Although performance characteristics such as acceleration and speed are almost equivalent to conventional gasoline engines, range is somewhat limited, but can be extended at the cost of capacity. The compressed gas of a CNGV is kept safely inside a pressurized tank which is designed to withstand extreme impact and temperatures. Since natural gas has an ignition temperature that is twice that of gasoline and dissipate into the atmosphere when released it is far less caustic than gasoline. "Per unit of energy, natural gas contains less carbon than any other fossil fuel, and thus produces lower carbon dioxide (CO2) emissions per vehicle mile traveled. Natural gas is generated from several sources including petroleum liquids, reservoirs containing natural gas, liquids and other materials, as well as gas from landfill and water/sewage treatment plants. While NGV do emit methane, another principal greenhouse gas, any slight increase in methane emissions would be more than offset by a substantial reduction in CO2 compared to other fuels."(ngvc, 2) Natural gas cost a third of what gasoline does for conventional

ICE vehicles and over half of the 1,300 natural gas fueling sites that exists across the US are for public use, also most CNG refueling sites are used by transit buses and commercial fleets. Most natural gas is produced domestically with almost all of the imports from Canada. CNG has been successful in multiple fleets across the US and is considered a beneficial approach to reducing vehicle emissions.

3. Overall summary of where technology currently stands

Although rising concern for the environment has caused many automobile customers to consider alternatives to the conventional ICE, many economists feel that it is the rising gas prices that have persuaded consumers to seek better fuel efficiencies. With gas prices averaging near $2 per gallon and surprising performance capabilities of hybrids many Americans have found themselves ditching their gas guzzlers and seeking vehicles with better fuel economy. This past March and April Honda sold record setting quantities of their hybrid Civic, while Toyota has over a 20,000 unit backlog order for its well known Prius. Overall, hybrids sales are estimated to more than double to 100, 000 units by the end of this year, which is good but still a small portion of the forecasted 17 million new car sales for 2004. Toyota currently has a six month waiting list for the basic package of the new Prius, and a year waiting list for the deluxe package. Although Hybrids technology is complex and requires trained technicians, Toyota insists they still make money off of each sale. Only costing $1,500-$2,500 more than a conventional sedan, the Toyota Prius has been ranked among the top seven recommended 2004 sedan models by Consumer Reports. Using a 76-hp, 1.5 liter gas engine and 67-hp electric motor and averaging 44 mpg, the 2004 Toyota Prius offers acceleration and top speeds comparable to conventional sedans, while maintaining a spacious interior and safety options that include front and side airbags. The battery pack is warrantied for 8 years/100,000 miles, with estimated replacement costs of $3,000-$3,500. "At $1.50 per gallon, cars in this

class burn about $1,000 of fuel in 15,000 miles. At this rate the Prius would save about $500 a year." (Consumer reports, 53) In terms of depreciation, the Prius is holding its value about as well as conventional automobiles. Common issues that have arisen for the Prius include the somewhat awkward gadget layout that may seem confusing for some, as well as the lack of feedback provided by the electric steering. Other than some lack of steering "Prius drivers have been completely satisfied with their car," explains Gilles Labelle of Westborough Toyota who is overwhelmed with back orders. "We want to sell it (hybrids) on the basis of advanced technology and performance," say Honda spokesmen Andy Boyd. That's a novel pitch for a hybrid. Only two years ago, such cars were small and under powered and, with their oddball designs, seemed destined to appeal mainly to environmentalists, technology buffs and Hollywood stars, who won p.r. points for driving them." (Fonda, 52). The government has been offering a $1,500 tax deduction, which starting next year will be changed to a tax credit. How mainstream alternative vehicles such as the hybrid will become over the next few years is of course up to the government, who, according to Gilles Labelle has currently placed restrictions on the number of hybrids his Toyota dealership is currently allowed to sell.

Up until now, the three main auto makers: GM, Ford and Chrysler have tighter fuel economy regulations and avoided efforts in hybrid and electric cars. Although several years behind in the technology of gas-electric cars, Ford has decided to step into the market with its Ford-Escape which will be made available in the summer of 2004. In contrast, GM, Chrysler, and Nissan all plan their

future around diesel and hydrogen powered cars. So while Toyota, Honda and Ford plan to use the knowledge the have attained through innovation of their gas-electric and electric vehicles to build future hydrogen powered vehicles, the remaining three are putting billions of dollars directly into hydrogen powered vehicles which they feel will be the wave of the future. Despite President Bush's efforts to promote hydrogen powered vehicles and the bold forecasts of availability of hydrogen powered vehicles made by GM, many people believe that the hydrogen fuel cell is farther off than people think. All car manufactures now have prototypes that are far from being considered commercially viable. Although car manufactures estimate their prototypes will be commercially viable by 1010, experts question the infrastructure of hydrogen. How will pure hydrogen be supplied on a commercial scale? The question of how automobiles will be refueled in both a safe and cost effective manner still remains. Some experts put the solution to hydrogen infrastructure by 2030, while other claim it will be later…If at all. The process of producing and compressing hydrogen requires a large amount of energy, and thus is costly and only as clean as the source from which the energy is being drawn. Like electric vehicles, the energy to produce and compress hydrogen may be being generated from a plant that is simply redirecting where the emissions come from. So clearly the notion of driving zero-emission automobiles lies in the progress of our ability to harness energy from clean sources. Lowery, the General Motors vice president, acknowledged that the industry will, of course, not be alone on the hydrogen frontier: It can't go out there alone in search of a hydrogen economy. Hydrogen

as power will make its way into homes, factories, computers, cell phones and as its application broadens so will the infrastructure to support it." (Boston Globe, F1)

Since hybrids still require oil dependence and hydrogen fuel cells appear to be practical only in the distant future, car manufactures are looking to optimize electric cars. The search for a more powerful and long lasting battery to increase the range of electric cars is well underway. Eliminating the need for gasoline to run our automobiles would decrease foreign oil dependence and help to control where we pollute but would still not solve the problem of generating electricity from clean energy sources. Although the technology surrounding gas-electric, electric and fuel cell powered vehicles is rapidly changing, it is clear that a reduction on the US dependence on oil must not only come from the economy, but from the cultural as well. We need a cultural change that would require westerners to refine how they view transportation and a government to make and enforce heavier restrictions on fuel emissions.

4. Experimental

4.1 Goals of Survey 1 and 2

A portion of the analysis of the results for both surveys will include discussing and interpreting relevant trends and correlations that exist within the tabulated results of the survey. Some of these trends and correlations results are quite straight forward and can be interpreted directly, while others are open to interpretation. For example it is no surprise that solar and gasoline powered vehicles are considered the safest to own while LPG, compressed natural gas, and hydrogen are considered the most dangerous. But the results are interesting because the overwhelming numbers demonstrate a bias that manufacturers will have to overcome if they want to market these "dangerous" vehicles appealing to the public.

Some cases involving the results are more ambiguous and might be open to various interpretations. For instance, in the section titled *general perceptions* the question asking the respondents to evaluate the different alternative energy vehicles in terms of cost to own yields results that indicate there may have been interpretation problems. The gasoline powered automobile received the most votes for being the cheapest to own and the most expensive to own. One interpretation is that for many people their experience has been that overall maintenance and repair has involved a reasonable cost and they can live with the fuel prices. While other people are probably quite concerned with the current cost of fuel and thus influenced by skyrocketing gas prices, which, coincidently, were racing toward historical highs just as the surveys were being

filled out.

Although these results are skewed toward the opposite ends of the spectrum, they do offer an interesting bit of information because it suggests that for a substantial number of people rising gasoline prices will at some point reach a threshold that will stimulate them into considering other forms of transportation.

Reviewing other sections of survey one will help to determine the typical owners of these automobiles and come up with a profile of just how these primary and secondary vehicles are being used and whether there is a distinct difference between a primary vehicle and a secondary vehicle.

By cross referencing some of the information I will also be able to tell how some opinions and types of use are affected by such things as gender, age, income, and size of family.

The second survey will enable me to come up with a set of standards for what capabilities people want from an alternatively powered vehicle, and then compare and note the difference between what people are willing to accept in the future and the way they use their vehicles now.

As I have gone along I have learned there are a number of questions I should have asked such as whom in the family has the most say in buying a new car and how devoted are people to there air conditioned cars. As a result I will offer a section on questions that might improve any future survey.

4.2 Description of Survey 1

Two surveys were formulated to elicit information that would provide automobile manufacturer's with an idea as to what specific criteria must be met by alternative vehicles in order to stimulate the public's interest to the point where they might consider purchasing an alternative energy automobile.

The perception people have of an automobile, regardless of whether or not it is an accurate one, is one of the first areas that must be addressed by a manufacturer if people are to be persuaded to purchase a certain brand or type of car. The first section of questions labeled "General Perceptions" are designed to find out how people perceive different types of alternative energy vehicles. Crucial areas of concern for automobile customers include the vehicle's cost, convenience, safety, and economy (which is addressed here as environmental impact). Thus it was of interest to find out if the names of some of the types of alternative fuel systems, would affect consumers opinion of theses vehicles' cost, convenience, safety and economy. The respondents were asked to rank the vehicles against each other according to their perception of the above topics to accurately evaluate their perceptions and determine which vehicle types inspire confidence and which would appear negative enough to frighten the public into not purchasing such a vehicle.

The following three sections were designed to both evaluate the demographics of who is currently driving automobiles and subsequently provide a detailed profile of how these automobiles are being used. The profile will make it possible to focus on both overall usage and specific trip usage. The specific

questions within the following sections are also designed to highlight the differences in usage between primary and secondary, and thereby evaluate the possibility of making alternative vehicles marketable to customers with more than one vehicle.

The last section on the first survey and all of the second survey are an attempt to determine exactly what people feel will be the necessary parameters to make an alternatively powered vehicle appealing enough to be purchased.

Information from the second survey has also been used to measure the gap between the way drivers are currently using their cars and what limitations they say they are willing to accept if it means they can own and drive a more environmentally friendly vehicle.

5. Results

5.1 Survey 1: General Perceptions

The information included in the following are observations and discussions that are derived from tabulating and scoring the remaining questions on the first survey. It must be noted that this survey records and analyzes people's perceptions, not what is necessarily accurate.

5.2.1 Section 1,Question 1

The first Question in the survey in section 1, titled General Perceptions asks the respondents to rank in order, seven listed alternative vehicles that they feel is the most practical to own in terms of both cost and convenience. The list of alternative vehicles includes: gasoline, electric, hybrid, compressed natural gas, liquefied petroleum gas, hydrogen and solar. The top four vehicles the respondents selected in order of most practical to least practical in terms of cost were gasoline, hybrid, solar and electric, with hydrogen being perceived to be the least. In terms of convenience, the respondents viewed the most practical to own in the descending order of gasoline, hybrid, electric and compressed natural gas. Then came liquefied petroleum gas, hydrogen and solar, with solar being considered the most inconvenient. Overall gas is rated as the most practical to own in terms of cost. The order of in which the respondents placed the vehicles may be due to the simple fact that gas fuelled automobiles are so familiar, while the remainder are not. Ironically gas also received the most tallies for most expensive to own, which may be because the surveys were filled out in the middle of a well publicized rise in gas prices that reached an all time high.

Hybrids rating as being second most cost effective may also be a result of the recent positive publicity that has led to long waiting lists to purchase this type of automobile. People also assume other types of more exotic forms of alternative energy automobiles have not been around long enough to make them cost effective and are aware that procuring fuel for them would be an expensive proposition. As to which is perceived to be the most convenient, hybrids were rated highly along with gas because people know they are commercially viable and they seem to have few performance limitations and can be fueled at any gas station. People were aware that electric cars seem a little less convenient because of size and performance limitations and the necessity of recharging. However people have heard about them and have occasionally seen them around, giving them some credibility and familiarity. Solar cars rank at the least convenient because people's only experience with them seems to involve a once a year news report of college students racing them across the dessert on a cloudless day. In the middle ground; are compressed natural gas, LPG, and hydrogen. For these vehicles people are aware that they exist and therefore they must have some value, but they know very little about them, seldom if ever see such cars, and have no knowledge of how they would be refueled.

5.2.2 Section 1, Question 2

The second question asked the respondents to rank the same seven automobiles in order of what they perceived to be the safest to own. By safety it was understood as all around safety which includes refueling, mechanical accidents, garage storage, maintenance, but not crash worthiness. How

exactly each individual interpreted “safety” cannot be known for certain. The respondents did agree mostly that solar were indeed the safest to own with gasoline, electric, and hybrid falling shortly behind it. Compressed natural gas was ranked in fifth place, then hydrogen and liquefied petroleum gas. Given that most of the individuals kept inquiring during the survey about what liquefied petroleum gas was, it can be assumed it was ranked as the least safe to own due to the lack of public knowledge that surrounds it. The results of safest to own are just what you would expect. The majority of the respondents used the rational that since a solar car involves no fuel there would be nothing to ignite, making them the safest to own. Gas fueled automobiles rank high because of their history and familiarity, while people feel electric cars use no volatile fuel but are never the less a little weary of electricity and batteries. Hybrids may have ranked the same as gas fueled autos except some people may be weary about the unknown electrical components the systems utilize. Also some respondents believed hybrids involved some of the more volatile fuels like propane. The last three categories natural gas, LPG, and hydrogen all are perceived of as accidents waiting to happen especially if allowed to sit in a closed garage. They also perceived the refueling process as being inherently dangerous. It seems the respondents have seen too many reports of houses exploding from gas leaks, hydrogen explosions involving dirigibles, or the occasional exploding factory. The data collected from this question is a clear indication that people are terrified of certain types of fuel used.

5.2.3 Section 1, Question 3

The following question then asks for the order of what the respondent perceives to be the most survivable in an accident. Solar was almost unanimously ranked as number one, then electric, gasoline, hybrid, compressed natural gas, liquefied petroleum gas and lastly, hydrogen. Since hydrogen and liquefied petroleum gas appeared at the bottom of the list in both safety questions it is safe to assume that the public has a common fear of hydrogen and a lack of knowledge of liquefied petroleum gas. Most respondents perceived solar and electric to be safer than a conventional internal combustion engine, even though they are small, light, and flimsy, because they also know that no fuel is used and they believe that no fuel combined with low top speeds makes up for their vulnerability. The respondents seem to universally believe that any collision involving LNG, LPG, or hydrogen would almost certainly result in an explosion. The data to this question again confirms the public's fear of fuels due to lack of knowledge.

5.2.4 Section 1, Question 4

The last question in this section asked the respondent to rank the same seven vehicles in order of what they perceived as being the most environmentally friendly. Solar was perceived to be the most environmentally friendly, then electric and hydrogen. Compressed natural gas and liquefied petroleum gas were stuck in the lower middle, with gasoline perceived to be the least environmentally friendly. Almost all of the respondents, who were questioned about the rankings to the environmentally friendly section, said they made their rankings solely on the type of fuel used and did not consider the manufacturing

process or the final disposal of the automobile. Solar was ranked number one for obvious reasons, while electric cars were ranked second, with a few respondents reporting that they did put thought into the origin of the electricity. Hydrogen finally got a high ranking, since most people assume the end result of using hydrogen is somehow just water, while admitting that they have no idea of what the process is that obtains the hydrogen in the first place or what environmental impact the process has. Hybrids rank in the middle for two reasons: some people thought it meant much better gasoline mileage or that there was a cleaner fuel such as ethanol mixed in with the gas. The respondents ranked natural gas and LPG next because they are though to be the cleanest burning of the fossil fuels. Everybody did however agree that gasoline is a pollution nightmare. Overall, from the data collected from the above four questions it is clear that people view hydrogen as neither practical nor safe, although the majority are aware that it is environmentally friendly. While gasoline is perceived as the most environmentally unfriendly, it is still viewed as being the most practical and safest to own.

5.2.5 Analysis of Section 1

Although there are no definite answers to the question of this survey since much consideration in the various aspects of each type of alternative vehicle is required an overall summary of accurate considerations for each vehicle is provided. Solar powered automobiles are safe, cheap to run, extremely costly to manufacture, environmentally friendly but are impractical to drive as they require conditions usually found only in the Australian outback during the

day. Electric powered automobile are safe, expensive to purchase, expensive to maintain, environmentally friendly depending on the electricity source, and somewhat practical to drive. Hybrid vehicles are cost effective and convenient to drive, safe and more environmentally friendly when compared to conventional combustion engines. Gasoline powered automobile are safe, comparably cheap to drive, convenient, but are an environmental disaster. Hydrogen powered automobiles are environmentally friendly but are expensive to operate, expensive to produce fuel for, are only as clean as the electrical plant which is generating the electricity to produce the hydrogen, and would require a dramatic change in re-fueling infrastructure. LPG powered automobile are relatively safe, have comparable performance characteristics to ICE, are more environmentally friendly than a gas automobile, have performance problems at low temperatures, less wear and tear on the engine, but are inconvenient due to lack of infrastructure throughout U.S.. Compressed natural gas powered automobile are more environmentally friendly than gasoline, safe to drive, and improves fuel consumption and engine efficiency. However, they have 10-15% lower power output than ICE, are not convenient to refuel, have a high cost of conversion, and the cylinders required to install do add a considerable amount of weight to the vehicle and take up space.

It would be interesting to take the same survey on a group of people who had been well informed on all the technicalities of the various forms of alternative energy transportation. The results might be quite different.

5.3 Section 2

The questions appearing on the second section of the survey titled Demographics were designed to obtain some personal information to help categorize and develop profiles of the individuals surveyed. The questions inquired about gender, number of people in household, number of licensed drivers per household and the number of automobiles owned per household. Not included in these were age and race, which did prevent some vital information from being extracted. Thus the results from many of the questions were primarily analyzed based on gender, with number of family members, licensed drivers and automobiles cross-referenced where appropriate. A total of 129 people completed the first survey: 77 males and 52 females. With a majority of 63% of the individuals surveyed having 4 or more people in their household and 83% owning 2 or more automobiles, it can be assumed that the majority of the respondents represent the older sector of the population. Further indication that significant portions of the population surveyed represents an older sector is that 50% reported having three or more licensed drivers in their household.

5.4 Section 3

Section 3, Your Car, was designed to evaluate how people use their vehicles in terms of speed range, occupants and cargo and to provide a possible comparison between how people use their different vehicles and if they have more than one. In this survey, it was explained to the respondents that the vehicle used most often for commuting and work related trips was to be considered the primary vehicle and that the secondary vehicle was to be

considered the one that is used for short local trips, long family trips or other purposes. To get an idea of what type of vehicle people are driving and what they use it for, the survey asked for the make, model and year of the current vehicle(s) the respondents are driving, and to indicate who in the family uses them and what they are used for. The data collected from this question will be discussed in the comparison of vehicle 2 at the end of this section. The following questions that will be discussed were asked for both the primary and secondary vehicles. These questions included: average number of occupants, length of most common type of trip, highest speed attained, amount of cargo carried, and number of miles the vehicle traveled per year. Results to these questions for vehicles one and two were then compared.

The answers to second question for both vehicle one and two has a fault in the listed answers since it lists the option of 2-3 occupants, as opposed to listing the options of 2 and 3 separately, which would have eliminated the distinction between whether or not a back seat would be required. Whether or not a back seat is required is an important consideration in determining whether or not there would be a possible market here for alternative vehicles. Therefore the only significant information that can be obtained with accuracy is that 40% of the males who took this survey were the single occupant on their most common type of trip. The data collected from this question also revealed that 96% of the most common trips taken by the overall population who completed this survey involve three or less occupants. It also shows that there are more males than females taking single car trips, which is an important factor in terms of vehicle marketing.

The next question, inquiring about the length of the most common type of trip, indicates that 91% of the length of the most common type of trip taken were less than 50 miles, with 58% of the trips being less than 25 miles. Even though the majority of the population surveyed reported they need a vehicle with long range, only 1% reported they travel over 100+ miles often. This points out a dichotomy of what respondents' actual driving habits are, compared to what they perceive they need. This is further supported by the fact that 71% of the respondents feel they require a vehicle with a range over 150 miles. The survey then goes on to ask what the highest speed attained on the most common type of trip was. When considering the data collected from this question it is important to note that this survey was completed by a population in the east coast, where the speed limits are not as high compared to those in the mid-west and west coast. The majority of the population, 29%, claimed they travel in the 65-80mph range regularly: 31% being male and 25% female. The remainder of the population spread fairly evenly across the 45-55mph and 55-65mph range. Less than 10% claimed to drive in the 80+mph range regularly, with twice as many males as females. Which supports Mr. Gilles of Westboro Toyota, claim that about 70% of his hybrid customers are women, since they are not advertised for their exceptional performance capabilities. Overall, according to this survey, 91% of the population would be satisfied with a top speed of 80mph. However, when comparing what the top speed of their vehicle should be, the data shows that 69% of the respondents feel that their vehicle should be able to go over 85mph. This raises the question of why people feel they need the option of traveling over

85mph. When asked after the survey, some respondents stated for emergency reasons, while others said they wanted to be able to keep up with highway traffic. Percentage wise, twice as many males as females claim they travel 80+mph routinely.

The fifth question asks if a significant amount of cargo is sometimes carried, but it does not ask if they do not carry extra cargo because either they don't have too or because they simply can't. With this slight fault in the question, the most significant point is that 45% of the population reported that they did not carry extra cargo. Which could work in the favor of many alternative vehicles seeing as they have a limited amount of extra space.

When exploring what the respondents indicated as being the number of miles their vehicle travels per year, for question 6, 46% of the population claimed their vehicle travels at least 10,000 miles per year. With only 22% respondents traveling 0-6,000miles per year and 16% traveling 6,000-10,000 miles per year. According to The 2004 Almanac, the average vehicle travel around 12,000 miles per year.

Out of the 129 people surveyed, only 55% had a secondary vehicle. To evaluate if and where there is a difference in how people use their secondary and primary vehicles, the respondents where asked to indicate the primary uses of each vehicle. The possible uses that were listed included: commuting, business, short local trips, long family trips and the option of other. While only about 31% of the secondary vehicles were reported as being used solely for short local, long family trips and other purposes for both genders. Interestingly more men

surveyed use their vehicle exclusively for commuting and business related trips than the females surveyed. Only 12% of the people who owned secondary vehicles use them for purposes other than commuting and business related travels. So clearly vehicles such as electric motors may have some application among those of the population who could or would be willing to drive a vehicle that would require lengthy recharging, but for the most part it is clear that in order for an alternative vehicle to be consider commercially viable it will have to satisfy multi-purpose requirements. These results are however skewed because the uses of the vehicles were not scaled, so if people use one option frequently and another rarely, they are counted equally and there is no clear distinction able to be made between the categories.

5.5 Vehicle Comparison

When exploring the difference in average number of occupants taken per trip between primary and secondary vehicles, it was found that there was a 10% increase in respondents making more single trips. Which may suggest that for families, the second vehicle may be being used as a family vehicle. Of the female respondents that completed this survey, 50% stated that there was no second vehicle; whereas 60% of the male respondents said there was a second vehicle. This difference may be due to the demographic of this survey and thus is open to interpretation. When comparing the length of trip between the primary and secondary vehicles, it should be noted that the results may be skewed given that a portion of the respondents were college students who may have put the

information for their car under vehicle #1 and the information for their families car under vehicle #2. The other scenario in interpreting this portion of data is that among the families surveyed the sedan is used for commuting and the mini-van or SUV is used for family trips. A long and detailed introduction as to what should be considered a primary and a secondary car could have avoided this ambiguity. Of the secondary vehicles, 17% were marked for trips with an average length of 50 miles or more as opposed to vehicle #1 which had only 9% for trips of 50 miles or more. The opposite result was expected since many people who have more than one vehicle separate their more fuel-efficient commuting vehicle from their larger, safer, and more comfortable traveling vehicle. For both vehicle #1 and #2, everybody who said they traveled more than 85+mph was single, with a greater percentage being male. Over twice as many respondents for vehicle #2 than vehicle #1 (percentage wise), reported that they travel 80+mph as their most typical speed, with equal amounts of men and women. Which suggests that majority of the respondents must be using their secondary vehicle more for highway driving. When comparing speed it was found that 25% of those that said their primary vehicle must be able to travel 80+mph said their secondary vehicle did not have to be able to travel as fast. Indicating that a portion of the population would be willing to sacrifice top speed in one of their vehicles. In terms of cargo there is a significant decrease, from 45% in the primary car to 65% in the second car. Females jump from, 44% to 77% in saying they seldom carry significant extra cargo in their secondary vehicle. Suggesting a portion of the market for this second car would also be willing to sacrifice cargo space. In

contrasting annual range that respondent's drive for the primary and secondary vehicles, it was found that 61% of the population claims their primary vehicle travels over 10,000 miles annually, as opposed to 49% for their second vehicle. In this decrease for the 10,000 annual miles traveled per year, females drop from 61% for their primary to 49% for their secondary, in contrast to males dropping from 62% to 57%. This reveals that the respondents' second vehicle is not being used as much as their primary. The figures surrounding the answer of 10,000 miles and up to this question are most significant based on the statistic given by The 2004 Almanac that the average annual vehicle mileage is around 12,000 miles per year. The significant decrease in annual miles traveled per year for secondary vehicles and the requirement for less cargo space, top speed and occupant capacity all suggest that their would be a substantial market for alternative vehicles with lesser performance capabilities. However, this section only reveals what people needs are based on how they use their current automobiles, not what they desire.

5.6 Section 4

Exploring the data collected fro the next section, Section 4: Your Driving Habits, will aid in creating a profile of what necessary criteria must be met by alternative vehicles to ensure they meet the market's desires as well as needs.

The questions asked in the following Section 4, called Your Driving Habits, of the first survey were designed to obtain information that would help in developing a profile of what criteria alternative vehicles may have to meet in terms of performance, to meet customers' needs by evaluating how people use

their current vehicles. The first question of section 4 asks how fast the individual feels their primary vehicle must be able to go. Between the choices of 65mph, 75mph, 85mph, 85+mph, 69% said their primary vehicle needed to be able to travel 85+mph. When asked what their average speed attained on their most common type of trip was, 91% of the same respondents reported that they did not travel over 85+mph. Of that same 69%, 72% of them were male and 64% were female, indicating that women are more willing to accept a reduced speed than are men. However, 31% of the respondents would be satisfied with a vehicle traveling at a maximum speed between 65-75mph. For the secondary vehicle, 61% of the respondents claim they need their second automobile to be able to travel 85+mph, again with more men desiring a faster speed. This 8% difference in top speed requirement between the primary and secondary automobile is significant. Leaving room for a significant portion of the population that could be targeted as buyers for more fuel efficient automobiles. To find out what people expect from their vehicle in terms of range, questions 3 and 4 asked what range people thought their primary and secondary vehicles ought to have before needing to being refueled. For both primary and secondary vehicles, there was no significant difference in what people expected from their primary and secondary vehicles in terms of range: 72% wanted 300+ miles for their primary and 71% wanted 300+ for their secondary vehicle. However, 10% more men expected mileage in the 150-300 mile and 300+ mile range as opposed to women. Women conversely expect mileage in the 100mi and 100-150mi range 10% more than men. This may be a significant trend or merely a question of how

aware people are of how many miles they actually travel before refueling. In retrospect, a way to evaluate this ambiguity would be to have included a question in Section 3, Your Car that would ask directly how much mileage they think they get and then compare the two. To get a general idea of how aware people are of their mileage the answers to the refueling questions were compared with the answers to the individual make and models asked in the previous section, and it is clear that the population surveyed thinks their vehicle travel farther before re-fueling than they actually do. Regardless, it is clear that people want the option of long range for both their primary and secondary vehicle, making it clear why electric vehicle are currently not commercially viable. Overall, people want their both their primary and secondary to have a top speed of 85+mph and a minimum range in the 150-300 miles. The last question in this section asks how much people could afford to pay for a vehicle at the present time. The majority of the population, 45% reported under $10,000, 29% in the $10,000-$20,000 range, 13% in the $20,000-$30,000 range and another 13% in the $30,000+ range. However it must be noted that a portion of the respondents were college students, thus accounting for the high 45% in the $10,000 and under category. Since the starting price of new hybrid cars is in the low $20,000 range and only $1,500 to $2,000 on average more expensive than conventional mid sized sedans, a significant portion of the population would be capable of purchasing one. Thus confirming that the gas-electric option is a potentially significant contender in the market place, as well as the fact that future alternative vehicles

will have to stay in a reasonable price range in order to be accessible to the majority of the population.

5.7 Section 5

Section 5 of this survey, Alternatively Powered Vehicles was designed to obtain an idea of how some of the public feels about alternative vehicles and how readily they would be willing to accept them. Although the questions were asked directly and can be interpreted clearly, it must be noted that the population was surveyed during a period where gas pricing were at unusually high prices and there were concerns about the use of foreign oil so the results may be skewed slightly depending on personal opinion. The first question asks how much extra the individual would be willing to pay per year to own a zero emissions vehicle. Only 17% of the population reported that they would not be willing to pay any extra money to own a zero emission vehicles, while 29% would pay 0-$500, 22% for the $1,000-$2,000 option and 32% claimed they would pay $2,000-$5,000 extra annually. Leaving an overall of 83% willing to pay extra to purchase an alternative vehicle. Although an equal percentage of 32% for both men and women claimed they would be willing to pay an extra $2,000-$5,000 annually to own a zero emission vehicle, this survey showed that women were about 6% more likely to pay more than men. The next question asks whether or not the individual would be willing to purchase an alternative vehicle after being told that some were cheaper than most midsized sedans available today. With 78% as they majority saying yes, both sexes were evenly divided. With only 22% of the population not willing to purchase a zero emissions vehicle regardless of the

reasonable price, it is clear that the majority of the population would be attracted. Finding out why this 22% is reluctant is something I left for the second survey. The third question asks how long people would be willing to spend refueling if they did own an alternative vehicle. Surprisingly 49% of the population reported they would be willing to spend 2-5min extra refueling and 21% claimed they would spend 1-2min. While 19% claimed they would be willing to take 5-15min extra, only 11% reported they would not be willing to spend any time at all. Men were four times as unwilling as women to spend extra time refueling. The next two questions ask whether or not the individual has ever driven an alternative vehicle and how they rate their experience. Out of the 129 people surveyed, 12% had driven an alternative vehicle with more than half rating their experience as excellent. The excellent rating of the hybrid collaborates with the consumer reports high rating of the hybrid vehicles, which is what is being assumed they have driven. I then chose to ask whether or not the appearance of alternative vehicles is appealing. Unfortunately there is no way to be sure what the individual answering the question is rating, since there have been many prototypes pictured in magazines, in addition to the hybrid vehicles that are being driven around now. But none the less 46% reported the physical appearance was acceptable, while 52% reported it was not. The survey then asked the respondents if they could see themselves owning an alternative vehicle now and 57% reported yes. Again some consideration may be taken into account with this percentage given the gas prices that were enraging the public at this time. To find out if it was the perception that an alternative vehicles performance would be limited, I then

asked if the individual would re-consider buying one at the present all limitations had been overcome and the figure rose from 57% to 91%. Overall, the survey shows that people would be willing to start purchasing alternative vehicles so long as their performance is fairly comparable to that of the conventional combustion engine.

5.8 Survey 1 Conclusions

Although other studies have shown women to be much liker to purchase an alternative vehicle than men, I made a point to try in find out on the next survey by focusing on actual performance characteristics. The most noticeable trends and points of data that were extracted are as follows. The majority of the respondents who answered the surveyed had a large number of licensed in their household, mostly in the 3+ range, and more than half had secondary vehicles. This is not unreasonable because according to the U.S. Department of transportation, there are 1.9 cars available to each household. The 2004 Almanac lists that for the first time cars out number drivers, as is also the case for this survey. The 2004 Almanac also lists 8% of the U.S. population has no vehicles (mostly city dwellers), which is a clear indication that the multiple cars people own are being used in different ways. Although the national survey listed in The 2004 Almanac, puts the average car per household at 1.9, that a statistic is included in the 8% of the households in the country that do not own a vehicle. This figure is comparable to the 49% of the respondents in this survey who have three or more cars. This survey was taken for the most part in an affluent and urban setting, which may account for why the ratio of automobiles to households

was so high. When reviewing the overall trends expressed in the data, it is clear that men use their vehicles for commuting and business related trips more exclusively than do women, who seem to be the segment of the population driving the multi-purpose vehicle, or family car. Since many families were surveyed, it can be inferred that women overall drive the larger vehicles. Women were also found to be willing to accept less in overall performance. The majority of the trips being taken by the population (91%) are under 50 miles, and 62% of all the trips taken never exceed a top speed of 65 mph. The average length of trips increase from in the secondary vehicles, as do the average maximum speed attained. There is also a significant amount of extra cargo carried in the second vehicle, especially when females are driving. Both genders expressed that feel they must have a vehicle that can travel at greater speeds than those they travel on a routine basis. This is one of the most telling statistics found because 91% of all the respondents claim their most common type of trip does not exceed 85mph. Both genders also insist they need a range for both their primary and their secondary that far exceeds the range taken on their most common type of trip, being that more than 50% of their most common trips are less than 25 miles. Clearly demonstrating that how people actually use their vehicles vs. how they feel they need to be able to use their vehicles are very different. Since this survey was designed to develop a general profile of how people use their use vehicles for automobile manufactures to go by when producing acceptable vehicles, I felt it was important to try and find out what if anything, people would be most likely to sacrifice in their vehicles, while still keeping them commercially viable. To get

a more accurate and specific idea of what kinds of people want from their automobile and what if any thing they would be willing to sacrifice, I developed a second survey focusing on performance characteristics.

5.9 Survey 2 Results

The second survey was designed to find out more specific information about what people expect and want from their automobiles that could be compared to the profile of how people used their cars in the first survey. Unlike the first survey, the second asks about age and marital status, to help develop a clearer profile of the types of people who will be inclined to seek currently available vehicles such as the hybrid. Of the 74 people that filled out the second survey, 39 males and 35 females filled out the survey. In terms of marital status, 48% were single while52% were married. The range of ages was fairly evenly spread with 12% being 21 and under, 26% in the 21-30, 19% in the 30-40, 20% in the 40-55, and 22% in the 55+ age range. The majority of the population surveyed fell into the $80,000+ income range with 27%, while the $60,000-$80,000 and $0-$15,000 annual income bracket shortly behind. The types of vehicles currently owned by the population surveyed were evenly spread with exception of SUV's and mini-vans being in the minority. When asked if they would consider a low-emissions vehicle at their next vehicle purchase 91% reported that they would. The only respondents who were not willing were single males in the 30-55 age range, who were also the most willing to pay the highest prices for gasoline at the pump and required the fastest traveling speeds. Of the 74 people surveyed, 43% were

willing to begin consider purchasing a low-emissions vehicle when gasoline prices hit $2.00, 28% reported they would wait until gas prices hit $3.00 and 14% said they would wait until $4.00. Still 7% claimed they would wait until prices soared to $5.00 per gallon and 8% remained firm through $6.00+ per gallon. While the majority of the respondents who said they would consider the purchase of a low-emissions vehicle when gas prices hit $2.00 fell into the 0-$15,000 income bracket, 70%of people making more than $80,000 a year think $3 is about the limit. Those who indicated they would switch at $3.00 were mostly in the $60,000-$80,000 and $80,000+ income bracket and were mostly married males with a family size of 3-5 and ranging in all ages. On the opposite end at $5.00 and $6.00+ per gallon the younger and single crowd, with lower incomes claim they will pay the most to maintain their internal combustion engine. Overall for all categories $3.00 is the cut-off for 66% of females and 77% of the men. Although the next question asks directly what they would be willing to pay in terms of initial purchase price, it cannot be interpreted accurately because there is not an option that allows for people to select that they would not pay any extra amount. Instead it only allows for the lowest amount to be $500, which 30% of the population selected. With 27% selecting $$1,000-$3,000, 12% choosing $3,000-$5,000 and 31% indicating they would pay $5,000+ for initial purchase price, it is clear the population surveyed is willing and enthusiastic to pay more for lower emissions vehicles. The most common among those willing to pay $5,000 and up in initial purchase are the single females in the 30-40 year old age range who would also be most willing to sacrifice top-speed and acceleration.

Both men and women that remained in the $500 range were equally unwilling to pay extra for a lower-emissions vehicle. When questioned about how much extra time they would be willing to spend re-fueling, 35% answered in the 1-2 minute range, 30% in the 3-5 minute range and 23% in the 5+ minute ranges. Only 11% states that they would not be willing to sacrifice any extra time at the pump. Leaving an overall is 89% of the respondents stating that they would be willing to spend extra time refueling, which is both significant and encouraging. Also noteworthy is that 15% of males refuse to wait versus only 6% of females who refuse to wait, indicating that males is may be harder to convince males to buy a car that requires a wait refueling. However, of the respondents that indicated that they were willing to wait, 28% of the males claimed they would wait longer than 5 minutes only versus 17% of the women: a possible indication that women are not as comfortable waiting around gas stations. The unexpected willingness of this population to spend some extra time re-fueling to the results of the first survey are similar, although in the first survey the durations of optional waiting times was longer. It can also be noted that married individuals with a family size of 3-5 are the most patient and willing to purchase a low-emissions vehicle. Whether this is a genuine patience or an inspired selection is open to interpretation. Regardless it is apparent that any alternative vehicle will have to have efficient refueling times and methods to make it commercially viable, indicating that a change in refueling infrastructure will most likely be necessary.

When asked what the top speed of their vehicle should be, both 80mph and 90mph categories received 39%, leaving 18% for 70mph and only 4% for 60mph.

While few respondents were willing to settle for 60mph, on average more married than single people were willing to settle for the lower speeds. A majority of 78% of the respondents feel that their automobile must be able to go at least 80mph, even though according to the first survey, less than 10% travel in excess of 80mph regularly. And almost 40% feel their automobile must be able to go 90mph. Which raises the question as to why do people who rarely travel over 80mph feel they need a vehicle that has the capability? Since the sample size for this survey was so small, there was no significant trend between gender and speed able to be noticed in this survey. There was however a correlation in age and top speed, with everyone in the under 21 and 21-30 year old age range reporting that they require their vehicle to travel at least 90mph: the younger the respondents were the faster they wanted to go. There was a big difference between the married and single respondents; only 24% of married respondents need a top speed of 90% compared to 56% of the singles. On the other hand note that 22% feel 70mph is fast enough. Despite the younger people need for speed, this question does reveal that there is a market for slower cars in the older and married sector of the population.

In the next question, respondents were also asked whether they prefer the acceleration of their next car to be "average" or "sporty". Of the 70% that felt their next vehicle should have an average acceleration: 61% of the males versus 80% of the women. While being more popular in the single and 30 and under age range, 89% the individuals who desired their cars to have a sporty acceleration were also willing to purchase a low-emissions vehicle. They also required a

range of no less than 300 miles, as opposed to the 35% that desired a vehicle of an average acceleration and would accept ranges as low as 100 and 200 miles. Those accepting an average acceleration and range of 200 miles were mostly married, over 30, and in the $30,000 and up income bracket, required a top speed of at least 80 and were willing to purchase a low-emissions vehicle when gasoline reaches a price of $2.00-$3.00 per gallon. Of married respondents, 84% would accept average acceleration versus only 56% of the single respondents. It should also be noted that the younger the respondents are the more likely they are to want sporty acceleration, while none of the 16 55+ respondents felt they needed sporty acceleration. In addition, 7 out of 8 males between 21-30 felt that they did need sporty a acceleration. These overwhelming statistics make it easy for automobile manufacturers to know where to target there quick accelerating cars. It could be that people who say they want high top speed are really looking for good(sporty) acceleration which they perceive as making for a safer car.

When questioned as to the desired capacity, 47% wanted a capacity of 6+ people, 39% wanted 4, and 14% settled for a capacity of 2. This question regarding capacity is similar to questions 3 and 4 of section 4 in survey #1, except we now have the ability to compare males and females, married and single, young and old. Of these categories, the most prominent statistic is that 82% of males versus 66% of females want that high range of 300 miles or more. In addition we can now note that an overall 27% are looking for an extremely

high range of 400 miles. Again, it is not clear why the respondents feel this is necessary especially in light of the fact that most trips are under 50 miles.

In terms of appearance, 65% preferred a practical appearance while 35% desired a stylish appearance. The question also offers answers that one may expect, such as 74% of the female respondents surveyed would accept a practical style car versus only 56% of men, and 74% of married respondents reported that they would accept a practical style versus 56% of single respondents surveyed. A percentage of 77% for those requiring a top speed of 90mph and sporty acceleration also desired a stylish appearance. The respondent's switchover from wanting stylish to accepting practical seems to come at thirty years of age (57% want stylish before thirty, and only 22% after the age of thirty). For example, 92% of women over forty years of age reported they would accept a practical style and 87% of males under age thirty want stylish. Such overwhelming figures make it easy to see who the target audience is in terms of style.

When asked what the desired model of their next vehicle, the most desired style was an SUV, with mid and large sized sedans, luxury and mini-vans following evenly with one another. Interestingly, the population that wanted their next model of SUV were also willing to pay more to drive an internal combustion engine; they also have incomes in the $30,000 and up range. The amount of money willing to be spent on initial purchase price for a vehicle meeting all of the criteria desired by any given individual spread evenly across the ranges of $10,000 and under, $10,000-$20,000, $21,000-$30,000 and $31,000+, with a

slight majority in the $21,000-$30,000 range. However 18% of the respondents reported that they do want their next car to be a compact, so despite the proliferation of large vehicles on the road (i.e. SUVs, mini-vans, and pick-ups and the current belief that bigger is safer and better) this statistic indicates that there is still a market for smaller automobiles. The 18% who wanted a compact were spread randomly in every category except one: they were all single. As expected, most of the people who expressed an interest in vans or mini-vans (I suspect that some people were confused and said van when what they meant mini-van) were married (12 out of 15 in this survey). Clearly the most prominent fact that stood out is that only 28% of respondents chose mid-sized or compact, supporting the truth that we have be come a nation that prefers their automobiles large.

The following question, 17 asks the respondents what initial purchase price they would be willing to pay for a new vehicle that met all of their personal criteria. From the data collected from this question it is clear that many people have overcome their sticker shock at the recent escalation of automobile prices. The data from those respondents earning less then $15,000 in this question can probably be eliminated since this survey was taken by a portion of college students. A huge 76% of the rest indicated that they are willing to spend more then $21,000 on an automobile, and 29% said they are willing to spend $31,000! There ought to be room for some pretty fancy alternative energy cars in those price ranges. Another figure that jumps out if you are trying to target a particular

demographics for expensive automobiles is that twice as many males as females are willing to spend $31,000 on there car.

To get an idea of what basic performance characteristics people value most in their vehicle and which ones they could do without, the survey listed several performance features and asked three to be selected as features they would most readily sacrifice at their next vehicle purchase. Top speed appears on 66% of the answers with appearance coming in shortly after it with 63% of the population. Quite a few were willing to sacrifice acceleration 42%. The respondents were not willing to compromise on safety (19%), expense to run (16%), or capacity (23%). A few respondents reported that they would sacrifice range (35%) and purchase price (35%). As expected those willing to sacrifice the safety feature belonged to the younger portion of the respondents surveyed.

To ask the population directly what characteristics of their vehicle they hold as the most important, the last question asks them to rank the same eight options in order of importance. Safety is by far the most important with a result of 73% of the population placing it as number one. Next come expense to run, then purchase price, capacity, acceleration, appearance and then top speed. Those that did feel top speed was the most important option were almost exclusively single males in the 30 and up age bracket that also drove luxury vehicles and SUVs. 80% of the females put safety as their first choice while the majority of the males who put safety as their first option were married and in the older age range. These overwhelming results from this question along with those from the previous question pretty much reveal the same thing: safety is in a category by

itself with very few people willing to compromise on it. Indicating the public will need to be convinced of safety standards before any alternative vehicle can become commercially viable. Money is also, as expense to run and purchase price both seem to rank high in terms of importance. Capacity, range, and acceleration fall into a middle category where there is some room for compromise. If there is a compromise to be made in overall performance characteristics, it is clear that people are more than willing to see it in top speed performance and appearance. There is however one oddity in these results that don't quite mesh with those of the other questions. In this question people consider purchase price fairly important yet in question #17 many people have expressed a willingness to pay big bucks for the right car. This may in fact be one of the more important results of the survey because it probably means that people are willing to spend a large amount of money for a new alternatively powered automobile but only if they feel they are getting real value for their money.

5.10 Survey 2 Conclusions

This second survey indicates that people of all ages and income levels are willing to pay for an alternative powered vehicle, but with a few caveats. Just like today's combustion engine automobiles they must come in many styles to suit various purposes. Importantly the public would have to be convinced that they are absolutely safe to own and drive. They don't necessarily have to be fast nor do they have to have the sharpest appearance, but they will need to have the capacity consumers need. This means that while there is a market for some

smaller more sporty cars, i.e. two-seaters, families are not going to be interested unless the automobile is large enough to suit their needs. They also show a willingness to compromise on range and acceleration. Respondents express that they do not want the automobile to cost too much to operate. Yet this is a subjective question because this survey does not enable us know what people think is too much. If the automobile industry is looking for target price for alternatively powered vehicles they might try this formula. The survey shows that people feel that when gasoline is $3 a gallon that would mean it was time to find another form of power. If we use the fleet average of 17mpg as given in the 2004 World Almanac that could mean that people are currently willing to spend up to about 18¢ a mile for fuel or about a third more than gasoline costs now. Which is an indication that alternative powered vehicles are in fact a good investment.

6. Conclusions

Integrating both the information attained through research and the data analyzed from both surveys it is apparent that a large number of people are willing to begin committing to driving lower emission vehicles, provided their performance is comparable to that of the conventional internal combustion engines. It is also clear from the surveys that much of the reservations people have in driving alternative vehicles is a result of their misconceptions and lack of knowledge regarding some of the alternative fuels being suggested: for example hydrogen and liquefied petroleum gas. A certain number embrace the alternatively powered vehicle as an altruistic substitute for the internal combustion engine, believing that making a small sacrifice that benefits the environment is worth the inconvenience. There is another group, not quite as environmentally conscious, that believe that when gas reaches the equivalent of about three dollars a gallon they would be willing to accept the slight privations of alternative powered vehicles. Both groups want more or less the same things out of their alternative powered vehicles in terms of performance capabilities and show similarities in the areas where they would be willing to accept some degradation in performance; specifically top speed, acceleration, range, and styling. While the vast majority will not compromise on safety, they do express a willingness to pay more for such vehicles and to put up with some inconvenience in regard to refueling. The information extracted from the surveys also reveal that there is a wide range in what the alternative powered vehicles will have to look and how they will have to perform in order to make commercially viable. Each

owner wants to use his or her vehicle in conjunction with their own particular lifestyle. Just as how today the free market system lends itself to providing a variety of vehicle options there are hundreds of styles and models for the general public to choose from, and the automobile manufacturers will have to continue to offer a wide variety of alternative powered vehicles if they hope to win over the majority of new car purchasers.

In terms of actual environmental friendliness, vehicles that offer future promise possible zero-emission standards such as electric and hydrogen are currently only as clean as the source from which they generate electricity giving the benefit of either zero emission or controlled release circumstances. Before the infrastructure for both of these options is implemented, the most practical alternative to the combustion engine is the hybrid which is cost effective, commercially viable and has available infrastructure. Although compressed natural gas vehicles and liquefied petroleum gas vehicles offer an improvement in emissions, they too lack infrastructure and do not have a performance that rivals the hybrid. After considering both the information attained through researching the various types of developing alternative vehicles and the data extracted from the two surveys it is clear that the position of each type of vehicle in terms of its progress towards commercial viability relies heavily on governmental regulations. Although some the success of the vehicles discussed in this document will rely heavily on consumer preference, the majority of their achievement will come from the governments employment of necessary infrastructure, incentives and governmental regulations. Even though the

demand for hybrid vehicles currently has dealerships with excess numbers of customers willing to commit to more fuel efficient vehicles, the U.S. government is restricting the number of models that can be sold. The programs enacted in the state of California has employed restrictions on fuel emissions using electric cars have proven to be both beneficial and successful: one may questions whether the government could help reduce fuel emissions in the remaining states via tax incentives and or regulations. With the ever increasing effects of global warming and global dimming it seems counterintuitive that " the White House and Congress enacted tax incentives such that the owner of a Hummer, which gets less than ten miles per gallon, receives a tax deduction of $34,000. The Deduction for an efficient hybrid car that gets over 50 miles per gallon is $4,000." (Morris, David)

As it currently stands the only alternatively powered vehicle that is finding its way to the general public is the electric car. In its current form I would have to classify this type of car as a novelty although eventually it appears that it will be an acceptable form of transportation, since it's current performance characteristics are simple and too compromised to appeal to the general public. Until then the hybrid is the one form of transportation that is poised to make a big splash in the automotive scene. Although technically not an alternatively powered vehicle because it still obtains all of it power from gasoline, I believe it is going to perform a very important function in our car oriented society. It is going to act as a bridge between today's gas guzzling vehicle and the true alternatively powered vehicles of the future. It will help the automobile manufacturers to

determine what characteristics their vehicles will need in order to make their vehicles attractive to the buyers. It will also show the automobile user that compromises in performance, styling, capacity, and expense is something we can learn to live with to preserve our environment.

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This is a survey evaluating alternatively powered vehicles. This survey will be used to inform automobile makers, energy suppliers and governmental agencies as to the necessary criteria to make alternative vehicles commercially viable.

Section1: General Perceptions

1) Place the following seven types of automobiles in the order of what you perceive to be the most practical to own. (1 being the most practical, 7 being the least practical)

In terms of cost:

___ Gasoline
___ Electric (using lead acid batteries)
___ Hybrid (battery and gasoline)
___ Compressed natural gas
___ Liquefied petroleum gas
___ Hydrogen
___ Solar

In terms of convenience:

___Gasoline
___Electric (using lead acid batteries)
___Hybrid (battery and gasoline)
___Compressed natural gas
___Liquefied petroleum gas
___Hydrogen
___Solar

2)Rank the same seven types of automobiles in order of what you perceive as being the safest to own. (1 being the safest, 7 being the most dangerous)

___Gasoline
___ Electric (using lead acid batteries)
___ Hybrid (battery and gasoline)
___ Compressed natural gas
___ Liquefied petroleum gas
___ Hydrogen
___ Solar

3)Rank the same seven types of automobiles in order of what you perceive would be the most survivable to an occupant in a serious accident(1 being the safest, 7 being the most dangerous):

___ Gasoline
___ Electric (using lead acid batteries)
___ Hybrid (battery and gasoline)
___ Compressed natural gas
___ Liquefied petroleum gas
___ Hydrogen
___ Solar

4)Rank the same seven types of automobiles in order of what you perceive as the most environmentally friendly. (1 being the most environmentally friendly, 7 being the least)

___ Gasoline
___ Electric (using lead acid batteries)
___ Hybrid (battery and gasoline)
___ Liquefied petroleum gas
___ Compressed natural gas
___ Hydrogen
___ Solar

Section 2: Demographics

Please check the box that best applies to you.

1)Gender: ☐ **M** ☐ **F**

2) How many people are in your household?
☐ **1** ☐ **2** ☐ **3** ☐ **4** ☐ **5+**

3)How many licensed drivers are in your household?
☐ **1** ☐ **2** ☐ **3** ☐ **4** ☐ **5+**

4)How many automobiles does your family own or lease?
☐ **1** ☐ **2** ☐ **3** ☐ **4+**

Section 3: Your Car

Please fill in the following information for each vehicle. Start with the vehicle that you feel is the most important to you/your family.

Vehicle #1

1)**Make**_____**Model**_____
Year_____
Driver (self, spouse, child):_____
Used for: **Commuting**_____**Business**_____
Short local trips____**Other**____

2)Typical number of occupants during the most common type of trip:
☐ **1** ☐ **2-3** ☐ **4-5** ☐ **5-7**

3)Length of the most common type of trip:
☐**1-25mi** ☐**25-50mi** ☐**50-100mi** ☐**100mi+**

4)Highest speed attained on most common type of trip:
☐**30-45mph** ☐**45-55mph** ☐**55-65mph**
☐ **65-80mph** ☐**80mph+**

5)Do you sometimes carry significant extra cargo in this vehicle? ☐**Yes** ☐**No**

6)Number of miles this vehicle travels per year?
☐ **0-6,000mi** ☐ **6,000-10,000mi**
☐ **10,000-15,000mi** ☐ **15,000mi+**

Vehicle#2

7) **Make**_____**Model**_____**Year**____
Driver(self, spouse, child):_____
Used for: **Commuting**_____**Business**_____
Short local trips___**Long family trips**___
Other____

8)Typical number of occupants during most common type of trip?
☐ **1** ☐ **2-3** ☐ **4-5** ☐**5-7**

9)Length of the most common type of trip?
☐ **1-25mi** ☐ **25-50mi** ☐ **50-100mi** ☐**100mi+**

10)Highest speed attained on most common type of trip?
☐ **30-45mph** ☐ **45-55mph** ☐ **55-65mph**
☐ **65-80mph** ☐ **80mph+**

11)Do you sometimes carry significant extra cargo in this vehicle? ☐ **Yes** ☐ **No**

12)Number of miles this vehicle travels per year?
☐ **0-6,000mi** ☐ **6,000-10,000mi**
☐ **10,000-15,000mi** ☐ **15,000mi+**

Section 4: Your Driving habits

For the following questions, a primary vehicle is the vehicle your family would own if you could only have one. A secondary is one that would be used for commuting and local trips. Please circle the answer that applies to you.

1)How fast do you feel your primary vehicle must be able to go?
☐ **65mph** ☐ **75mph** ☐ **85mph** ☐ **85mph+**

2)How fast do you feel your secondary vehicle must be able to go?
☐ **65mph** ☐ **75mph** ☐ **85mph** ☐ **85mph+**

3)What range before refueling do you feel your primary vehicle must provide?
☐ **100mi** ☐ **100-150mi** ☐ **150-300mi** ☐**300mi+**

4)What range before refueling do you feel your secondary vehicle must provide?
☐ **100mi** ☐ **100-150mi** ☐ **150-300mi** ☐**300mi+**

5)How much could you afford to pay for a vehicle at the present time?
☐ **1-10,000$** ☐ **10,000-20,000$**
☐ **20,000-30,000$** ☐ **30,000$+**

_____

_____

Section 5: Alternatively Powered Vehicles

1)Assuming that the inconvenience was negligible and the performance acceptable, how much extra money would you be willing to pay per year to drive a zero emission vehicle?
☐ **0$** ☐ **0-500$**
☐ **1,000-2,000$** ☐ **2,000-5,000$**

2)If you were informed that some alternatively powered vehicles that are commercially available today are cheaper than most mid-sized sedans, would you consider purchasing an alternatively powered vehicle?
☐ **Yes** ☐ **No**

3)If you owned an alternatively powered vehicle, how much **extra** time would you be willing to spend refueling?
☐ **0min** ☐ **1-2min** ☐ **2-5min** ☐ **5-15min**

4)Have you ever driven an alternatively powered vehicle? ☐ **Yes** ☐ **No**

5)If yes, how would you rate your experience?
(1 = very good, 10 = very bad)_____.

6)Is the physical appearance of alternatively powered vehicles appealing to you? ☐ **Yes** ☐ **No**

7)Could you see yourself owning an alternatively powered vehicle at the present time?
☐ **Yes** ☐ **No**

8)If all the limitations had been overcome (fueling, range, safety, etc.), and the performance was acceptable, could you see yourself owning an alternatively powered vehicle as your primary vehicle in the future?
☐ **Yes** ☐ **No, If No, why?**

9) Would you consider owning an alternatively powered vehicle as a secondary vehicle to be used for limited purposes?
☐ **Yes** ☐ **No, If No, Why?**

This is a survey evaluating alternatively powered vehicles. This survey will be used to inform automobile manufactures with the necessary criteria to help make alternatively powered vehicles commercially viable.

Please check the box that best applies to you.

1)Age: □ under 21 □ 21-30 □ 30-40 □ 40-55 □55+

2) Gender: □ M □ F

3) Marital Status: □ Single □ Married

4) Size of family: □ 1 □ 2 □ 3-5 □ 5+

5) Income:

□0-15,000$ □15,000-30,000$ □ 30,000-60,000$ □60,000-80,000$ □$80,000+

6) What type of vehicle do you currently own?

□ Compact □ Mid-sized sedan □ Large sedan □ SUV

□ Luxury □ Mini-Van □ Van □ Pick-up truck

7) Would you consider purchasing a low-emissions vehicle (such as a hybrid or compressed gas) for your next vehicle purchase? □ Yes □ No

8) What price per gallon will gasoline have to reach before you would consider purchasing a vehicle with lower performance but better gas mileage?

□$2.00 □$3.00 □$4.00 □$5.00 □$6.00+

9) How much extra would you be willing to pay in terms of initial purchase price to own a lower-emissions vehicle?

□ $500 □1,000-3,000$ □3,000-5,000$ □$5,000+

10) How much extra time would you be willing to spend re-fueling?

□0min □ 1-2min □ 3-5min □ 5+min

11) What do you feel must be the top speed of your next vehicle?

□ 60mph □ 70mph □ 80mph □ 90mph

12) What type of acceleration must your next vehicle have? □ Average □ Sporty

13) What maximum range must your next vehicle have?

□100mi □200mi □300mi □ 400mi

14) What is the capacity you feel your next vehicle have? □ 2 people □ 4 people □ 6+ people

15) What must the appearance of your next vehicle be? □ Practical □ Stylish

16) What is the desired style of your next vehicle?

□ Compact □ Mid-sized sedan □ Large sedan

□ Luxury □ SUV □ Pick-up truck

□ Mini-Van □ Van

17) What price would you be willing to pay for a new vehicle that met all of your criteria?

□ Under $10,000 □ 10,000-20,000$

□ 21,000-30,000$ □ $31,000+

18) Please indicate three of the following that you would be willing to sacrifice in your next vehicle purchase?

□ Top speed □ Capacity □ Safety

□ Acceleration □ Range □Purchase Price

□ Expense to run □ Appearance

19) Please rank the following in terms of importance to you: (1 being the most important, 8 being the least important)

___Top speed ___ Capacity ___ Safety

___ Acceleration ___ Range ___Purchase Price

___ Expense to run ___ Appearance

Survey 1

Section 2

Question1 **Gender**

male	77	60%
female	52	40%

Question2 **Household #**

	1		2		3		4		5+	
female	5	10%	7	13%	8	15%	19	37%	13	25%
male	5	7%	8	11%	14	18%	25	32%	25	32%
all	10	8%	15	12%	22	17%	44	34%	38	29%

Question3 **Licensed drivers**

	1		2		3		4		5+	
female	10	19%	22	42%	7	14%	10	19%	3	6%
male	9	12%	23	30%	23	30%	14	18%	8	10%
all	19	15%	45	35%	30	23%	24	19%	11	8%

Question4 **Auto's owned or leased**

	1		2		3		4+	
female	10	19%	22	42%	8	16%	12	23%
male	11	14%	23	30%	26	34%	17	22%
all	21	16%	45	35%	34	27%	29	22%

Section3

Question1 **What vehicle #1 used for**

male	**veicle1**		**vehicle2**		**female**	**vehicle1**		**vehicle2**	
					biz,slt	2	4%		0
biz	2	3%	3	5%	**biz**	2	4%		0
biz,o,slt	1	2%	1	2%	**biz,o,slt**	1	2%		0
com	11	16%	8	14%	**com**	10	20%	10	35%
com,biz	6	4%	2	4%	**com,biz**		0	2	7%

com,biz,o	1	2%			0	**com,biz,o**	1	2%	1	3%		
com,biz,slt	4	6%	2	4%		**com,bizslt**	2	4%			0	
com,biz,slt,o	21	31%	1	2%		**com,biz,slt,o**	6	12%	2	7%		
com,biz,slt,lft			0	6	11%				0		0	
com,o	1	2%	1	2%		**com,o**	2	4%			0	
com,slt	9	13%	3	5%		**com,slt**	13	25%	3	11%		
com,slt,lft			0	6	11%	**com,slt,lft**			0	1	3%	
com,slt,o	4	9%	9	16%		**com,slt,o**	3	5%	1	3%		
o	3	5%	6	11%		**o**	2	4%	2	7%		
lft			0	1	2%				0		0	
slt	3	5%	4	7%		**slt**	6	12%	4	14%		
			0		0				0		0	
slt,o		2%	1	2%		**slt,o**	1	2%	2	7%		
slt,lft			1	2%		**slt,lft**			0	1	3%	
total		67			55	**total**		51			29	

Question2 **Number of occupants during most common type of trip**

	1		**2--3**		**4--5**		**5--7**	
All	46	36%	77	60%	6	4%		
F	15	29%	34	65%	3	6%		
M	31	40%	43	56%	3	4%		

Question3 **Length of the most commonjm type of trip**

	1--25		**25--50**		**50--100**		**100+**	
All	74	58%	43	33%	10	8%	2	1%
F	27	52%	18	35%	6	11%	1	2%
M	47	61%	25	33%	4	5%	1	1%

1occupant	28	15	2
2-3occ	40	28	6

Question4 **Highest speed on most common type of trip**

	30--45	45--55	55--65	65--80	80+
M	10 13%	19 25%	15 19%	24 31%	9 12%
F	7 13%	11 21%	18 35%	13 25%	3 6%
All	17 13%	30 23%	33 26%	37 29%	12 9%

Question5 Do you sometimes carry sig. extra cargo

	yes	no
All	71 55%	58 45%
M	43 56%	34 44%
F	28 54%	24 46%

Question6 Number of miles you travel per year

	0--6000	6000--10	10000-15	15+
M	17 22%	11 15%	22 29%	26 34%
F	11 21%	10 19%	16 31%	15 29%
All	28 22%	21 16%	38 30%	41 32%

Question8 car #2 Typical number of occupants

	1	2--3	4--5	5--7	NA
M	22 29%	21 27%	3 4%	0	31 40%
F	11 22%	13 25%	1 3%	1 3%	26 50%
All	33 26%	34 26%	4 3%	1 1%	57 44%

Question9 Legnth of trip

	1--25	25--50	50--100	100+	NA
M	19 25%	20 26%	4 5%	3 4%	31 40%
F	12 23%	9 17%	5 10%	0	26 50%
All	31 24%	29 23%	9 7%	3 2%	57 44%

Question10 Highest Speed

	30--45	45--55	55--65	65--80	80+
F	4 15%	8 31%	6 23%	5 19%	3 12%
M	4 9%	11 24%	9 19%	11 24%	11 24%
All	8 11%	19 26%	15 21%	16 22%	14 20%

Question11 Significant cargo

	yes	no

M	19 41%	27 59%
F	6 23%	20 77%
All	25 35%	47 65%

Question12

Number of miles per year

	0--6000	**6000-10**	**10000-15**	**15000+**
M	7 15%	12 27%	12 27%	14 31%
F	9 35%	8 31%	4 15%	5 19%
All	16 23%	20 28%	16 23%	19 26%

Section4

Question1

How fast do you think your primary vehicle must be able to go

	65	**75**	**85**	**85+**
M	4 6%	17 22%	21 27%	35 45%
F	8 15%	11 21%	16 31%	17 33%
All	12 9%	28 22%	37 29%	52 40%

Question2

Speed of secondary auto

	65	**75**	**85**	**85+**
M	7 9%	20 26%	20 26%	30 39%
F	10 19%	13 25%	15 29%	14 27%
All	17 13%	33 26%	35 27%	44 34%

Primary vs. secondai auto

65-65	65-75	65-85	65-85+
11	1	0	0

75-65	75-75	75-85	75-85+
3	22	3	0

85-65	85-75	85-85	85-85+
1	6	25	5

85+-65	85+-75	85+-85	85+-85+
2	3	8	39

Question3

	range of primary							
	100		**100-150**		**150-300**		**300+**	
M	5	6%	12	16%	37	48%	23	30%
F	7	14%	13	25%	22	42%	10	19%
All	12	9%	25	19%	59	46%	33	26%

Question4

	range of secondary							
	100		**100-150**		**150-300**		**300+**	
M	4	5%	14	19%	34	46%	22	30%
F	8	17%	16	33%	13	27%	11	23%
All	12	10%	30	25%	47	38%	33	27%

Primary vs. Secondary

	100-(100)	**100-(100-150)**	**100-(150-300)**	**100-(300+)**
All	8	3	1	0

	100-150-(100)	**100-150-(100-150)**	**100-150-(150-300)**	**100-150-(300+)**
All	4	17	4	NA

	150-300-(100)	**150-300-(100-150)**	**150-300-(150-300)**	**150-300-(300+)**
All	0	10	38	7

	300+-(100)	**300+-(100-150)**	**300+-(150-300)**	**300+-(300+)**
All	0	1	5	26

vehicle#1		**vehicle#2**	
speed	**range**	**speed**	**range**
85+	(150-300)	85+	(150-300)

Question5

	How much could you afford to pay for a vehcile at the present moment							
	under 10		**10--20**		**20--30**		**30+**	
M	36	47%	18	24%	16	21%	6	8%
F	16	32%	16	32%	9	18%	9	18%

All	52	45%	34	29%	15	13%	15	13%

Section5

Question1 Assuming that the convience acceptable...would you buy zero emmision

	0		0-500		1000-2000		2000-5000	
M	14	18%	23	30%	17	22%	23	30%
F	6	11%	12	23%	19	37%	15	29%
All	20	17%	35	29%	26	22%	38	32%

Question2 If you were informed that some alternatively powered vehicles that one commercially...would you buy one

	yes		no	
F	40	77%	12	23%
M	61	79%	16	21%
All	101	78%	28	22%

Question3 If you owned an alternatively powered vehicle how m extra time would you be willing to spend refueling

	0		1--2		2--5		5--15	
M	12	16%	16	21%	33	44%	14	19%
F	2	4%	11	21%	28	55%	10	20%
All	14	11%	2	21%	61	49%	24	19%

Question4 Have you ever driven an alternatively power vehicles

yes		no	
16	12%	113	88%

Question5 If yes how would you rate your experience

1	2	3	4	5	6	7	8	9	10
4	1	2	1	3	1	1			

Question6 Is the physical appearance of alternatively powered vehciles appealing to you

	yes		no		NA		
M	34	44%	41	53%	2	3%	
F	26	50%	26	50%			0
All	60	46%	67	52%	2	2%	

Question7 could you seee yourself owning an alternatively powered vehicle at the present time

	yes		no		NA	
M	39	51%	38	49%		0
F	34	65%	17	33%	1	2%
All	73	57%	55	43%		0

Question8 If all the limitation had been overcome…could you seee yourself owming an alt. vehicle in future

	yes		no	
M	70	91%	7	9%
F	48	92%	4	8%
All	118	91%	11	9%

Question9 would you consider owning an alt vehicle as a secondary vehicle

	yes		no	
M	67	87%	10	13%
F	49	94%	3	6%
All	116	90%	13	10%

Section 3 Your Car

	vehicle1	vehicle2
acura	1	1
audi	1	1
buick	1	0
bmw	0	4
camry	18	0
corolla	10	0
chevy	5	15
chrysler	3	2
dodge	14	5
ford	8	4
geo	2	1
gmc	2	0
honda	8	9
hummer	1	0
hyndai	3	0

isuzu	1	0
jeep	9	5
land rover	1	0
lexus	1	0
lincoln	2	0
mazda	2	0
mercedes	3	2
mercury	6	1
mitsubishi	3	0
nissan	3	2
oldsmobile	1	0
plymouth	1	0
pontiac	2	1
porche	1	0
sabb	1	1
saturn	1	1
suburu	2	5
toyota	33	14
volvo	2	2
volkswagon	7	4
NA		57

foreign	73	57%
domestic	56	43%

Survey #1 : Section 1: General Perceptions

1)

cost:

1 gasoline
4 electric
2 hybrid
5 cng
6 lpg
7 hydrogen
3 solar

convience:

1 gasoline
3 electric
2 hybrid
4 cng
5 lpg
6 hydrogen
7 solar

2)

2 gasoline
3 electric
4 hybrid
5 cng
7 lpg
6 hydrogen
1 solar

3)

3 gasoline
2 electric
4 hybrid
5 cng
6 lpg
7 hydrogen
1 solar

4)

7 gasoline
2 electric
4 hybrid
6 lpg
5 cng
3 hydrogen
1 solar

Survey 2
Ques. 7

yes	67	91%
no	7	9%

Ques. 8

		$2		**$3**		**$4**		**$5**		**$6+**	
All	32	43%	21	28%	10	14%	5	7%	6	8%	
income											
0-15	10	31%	2	9.95%	2	20%	1	20%	2	33%	
15-30	7	22%	2	9.95%	3	40%			0 1	17%	
30-60	5	16%	2	9.95%			0 1	20%			0
60-80	4	12%	7	33%	2	20%	2	40%	1	17%	
80+	6	19%	8	38%	3	40%	1	20%	2	33%	
fam size											
1	11	34%	2	10%	5	50%	1	20%	2	33%	
2	5	16%	2	10%	1	10%	3	60%	4	67%	
3 5	13	41%	13	62%	4	40%	1	20%			0
5	3	9%	4	19%		0		0			0
female	15	47%	8	38%	6	60%	3	60%	3	5-%	
male	17	53%	13	62%	4	40%	2	40%	3	50%	

age

-21	5	16%		0	2	20%	2	40%		0
21-30	9	28%	6	29%	2	20%	2	40%	1	16.95%
30-40	7	22%	3	14%	1	10%		0	3	50%
40-55	6	18%	7	33%	1	10%		0	1	16.95%
55+	5	16%	5	24%	4	40%	1	20%	1	16.95%

Ques. 9

	0		**0-500**		**500-1000**		**1000-3000**		**3000-5000**		**5000+**	
all	7	9%	15	21%	15	21%	15	21%	9	12%	12	16%

Ques. 10

	0 min.		**1-2min**		**3-5min**		**5+**	
all	8	11%	26	36%	22	30%	17	23%
male	6	16%	13	34%	8	21%	11	29%
female	2	6%	13	37%	14	40%	6	17%

Ques. 11 **What do you feel must be the top speed of your vehicle**

	60		**70**		**80**		**80+**	
All	3	4%	13	18%	29	39%	29	39%
F	2	6%	6	17%	15	43%	12	34%
M	1	2%	7	18%	14	36%	17	44%

Age

-21	0		0	2	3%	7	9%	

21-30			0	1	1%	8	11%	10 14%
30-40	1	1%		4	6%	3	4%	6 8%
40-55			0			0	11 15%	4 6%
55+	2	3%		8	11%	5	7%	1 1%
single	1	1%		4	6%	11	15%	20 27%
married	2	3%		9	12%	18	24%	9 12%
single M			0	2	6%	4	11%	10 29%
single F	1	2%		2	6%	6	17%	10 29%
Family#								
1			0	3	14%	6	29%	12 57%
2	1	7%		3	20%	2	13%	9 60%
3--5	2	7%		6	20%	15	50%	7 23%
5+			0	1	2%	50	96%	1 2%
21-30 M			0			0	3 37%	5 63%

Ques. 12 **What type of acceleration must your vehicle have**

	Average	**Sporty**
All	52 70%	22 30%
M	24 62%	15 38%
F	28 80%	7 20%

	Single	20	56%	16	44%			
	Married	32	84%	6	16%			
	Age							
	-21	3	33%	6	67%			
	21-30	10	53%	9	47%	(7M 78%, 2F 22%)		
	30-40	12	86%	2	14%			
	40-55	10	67%	5	33%			
	55+	16	100%			0		
	21-30 M	1	13%	7	87%			

Ques. 13 **What maximum range must your next vehicle have**

	100		**200**		**300**		**400**	
All	4	6%	15	20%	35	47%	20	27%
M	1	3%	6	15%	20	51%	12	31%
F	3	8%	9	26%	15	43%	8	23%
Married	1	3%	8	21%	18	47%	11	29%
Single	3	8%	7	20%	17	47%	9	25%
Age: -21	0		1	11%	5	56%	3	33%
21-30	0		5	26%	10	53%	4	21%
30-40	1	7%	4	29%	6	43%	3	21%
40-55	2	12%	3	19%	6	38%	5	31%

note: people think there is more range in current cars than there are

	55+	1	7%	2	12%	8	50%	5	31%

Ques. 14 **what is the capacity you feel your next vehicle must have**

		2		**4**		**6+**	
All	10	14%	29	39%	35	47%	
M	6	15%	12	31%	21	54%	
F	4	11%	17	49%	14	40%	
Married	4	11%	13	34%	21	55%	
Single	6	17%	16	44%	14	39%	
Age: -21	0		5	56%	4	44%	
21-30	2	11%	8	12%	9	47%	
30-40	4	28%	5	36%	5	36%	
40-55	1	6%	3	19%	12	75%	
55+	3	19%	8	50%	5	31%	

Ques. 15 **What appearance must your next auto have**

	Practical		**Stylish**	
All	48	65%	26	35%
M	22	56%	17	44%
F	26	74%	9	26%
Single	20	56%	16	44%
Married	28	74%	10	26%

Age:	**-21**	4	44%	5	56%
	21-30	8	42%	11	58%
	30-40	11	79%	3	21%
	40-55	14	88%	2	12%
	55+	11	69%	5	31%
Age:	**21-30 M**	1	12%	7	88%
	40-55 F	6	100%	0	
	55+ F	6	86%	1	14%
	55+ M	5	56%	4	44%
	40-55 M	8	80%	2	20%

Quest. 16 **What is the desired style of your next vehicle**

		comp	mid-size	large	luxury	suv	pick-up	mimi-van	van
	All	13 18%	8 11%	8 11%	12 16%	15 20%	3 4%	9 12%	6 8%
	M	6 15%	2 5%	4 10%	8 21%	8 21%	3 8%	4 10%	4 10%
	F	7 20%	6 18%	4 11%	4 11%	7 20%	0	5 14%	2 6%
Age:	**-21**	5 56%	0	0	1 11%	1 11%	1 11%	1 11%	0
	21-30	1 5%	3 15%	2 11%	1 5%	4 21%	2 11%	2 11%	4 21%
	30-40	3 22%	2 14%	1 7%	3 22%	1 7%	0	2 14%	2 14%
	40-50	2 13%	1 6%	1 6%	3 19%	7 43%	0	2 13%	0
	55+	2 13%	2 13%	4 27%	3 21%	2 13%	0	2 13%	0

	married			0	5	13%	7	18.33%	6	16%	7	18.33%	1	3%	7	18.33%	5	13%
	single	13	36%		3	8%	1	3%	6	16%	8	22%	2	6%	2	6%	1	3%

Ques. 17 **What price would you be willing to pay for a new vehicle that met all your criteria**

	All	15	20%	19	26%	21	28%	19	26%
	F	8	23%	11	31%	10	29%	6	17%
	M	7	18%	8	21%	11	28%	13	33%
	married	5	13%	8	21%	14	37%	11	29%
	single	10	28%	11	31%	7	19%	8	222%
	-21	5	56%	2	22%	1	11%	1	11%
	21-30	4	21%	8	42%	3	16%	4	21%
	30-40	4	21%	8	42%	3	16%	4	21%
	40-55	1	7%	2	13%	7	47%	5	33%
	55+	1	6%	2	12%	7	44%	6	38%
income:	**-15**	9	50%	5	28%	1	5%	3	17%
	15-30	4	33%	5	42%	2	17%	1	8%
	30-60			0	3	38%	5	63%			0
	60-80	2	13%	2	13%	7	44%	5	31%
	80+			0	4	20%	6	30%	10	50%

Ques. 18 **Please indicate 3 of the following that you would be willing to sacrafice in your next vehicle**

	TopSpped	**Capacity**	**Safety**	**Acc.**	**range**	**purch. Pr**	**$ to run**	**app.**
All	**41,7,1**	**9,7,1**	**5,4,5**	**9,20,2**	**2,17,7**	**3,8,15**	**3,1,8**	**2,10,35**

Ques.19 **rank in order of importance, 1=most important**

	topspeed	**capacity**	**safety**	**acc.**	**range**	**purch. Pr**	**$ to run**	**app.**
1	7 9%	2 3%	54 72%	0	0	8 11%	2 3%	1 1%
2	0	18 24%	8 10%	6 8%	5 7%	17 23%	18 25%	2 3%
3	3 4%	11 15%	4 5%	11 15%	7 9%	9 12%	26 36%	3 4%
4	6 8%	11 15%	1 1%	12 16%	16 22%	14 19%	9 12%	5 7%

5	7	9%	9	12%	2	3%	13	18%	23	31%	9	12%	5	7%	6	8%
6	20	27%	11	15%	2	3%	13	18%	9	12%	6	8%	6	8%	7	10%
7	18	25%	6	8%	2	3%	15	20%	10	14%	5	7%	4	5%	14	19%
8	13	18%	6	8%	2	3%	4	5%	4	5%	6	8%	3	4%	35	48%