



A Study on Hybrid Cars: Environmental Effects and Consumer Habits

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Abstract

This paper focused on hybrid vehicle technology and its integration into society. The encompassing issue answered in this project was whether hybrids meet the expectations for environmental benefits suggested by many people. Research was done in the areas of types of hybrids, consumer trends, and the future of hybrid technology. Hybrid production and efficiency data were analyzed to examine the technical aspects of the technology. A focus group of people who recently bought cars, both hybrids and non-hybrids, revealed what consumers look for in their cars. Analysis of the needs of hybrid technology helped determine how feasible widespread change to hybrids would be in the future. With all information taken into account, we concluded that hybrids have several drawbacks that offset their fuel efficiency. Their higher price both turns consumers away and makes the vehicles a less attractive economic investment. Energy efficient processing techniques need to be developed before the advanced materials in hybrids can help add to their clean image. Widespread change to advanced hybrid technologies is not a feasible option in the near future because of both cost and the limited amount of hybrids on the road today. Overall, hybrid technology has a lot of potential in the distant future, but as for right now they are not a significant improvement over today's internal combustion engine.

Executive Summary

This Interactive Qualifying Project focused on the ever advancing hybrid vehicle technology and its integration into society. Society has been making a large effort to make everything green and cleaner in today's world, including transportation. Advertisements have led people to believe that hybrid cars pollute less, will save money and reduce dependence on natural fuel sources. The encompassing question answered in this paper was; do hybrids live up to expectations that society has suggested of them in the past decade?

The push to develop green technologies stems from the fact that the earth's atmosphere is rapidly changing. This change is largely due to human activity; industry, transportation, waste, and everyday living. Everyday large amounts of pollutants are released into the atmosphere leading the greenhouse effect and global warming. This global warming can cause major issues such as the melting of polar ice caps and a rise in sea level, which in turn would cause intense flooding in most if not all coastline areas, giving cause to other disasters such as mass erosions, mud slides, outbreaks of disease to more humid climates, coastal reformation, and other disasters. Given enough time, a steady increase of these gasses would also change the length and intensity of the seasons, create droughts, and increase the frequency and impact of large storms. Conjoined efforts are being made by countries to understand this growing dilemma, and scientists are trying to theorize ways to slow its effects.

Industry plays a large role in the amount of emissions that are released into the atmosphere. Every vehicle manufactured produces emissions, both while being made and while driving on the road. These emissions include nitrogen gas (N₂), carbon dioxide (CO₂), water vapor (H₂O), carbon monoxide (CO), hydrocarbons or volatile organic compounds (VOCs), and nitrogen oxides (NO and NO₂, together called NO_x).¹ Regulations have been placed on industries to try and reduce the amount of pollutants released into the atmosphere, but further steps need to be taken. Energy consumption by industries, in the manufacturing of products, also leads to pollutants. Whether oil, coal, nuclear, or even water or wind power is used to create energy, harmful by-products are still produced.

¹ Randy 2009

People buy new cars for a variety of reasons, sometimes out of necessity, sometimes for vanity, and sometimes for fun. Buying a car is a big investment and requires the consideration of many different variables. People look into price, performance, safety, and reliability when searching for a new car. With the growing interest in saving our planet, many companies have created hybrid cars and the government is developing incentive programs. These factors have enticed many people to consider buying these vehicles.

With many types of hybrid technology available there is much interest in widespread conversion to hybrid transportation. With such a massive world population and high dependency on transportation, a significant switch to hybrids from gasoline and diesel vehicles must be met before any changes can be seen. This could mean converting all of our gas stations; possibly to electric plug in stations or hydrogen fill up stations. A widespread change to hybrids requires an extended period of time and also may not be cost effective. Many of the outcomes are not worth all that goes into getting the advanced technology on the road.

After extensive research we decided to focus on car production, efficiency, what things people take into consideration when buying a car, and what current purchasing trends are. To do this we analyzed emissions, energy and material data allowing us to compare energy consumption values, emission levels, and vehicle efficiency. This data was then graphed to draw conclusions. Focus groups were organized, for both people that bought hybrids and non-hybrids, to gather consumer purchasing information. An interview was conducted with a local car dealership owner to discuss hybrid marketing strategies.

The data suggested that the production of hybrids consumes more energy and releases more emissions than the production of conventional cars. This is mostly because of the advanced materials that are required in hybrids. It was also determined that hybrids are not a great investment for the consumer. For a hybrid to break even with the higher price a consumer will have to drive primarily in the city and for more miles than the average person keeps a car for.

Focus group participants indicated that there are a variety of different reasons for individuals to purchase new vehicles. The most prominent deciding factors were related to lifestyle; having to do with family necessities, daily commute, different personal activities, or

weather conditions. Another major deciding factor for purchasing a new vehicle was affordability. The interview with the local car dealer verified that their currently is not much of a market for hybrid vehicles

We made several conclusions about hybrid vehicles. We found that hybrid vehicles create much more emission in their production, before even being driven, in some cases consuming up to four times the energy. Although hybrid cars typically achieve better gas mileage, they are initially much more expensive than conventional vehicles. If the increased initial cost of a hybrid is too much, the investment will be very hard to break even with. Hybrids must be driven to high mileages in certain conditions to really be worth paying for; these mileages are often many times higher than the average mileage that a consumer keeps their car for. In our focus group of non hybrid vehicles, the additional investment of a hybrid car was often a deciding factor against purchasing a hybrid vehicle. Others in the non-hybrid focus group were unable to find hybrid vehicles that fit the requirements that were necessary to accommodate their lifestyles. Those that purchased hybrid vehicles were often doing so as a statement about their concern and efforts to saving the environment. Industry needs to find cleaner and more efficient way of producing lightweight materials such as aluminum and carbon fiber, which is used in the car bodies. More effective and increased levels of recycling would lead to much lower energy consumption and would add to the clean image of hybrids. Hybrid vehicles need to be utilized in situations that will benefit the most from them, such as public transportation. It can also be concluded that widespread implementation of hybrid technology is not feasible at this time. The production of equally efficient hybrid vehicles is not great enough to compete with non-hybrids, both economically and numerically.

Chapter 1. Introduction

As modern culture and technology continue to develop, the growing presence of global warming and irreversible climate change draws increasing amounts of concern from the world's population. Earth's climate is beginning to transform, proven by the frequent severe storms, the drastic shrinking of polar ice caps and mountain glaciers, the increased amount of flooding in coastal areas, and longer droughts in arid sections of the world. There are large holes in the ozone layer of the earth's atmosphere and smog levels are ever increasing, leading to decreased air quality². It is true that natural causes such as geothermal vents and volcanic hotspots are part of the global warming problem but many of the issues are still a result of the massive quantities of greenhouse gases that the world's population has produced in the past few centuries. It has only been within the past few decades that modern society has actually taken notice of these changes and decided that something needs to change if the global warming process is to be stopped, or even slowed at this point in time. Countries around the world are working to drastically reduce CO₂ emissions as well as other harmful environmental pollutants. Everything from cars and industries to livestock and crops are being studied and regulated with plans of minimizing pollution levels.

Amongst the most notable producers of these pollutants are automobiles, which are almost exclusively powered by internal combustion engines and spew out unhealthy emissions. Cars and trucks are responsible for almost 25% of CO₂ emission, and other major transportation methods account for another 12%.³ With a global population in excess of six billion, and over 50% of whom live in urban areas and rely on transportation to contribute to society. In the opinion of many, cars are a large contributor to urban pollutions levels and, in the bigger picture, global warming. With immense quantities of cars on the road today, pure combustion engines are quickly becoming a target of global warming blame. Internal combustion engines account for a lot of the pollution problems, but the issue still stands as to what system will drive the next wave of automotive vehicles.

One potential alternative to the world's dependence on standard combustion engine vehicles are hybrid cars. Hybrids, like their name suggests, are vehicles that utilize multiple

²Shanklin 2009

³ Hopwood et al. 2009

forms of fuel to power their engines. In the majority of modern hybrids, cars are powered by a combination of traditional gasoline power and the addition of an electric motor. In this sort of hybrid engine, the combustion engine is used at high speeds for long distances, such as the highway, and the electric engine at low speeds and short distances, such as in urban areas. By incorporating alternative energy drive-trains into vehicles that also use combustion engines, they allow for a slightly cleaner mode of transportation. Hybrids however, do still use the petroleum based engine while driving so they are not completely clean, just cleaner than petroleum only cars. This enables hybrid cars to have the potential to segue into new technologies that rely strictly on alternate fuel sources.

Just as combustion engines are still being improved, alternate fuel based technologies are making advancements as well. Automotive companies are currently in production of strictly electric cars along with many more designs that are still in the prototype stages. Alternative fuels, such as hydrogen, natural gas, and bio diesel are extensively studied and explored in hopes of widespread future implementation into society. However, many of these alternative fuels will require far too many resources for the world's population to fully convert to within the near future, if at all. Fuel cells would require a complete reinvention of the automobile, not to mention the nation's gas stations, and the technology to put them on the road is still a long way from fruition.⁴ As is the case with many alternative fuel sources, a great amount of time and money would have to be spent to change the current gas stations so that they are alternative fuel compatible.

The introduction of hybrid technology in the past decade was the first step towards turning the world's population into a more fuel efficient and emissions conscious society. There are different claims, however, as to how helpful hybrids actually are in the race to save the environment, with projections ranging from significantly to marginally. Some sources say hybrid cars cause significantly less damage to the environment than the current standard combustion engine drive-train, while others argue that if one looks at growth projections for oil consumption, hybrids will slow the growth rate of oil imports only marginally, at best, with the

⁴ Hakim 2005

amount depending on how many hybrids are sold.⁵ Many people think that hybrids are a key answer to many of the greenhouse gas issues; however they are overlooking the greater picture regarding the subject of the hybrids themselves. The manufacturing of these cars and the nature of all the advanced electronics in them may conflict with the greener image they pose. Hybrids are cleaner on the road but their production may not be able to boast the same standard. To fully know if hybrids give more than they take, one would need to look into energy consumption and emissions before, during and after their life on the road.

Our goal was to investigate the overall effects on the environment due to hybrid cars when compared to their competition. By comparing their manufacturing processes, their function in modern society, and consumer behavior towards them, we gained a better understanding of hybrid vehicles and their effect on the environment. The result of analyzing the full life of a car, both from technical and consumer standpoints lead us to many questions about the significance of hybrid technology. This allowed us to determine a better approach with future conversion from combustion engines to newer propulsion systems. This paper includes our conclusions on how to best approach the future of hybrid cars, both economically and resourcefully, and also gives our final verdict on the efficiency of the hybrid car, not only as an alternative to combustion engines in terms of environmental impact, but from a financial, economic, and social standpoint as well.

⁵ Hakim 2005

Chapter 2. Literature Review

There has been much written about hybrid technology and alternate energy drive-trains in the past decade. There are arguments both for and against almost any subject in the large topic. In our pursuit of fully understanding this new technology and its impacts we explored much of this information and try to apply it to our project. We separated this information into categories including environmental effects, emissions, car production, and consumer and marketing trends.

2.1 Environmental Effects

The fear that mankind has been tampering with the earth's ecosystem in irreparable ways has been around for many years, whether it be driven by religion or science. Yet it has only been recently that such fears not only have been justified, but been proven as well. There is an increase in anxiety about the current global situation as the average global temperature slowly, but steadily increases.

A large portion of the probable ecological harm has been associated with the change in the atmosphere of our planet and how the change in climate is affected by what modern day society currently considers standard activity. Humans are constantly adding harmful gases, commonly known as greenhouse gases, to the atmosphere at an alarming and extremely harmful pace. While many of the gasses that are released into the atmosphere, such as carbon dioxide, are naturally occurring compounds, there are others that are mostly man-made, in particular chlorofluorocarbons (CFCs), which supply the environment with extra greenhouse gases.⁶ Greenhouse gasses are called as such because they trap heat inside the earth's atmosphere effectively protecting and insulating it, which in most cases is a good thing. However, if there is too much of these gasses, then the overall surface temperature of the planet will rise as more heat is trapped in. It is this reaction that is causing the distinct climate change that we are seeing today, appropriately labeled as global warming.

This global warming can cause major issues such as the melting of polar ice caps and a rise in sea level, which in turn would cause intense flooding in most if not all coastline areas,

⁶ Desonie 2002

giving cause to other disasters such as mass erosions, mud slides, outbreaks of disease to more humid climates, coastal reformation, and other disasters. Given enough time, a steady increase of these gasses would also change the length and intensity of the seasons, create droughts, and increase the frequency and impact of large storms. Organizations around the world such as the Intergovernmental Panel on Climate Change (IPCC) examine the potential causes and effects of human-related climate change, and attempt to understand the impacts through national inventories and other findings.⁷

Conjoined efforts are being made by countries to understand this growing dilemma, as well as countries conducting their own individual research. National groups like the U.S. Environmental Protection Agency (EPA), also establish regulations to help reduce greenhouse gas emissions.

According to the EPA, the average surface temperature of the Earth has increased by about 1.2°F to 1.4°F in the past one hundred years. Experts predict that the average could, and most likely will increase to around 3.2°F to 7.2°F by approximately the year 2100.⁸

In order for mankind to control and reduce the greenhouse gases that we are emitting into our atmosphere, as they continue to shape the environment, there must be an investigation into why they are becoming more abundant. “Many scientists believe that global warming is the most serious threat to our planet. By 2025 the world's energy demand is projected to be 3.5 times greater than in 1990, with annual CO2 emissions nearly 50 percent higher”.⁹

It is imperative for us to understand the negative effects that energy consumption has on our environment. However it is also important to identify where the majority of this consumption is coming from. Homes, lighting and heating are all contributing to the problem, yet cars are among the most significant as they are available in the greatest numbers all across the world, and are very high on the list of things to change.

Regretfully, the demands on today’s energy sources are very extensive. People generally do not think about the production of energy, a flick of a switch or push of a button to

⁷ Irving et al. 2009

⁸ Randy 2009

⁹ Desonie 2002

turn it on, and the instantaneous power provided leads to it being overlooked. A decrease in energy consumption will reduce the negative effect upon the environment, giving us more time to find a reliable way to manage everyday life without severely impairing our planet.

“In the United States, our energy-related activities account for three-quarters of our human-generated greenhouse gas emissions, mostly in the form of carbon dioxide emissions from burning fossil fuels. More than half the energy-related emissions come from large stationary sources such as power plants, while about a third comes from transportation”.¹⁰

As the evidence of our carelessness becomes more blatant and hazardous to the Earth’s inhabitants, the main question being asked now is: what should we do to fix this? Because these issues are directly linked to the amount of energy that humans consume on a daily basis, it becomes more imperative that changes must be made to save energy and reduce our waste production. It is important to investigate all factors in modern, everyday life to solve this issue. It is required that we continue to look into ways to slow, and at some point, fix the damages we have done to the environment.

2.2 Emissions

Whenever a car is started, sitting idle or driving it is producing emissions that are filling our atmosphere. These emissions include nitrogen gas (N₂), carbon dioxide (CO₂), water vapor (H₂O), carbon monoxide (CO), hydrocarbons or volatile organic compounds (VOCs), and nitrogen oxides (NO and NO₂, together called NO_x).¹¹ The air we breathe is made up of 78-percent nitrogen gas and in the case of an engine; most of it just passes right through and is not considered a harmful emission. A product of combustion is carbon, which when bonded to oxygen produces CO and CO₂, a poison gas and a believed culprit of global warming. VOCs are produced from evaporated, unburned fuels and are a major component of smog. NO_x are also major component of smog as well acid rain. Many of these emissions are naturally occurring compounds but the concerning part about them is the levels in which they are produced by cars. The Federal Highway Administration has documented the levels of these emissions and how much of each compound is produced by cars (see Figure 1).

¹⁰ Randy 2009

¹¹ Bryant et al. 2008

Air Pollutant	Proportion from On-road Motor Vehicles	Note
Oxides of Nitrogen (NO _x)	34%	precursor to ground-level ozone (smog), which damages the respiratory system and injures plants
Volatile Organic Compounds (VOC)	34%	precursor to ground-level ozone (smog), which damages the respiratory system and injures plants
Carbon Monoxide (CO)	51%	contributes to smog production; poisonous in high concentrations
Particulate Matter (PM ₁₀)	10%	does not include dust from paved and unpaved roads, which are the major source of particulate matter pollution (50% of the total)
Carbon Dioxide (CO ₂)	33%	thought to be primary contributor to global warming

Figure 1: Transportation Air Quality: Selected Facts and Figures 2002¹².

According to the EPA.gov website, for every gallon of gasoline used, about 20 pounds of carbon dioxide (CO₂) are pumped into the air. Here's how it adds up: A gallon of gasoline weighs just over 6 pounds. When burned, the carbon in it combines with oxygen to produce about 19 pounds of CO₂. Adding in the energy that went into making and distributing the fuel, the total global warming pollution is about 25 pounds of CO₂ per gallon. An average car that gets 21 mpg and is driven about 30 miles a day uses 1.4 gallons daily and emits 35.7 pounds of CO₂ every day.¹³ An average household with two medium-sized sedans emits more than 20,000 pounds of carbon dioxide (CO₂) a year.¹⁴ One also has to think about all of the families that own more than two cars or have a vehicle other than a sedan, such as a truck or SUV. Not all vehicles burn the same amount of gasoline and therefore do not all produce the same amount of emissions. For the purpose of this paper, one can place all trucks and mid-sizes in the category of SUVs. On average, SUVs emit 40% more exhaust than smaller cars and the percentage of SUVs on American roads today is over 30%.¹⁵ When taking into account the amount of larger vehicles on the road today, the numbers provided for the average CO₂ emissions for a two sedan family can be significantly increased to reflect actual amounts of pollution.

¹² Sterba 2009

¹³ Desonie 2002

¹⁴ Irving et al. 2009

¹⁵ Antenora 2008

Hybrid cars should not create as much emissions while driving, because the gasoline engine is not on all of the time. The whole concept of a second power source, however, adds weight to a car without being able to remove any weight. Electric engines are made up of large amounts of copper wires which ultimately just add mass to the car. Hybrids are commonly the same weight and sometimes heavier than a similarly sized car, which means more power has to be produced than usual to achieve comparable performance. The need to produce more power adds emissions to the hybrids lowered emission levels which brings them closer to even with conventional cars. In cities or stop and go traffic hybrids are great for the environment, creating almost zero emissions, but when hybrid cars are driving on roads such as highways they are in essence normal cars because the electric motor is not running at all. Taking all of these factors into account, hybrid cars, on average only create about a 20-percent reduction in CO2 emissions.¹⁶

2.3 Production of Cars

When most people think about cars they generally don't consider what goes into making them. Raw materials have to be obtained, whether that means being mined, melted, and carburized or some other method. These materials must be transported to various plants and factories before they are made into car components. Transportation, whether it is by plane, train or automobile all requires resources like fuel and oil and manpower. Once in a production area, even more resources are used to create parts and then eventually finished products. This is all before a car is even seen by a consumer, but what happens after the consumer is finished with the car? Recycling is a major business in this day and age, but how much of a car can be recycled? How much emissions are being produced by these recycling processes. What kinds of by-products are being produced, throughout the entire lifetime of cars?

2.3.1 Production Emissions

Cars with different propulsion devices are going to need different types of materials. Things like tires, windows and paint are things that are pretty much all the same in all cars and you do not find much variation in the amount needed to complete a car. Materials like lead and nickel, however, have a large difference between cars. Traditional ICE cars have lead based

¹⁶ Giggs 2009

batteries and zero nickel components, while hybrids have large nickel based batteries and no lead. Emissions levels, specifically CO₂ levels, for the processing of the material that make up cars can be looked at and compared against each other to help understand if hybrids are better for the environment. In the case of the batteries, for example, from the raw material state, the production of lead based batteries produces 9 kgC, and the production of nickel based batteries produces 24-30 kgC and as high as 215 kgC in the case of a strictly electric car. If companies were to use 100% recycled materials, the difference between the CO₂ emissions levels would be even more severe. Figure 2 and Figure 3 show CO₂ the emissions (kgC) resulting from the production of automobile components from both raw materials and 100% recycled materials.

Power Plant	Current	Baseline	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced
Fuel	SI ICE	SI ICE	SI ICE	CI ICE	SI Hybrid	CI Hybrid	SI Hybrid	FC Hybrid	FC Hybrid	FC Hybrid	Electric
Drive	Gasoline	Gasoline	Gasoline	Diesel	Gasoline	Diesel	CNG	Gasoline	Methanol	Hydrogen	Electricity
Body	Auto	Auto-cl.	Auto-cl.	Auto-cl.	CVT	CVT	CVT	Direct	Direct	Direct	Direct
Total Ferrous Metals	778	589	285	333	307	340	304	563	496	419	373
Aluminum	290	348	1224	1205	1193	1179	1247	1090	1088	1269	1086
Glass	22	22	22	22	22	22	22	22	22	22	22
Magnesium	57	117	117	117	117	117	117	117	117	117	117
Copper	18	18	18	18	22	22	22	22	22	22	22
Zinc	7	7	3	3	3	3	3	3	3	3	3
Lead	9	9	9	9	0	0	0	0	0	0	0
Plastics	188	182	188	203	180	190	196	135	133	185	149
Rubber	79	74	74	74	74	74	74	74	74	74	74
Wood, Felts, Carpets, etc.	120	120	120	120	120	120	120	120	120	120	120
Paint, Coatings	9	9	9	9	9	9	9	9	9	9	9
Nickel	0	0	0	0	24	24	24	30	28	27	215
Others	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	1577	1492	2069	2113	2070	2100	2137	2206	2129	2282	2194

Figure 2: CO₂ Emissions (kgC) Resulting from the Production of Automobile Components from Virgin Materials for all vehicles considered in this study, by material.¹⁷

¹⁷ AuYeung et al. 2009

Power Plant	Current	Baseline	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced
Fuel	SI ICE	SI ICE	SI ICE	CI ICE	SI Hybrid	CI Hybrid	SI Hybrid	FC Hybrid	FC Hybrid	FC Hybrid	Electric
Drive	Gasoline	Gasoline	Gasoline	Diesel	Gasoline	Diesel	CNG	Gasoline	Methanol	Hydrogen	Electricity
Body	Auto	Auto-cl.	Auto-cl.	Auto-cl.	CVT	CVT	CVT	Direct	Direct	Direct	Direct
Total Ferrous Metals	481	362	176	206	190	210	188	348	307	259	231
Aluminum	59	70	248	244	242	239	253	221	220	257	220
Glass	11	11	11	11	11	11	11	11	11	11	11
Magnesium	6	11	11	11	11	11	11	11	11	11	11
Copper	8	8	8	8	10	10	10	19	18	17	12
Zinc	2	2	1	1	1	1	1	1	1	1	1
Lead	2	2	2	2	0	0	0	0	0	0	0
Plastics	94	91	94	102	90	95	98	68	66	93	75
Rubber	79	74	74	74	74	74	74	74	74	74	74
Wood, Felts, Carpets, etc.	60	60	60	60	60	60	60	60	60	60	60
Paint, Coatings	5	5	5	5	5	5	5	5	5	5	5
Nickel	0	0	0	0	24	24	24	30	28	27	215
Others	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	806	698	690	723	716	740	733	847	801	814	913

Figure 3: CO2 Emissions (kgC) Resulting from the Production of Automobile Components from Secondary Materials for all vehicles considered in this study, by material.¹⁸

¹⁸ AuYeung et al. 2009

Carbon dioxide is not the only emission that is harmful to the environment though, many other bi-products are released. Other pollutants may come from painting, fiber glassing, molding and cleaning parts. For the purpose of this paper, we can assume that these are fairly constant in their bi-products and they do not vary from hybrids to traditional cars enough to make a significant difference in our data.

2.3.2 Production Energy Consumption

The materials in which cars are made from need to come from somewhere, and by whatever process that may be, all of them use energy. Certain processes take more energy than others and all of this adds to both the cost of the car and the effect it has on the environment. The energy that goes into these processes has to come from a power plant of some sort. Power plants may be coal-fired, nuclear, hydro electric, wind powered or run by various other smaller methods. No matter what source the energy has come from, there are negative effects to the environment that go hand in hand with them. Figure 4 shows energy use that goes into the production of vehicle materials.

	Primary Production (0% Recycling)			Secondary Production (100% Recycling)	
	Automotive Engineering (1996)	Singh et al. (1998)	This Study	Automotive Engineering (1996)	This Study
Ferrous Metals			40.0		30.0
Steel	40.0	52.3 ⁽¹⁾		18.1	
Iron	34.0	19.3 ⁽²⁾		24.0	
Aluminum			220.0		40.0
Wrought	196.0			26.7	
Cast	189.0	206.6		26.0	
Stamped		205.2			
Plastics	90.0	30.0-78.7 ⁽³⁾	90.0	15.0	45.0
Glass	30.0	21.6 ⁽³⁾	30.0	13.0	15.0
Magnesium, Cast	274.0		280.0	27.2	27.00
Copper	100.0	113.7	100.0	45.0	45.0
Zinc	53.0		50.0	15.9	16.0
Lead	41.1	28.0 ⁽³⁾	40.0	8.0	8.0
Rubber	67.6	40.5 ⁽³⁾	70.0	43.6	N/A
Nickel		110.0	110.0		110.0

Figure 4: Energy Use in Vehicle Production (in MJ per kg of material).¹⁹

¹⁹ AuYeung et al. 2009

NOTE: All numbers are expressed in primary energy requirements. The columns “This Study” indicate the rounded numbers that we have employed in this study; as we do not distinguish between iron and steel, energy intensities are identical for both materials and are included in our aggregate category “ferrous metals”.
⁽¹⁾ Virgin steel parts; ⁽²⁾ pig iron; ⁽³⁾ main production process only. Source: “One the Road in 2020”, October 2000.

Many hybrid companies are designing their cars to be lighter in or order to try and use energy more efficiently while driving. The way in which many companies achieve this is by using lighter materials, such as aluminum, in the body as opposed to steel which is about three times as dense as aluminum. This does help to use the car’s energy more efficiently if the is car lighter, but at what expense? The processing of aluminum can use up to ten times the amount of energy use to process the same amount of steel. Chances are that the amount of extra energy used to produce the aluminum is not justified by the amount of energy saved in the driving of the hybrid car. Figure 5 shows amounts of certain materials and how the vary in different cars. Using the masses in Figure 5 and the energy usage in Figure 4, we can calculate how much more energy goes into certain processes of making a car. By comparing the differences in energy consumption of production to the energy saved by driving a lighter car, we are able to determine if the extra production is justified.

Power Plant	Current	Baseline	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced	Advanced
Fuel	SI ICE	SI ICE	SI ICE	CI ICE	SI Hybrid	CI Hybrid	SI Hybrid	FC Hybrid	FC Hybrid	FC Hybrid	Electric
Drive	Gasoline	Gasoline	Gasoline	Diesel	Gasoline	Diesel	CNG	Gasoline	Methanol	Hydrogen	Electricity
Body	Auto	Auto-cl.	Auto-cl.	Auto-cl.	CVT	CVT	CVT	Direct	Direct	Direct	Direct
Ferrous Metals	886	667	325	379	350	387	346	640	565	477	425
Aluminum	81	97	342	337	334	330	349	305	304	355	304
Glass	35	35	35	35	35	35	35	35	35	35	35
Magnesium	10	20	20	20	20	20	20	20	20	20	20
Copper	9	9	9	9	10	10	10	21	19	18	13
Zinc	7	7	3	3	3	3	3	3	3	3	3
Lead	10	10	10	10	0	0	0	0	0	0	0
Plastics	100	97	100	108	96	101	104	72	71	99	79
Rubber	54	50	50	50	50	50	50	50	50	50	50
Wood, Felts, Carpets, etc.	64	64	64	64	64	64	64	64	64	64	64
Paint, Coatings	5	5	5	5	5	5	5	5	5	5	5
Nickel	0	0	0	0	10	11	10	13	12	12	93
Others	9	9	9	9	17	17	17	76	62	37	84
Total	1323	1108	1007	1061	1022	1059	1038	1329	1251	1177	1175

Figure 5: Vehicle Mass (in kg) by Material for all Vehicles Considered in This Study.²⁰

²⁰ AuYeung et al. 2009

2.3.3 Raw Materials and Recycling

In today's society, recycling is a very mature business; almost anything that can be recycled is urged to be recycled. Recycling is not only good for the environment, but also less expensive for industry when compared against starting from raw material all over again. Referring back to Figure 4, all of the materials displayed are cheaper to process in a recycled state because the original stages of production, such as mining, can be skipped. In some cases, such as cast magnesium, recycling production takes 90% less energy than producing the raw material.

Conventional cars, for the most part, have lead-acid batteries to power their electrical systems. The auto industry uses over one million metric tons of lead every year, with 90% going to conventional lead-acid vehicle batteries. More than 40,000 metric tons of lead is lost to landfills every year. According to the federal Toxic Release Inventory, another 70,000 metric tons are released in the lead mining and manufacturing process.²¹ Not all of the 110,000 metric tons of lead that is released into the environment every year comes from the auto industry, but they are still a contributor. This amount of released lead is quite large when one thinks about the lead recycling industry, which is very mature. Objects containing lead, like car batteries, are highly encouraged to be cleanly recycled and not just thrown in the garbage at the end of their lives. Car companies encourage clean recycling to try and reduce their negative impact on the environment and many even offer to do the recycling themselves. Toyota offers a \$200 bounty to ensure that every battery comes back to the company. In a press release, Toyota states, "Every part of the battery, from the precious metals to the plastic, plates, steel case and the wiring, is recycled." Honda collects the battery and transfers it to a preferred recycler to follow their prescribed process: disassembling and sorting the materials; shredding the plastic material; recovering and processing the metal; and neutralizing the alkaline material before sending it to a landfill.²²

²¹ Berman 2006

²² Berman 2006

2.4 Consumer Behavior and Marketing Strategy

There are many reasons why people decided to purchase a new vehicle. In 2009 it was found that the primary motivation for buying a new car was high mileage on the consumer's previous or current car. When a vehicle attains high mileage, typically problems with the cars condition arise, whether the exterior of the car is eroding or beginning to look worn, the interior might be unkempt and grungy, or the car might begin to have mechanical problems. "Cars which continually breakdown and spend excessive amounts of time being repaired can work out to be a very costly expense. In the long run it is more economical to buy new and have the satisfaction and knowledge that the car will be covered under a warranty"²³, before problems arise, most people try to sell his or her car and then purchase a new one, or, if these problems occurred unexpectedly, rather than spending money senselessly on a vehicle that might not be worth it, it is more resourceful for the owner to invest in a new car.²⁴

Others sometimes just get tired of their vehicle and desire something more updated. They might wish for something with more modern technology, equipped with the latest machinery and features, something more comfortable and with a contemporary sleek appearance, "Many people are choosing to get a newer car because many safety features now come as standard on most makes and models. Airbags fitted to both the driver's and front passenger are a key feature many people now look for. Additional back seat airbags and side impact airbags are becoming increasingly requested safety features by people looking for family cars."²⁵ Correspondingly newer vehicles have advanced sound systems and navigation systems, electronic power features and innovative voice notification for routine maintenance and reminders, keyless entry, sun roofs, increased comfort of seating and amenities, and enhanced lighting, among various other luxuries. Also having to do with appearance is the size of the vehicle. Many people require a vehicle with more room and additional space to compensate for a growing family, extracurricular activities, etc. Corporations are continually producing new and improved SUV's, minivans, trucks, and larger cars with added room and extra seating that

²³ Giggs 2009

²⁴ Giggs 2009

²⁵ Giggs 2009

are requisites for their customers. These larger options likewise are equipped with the updated modern technology and features mandatory for automobiles produced today.

A popular benefit of the cars produced presently is that typically they feature improved gas mileage. Because of this increase in gas prices a prevailing rationale for getting a new car is this new characteristic of improved gas mileage. Going hand in hand with the desire for better gas mileage is the decision for people to “go green”. Many of the vehicles that are made with better gas mileage, or that feature the greatest gas mileage, are hybrid vehicles that are also better for the environment and appeal to those concerned with global warming and pollution, “Going 'green' is high up on the list for many people. Saving on fuel and running costs is given careful consideration by many people.”²⁶

1. Old car had high mileage (35%)
2. Just tired of old car, wanted something new (22%)
3. Old car was always in for repairs (20%)
4. Wanted a car with better gas mileage (19%)
5. Old car died (18%)
6. Not sure (17%)
7. Like the styling of newer models (15%)
8. Wanted a vehicle with better safety features (15%)
9. Good deals too hard to pass up (14%)
10. Needed another car for family (14%)
11. Significant other wanted a new car (12%)
12. Needed a vehicle with more room (9%)
13. Wanted a car with more high-tech toys (6%)
14. Lease on old car is up (5%)

Figure 6: Top Fourteen Reasons People Buy Hybrids. Source: Road and Travel Magazine, June 24, 2009.

Studies have been performed on the consumers of hybrid vehicles, which have revealed that these people have certain aspects in respect to their personalities that give them a unique profile. One study that looks at the profile of hybrid consumers is the J.D. Power and Associates “2008 Power Auto Offline Media Report - Spring Edition.” This study had a target audience of 44,931 drivers of new cars and trucks. The study explores the characteristics of hybrid owners and potential hybrid owners. It also evaluates media viewing and readership behaviors.

²⁶ Giggs 2009

The characteristics of hybrid owners are for the most part logical. For example, “Those who purchase hybrid vehicles tend to have much higher levels of education and report much higher household incomes”.²⁷ Car buyers who have more knowledge can make an educated and rational decision before committing to a large financial purchase. A higher level of education benefits the buyer because the tools of research and decision-making can ensure that the buyer receives the vehicle that fits his or her needs. It also comes as no surprise that hybrid owners have higher incomes than those of traditional vehicles. The average \$5000 price difference between hybrids and non-hybrids is not something many families can afford to pay up front. This quickly eradicates the option of a hybrid. The average age of a hybrid buyer is fifty-four while the average traditional car buyer is age fifty.

J.D. Power’s study revealed some positive outcomes about hybrid owners. The study showed that “Hybrid owners tend to be proud advocates of their vehicles” (Mindset profile). This suggests that they are pleased with the hybrid technology and they enjoy sharing it with others. In general, they give more affirmative suggestions than those of other vehicle buyers. This facilitates the hybrid market because those who have actually purchased a hybrid are giving recommendations to others, who may, in return, purchase a hybrid themselves.

Many people have a desire to purchase an environmentally friendly vehicle. This can be seen by the large number of hybrids being both purchased and produced. However, the demographics for people that desire ‘green’ cars, is interesting. A J. D. Power study discovered that females are more eager to pay more for an environmentally friendly vehicle. In the United States, certain areas are more supportive of this purchase. The western U.S. has the greatest support, while the Midwest has the least support. The environmentally friendly consumers show interest in compact vehicles. Furthermore, most have previously owned smaller vehicles. The percentage is much greater than other new car buyers. This justifies that environmentally conscious consumers have a trend in purchasing vehicles that have exceptional fuel efficiency.

Mindset Media created a psychographic profile of hybrid owners that point out some distinct personality classifications. One is that hybrid drivers are 78% more creative than the common population. “That is, they are inventive and imaginative and also tend to be

²⁷ Perryman et al. 2008

emotionally sensitive and intellectually curious” (mindset profile). The creative personality would explain why they partake in the new technology offered. Another reason for this is they are more liberal than the broad population. The open-mindedness and spontaneity gives them interest in new hybrids, not leaving them with a sense of distrust in the advanced technological aspects of the vehicles.

Even though there are many people who are environmentally aware, not all of them take action. The J.D. Power study revealed that only 11% of consumers are “very willing” to pay more to buy an environmentally friendly vehicle. Also, only one out of ten environmentalists has purchased a hybrid.²⁸ The study proved that the interest in environmentally friendly vehicles is limited to hybrids. “Consumers are not interested in buying so-called clean diesel vehicles.”²⁹ Many of the negative aspects of diesel vehicles, such as the dirty exhaust, have persisted with consumers.

Through research, interviews, and studies examiners have concluded that specific symbols exist for those who own hybrid vehicles. In a study done by the Institute of Transportation Studies at the University of California, Davis it was concluded that a certain symbolism applies to the market for hybrids. In response to household interviews, the denotations of preserving the environment, opposition to war, management of personal finances, reduction of support to oil producers, and the embracement of new technology were justified. Ethics was a major factor in these denotations. Independence and a sense of individuality also came into play. The owners of hybrids feel as though it is “the right thing to do and characterize their vehicles as something they can feel good about.”³⁰ Therefore, owners give precedence to his or her purchase in an ethical viewpoint. It shows that they care. Owners happily sacrifice some personal interests for the greater good. In conjunction with this sacrifice, owners hope that the purchase of a hybrid will help set an example and create a future where “everyone drives hybrids.”³¹

²⁸ Perryman et al. 2008

²⁹ LaMonica 2008

³⁰ Heffner et al. 2007

³¹ Heffner et al. 2007

When marketing a new product, the general wants and needs of your target market should be your focus, and fulfilling those determined requirements should be the overall objective. The new product should be an improvement over what it is attempting to replace, more technologically advanced and esthetically pleasing to entice the public into purchasing this new merchandise. “Traditionally, economists and market researchers have been interested in identifying the factors that affect consumers' car buying behaviors to estimate market share, and to that end they have developed various models of vehicle type choice. However, they do not usually consider consumers' travel attitudes, personality, lifestyle, and mobility as factors that may affect the vehicle type choice.”³²

Lifestyles determine the types of vehicles that individuals purchase. Someone that makes a substantial amount of money, an individual with a higher status or a more elite ranking in society is typically interested in a lavish vehicle that is representative of the accomplishments made or the position upheld, “Status seekers are more likely to drive an expensive car (luxury and sports categories) because such cars are common status symbols in modern society.”³³ Whereas someone that makes a less significant amount of money has to purchase a vehicle more modest and in line with what is affordable. Families require automobiles that are capable of carrying multiple passengers; therefore they necessitate larger cars, trucks, or SUV's. Single persons or couples usually have little use for larger vehicles and might prefer something smaller or more compact.

Demographically, a person that lives in the country might require a truck or larger vehicle with four wheel drive or the capabilities of driving on roads that are not in the best condition, whereas people that drive in cities might desire a car that is more compact so compensate for limited space and small parking areas, “Those who like living in high-density areas may choose a smaller car (small and compact categories) because they have accessible public transit and restrictions on parking, making them less likely to commute by car.”³⁴

Some people dread their commute to work or traveling anywhere in general. To atone for their dislike of driving they are more likely to buy a larger, more comfortable vehicle so that

³² Choo et al. 2003

³³ Choo et al. 2003

³⁴ Choo et al. 2003

they might relax while driving and make their experience less frustrating and more pleasant. Though, even those that enjoy traveling are likely to buy these extravagant vehicles in order to make their experience that much more gratifying.

People that are concerned with the effects of emissions on the environment are more attracted to smaller vehicles with better gas mileage in an attempt to have a more positive effect on the environment, “Those who strongly support pro-environmental policies are more likely to prioritize reducing mobile source emissions and therefore to drive a smaller car (small and compact categories).”³⁵

Hybrid vehicles can be an overall improvement over conventional vehicles, but only when many positive factors all culminate at once, which is unlikely. These vehicles are now available in numerous models of all different sizes, capable of filling the requirements for single individuals or families. They are more technologically advanced, characteristically their appearance is more modern and desirable, and because there are so many different models and versions of these cars now, they are better suited for a whole spectrum of people with different desires and personalities. At a time when gas prices continue to increase, the economy continues to struggle, and many individuals are becoming increasingly aware of contamination of our environment, the hybrid vehicle has become alluring to many as it also addresses these about mobility, travel attitudes and lifestyle. Hybrid vehicles are an overall improvement over conventional vehicles, being more technologically advanced, characteristically their appearance is more modern and desirable, it is appealing to those that are looking to save money on fuel, and is also tempting to those concerned with the environment and the current issues surrounding global warming and pollution. At a time when gas prices continue to increase, the economy continues to struggle, and many individuals are becoming increasingly aware of contamination of our environment, the hybrid vehicle has become alluring to many.

Due to the steadily increasing gas prices, the popularity of Hybrid vehicles among society has also escalated. There are many reasons for purchasing these new technologically advanced automotives; however, one of the more current reasons is the amount of money

³⁵ Choo et al. 2003

customers save on fuel. These new cars are advertised to achieve exceptional gas mileage when compared with conventional cars. It is said that even though they are typically more expensive initially, the amount that you save on gas eventually allows the purchaser to break even and save money, "...with gas prices rising even further ...it is likely that you will recoup that up-front premium in just a few short years."³⁶ For example, the Toyota Camry Hybrid gets about 31 miles per gallon in the city and 32 miles per gallon on the highway, while the Toyota Camry V6 gets about 21 miles per gallon and 31 miles per gallon respectively. If an individual was to drive about 15,000 miles in a year with gas prices at about \$3.20 a gallon, the person would save approximately \$547.00 a year, taking three years to recoup the upfront premium.³⁷

Another issue facing the economy is global warming and the effects of pollution on us and the environment. Those that believe and support in the world "going green" look at the lower fossil fuel emissions of hybrid vehicles as a reason to buy these cars. With the combination of a gasoline engine and an electric motor, hybrid cars produce less emissions while being driven, thus saving on gas and also helping the environment. While most hybrid cars still burn gasoline in an internal combustion engine, they also use other forms of motive power to help limit how much gasoline they burn. This means that hybrid cars cause significantly less damage to the environment than normal cars. It is said that every gallon of fuel burned produces 26 pounds of carbon dioxide that is then released into the environment. By driving a car that is more fuel efficient, a car that gets about 10 miles more per gallon in comparison to your old car, an individual can reduce the amount of carbon dioxide released into the environment by about 2,500 pounds each year.

Other than the potential savings on fuel and the opportunity to give back to the environment, there are also state and federal tax benefits to persuade customers to spend the additional money in purchasing a new hybrid vehicle, "The Energy Policy Act of 2005" replaced the clean-fuel burning deduction with a tax credit. A tax credit is subtracted directly from the total amount of federal tax owed, thus reducing or even eliminating the taxpayer's tax obligation. The tax credit for hybrid vehicles applies to vehicles purchased or placed in service on or after January 1, 2006. The credit is only available to the original purchaser of a new, qualifying vehicle. If a qualifying vehicle is leased to a consumer, the leasing company may

³⁶ Ransom 2008

³⁷ Ransom 2008

claim the credit.”³⁸ There are many rules and requirements that must be followed to make an individual eligible for these tax credits, some of these being that the hybrid must be purchased new, not used, the car must be used primarily within the United States, the vehicle must be purchased within a certain time period, and the date that the vehicle is bought is somewhat a determining factor in the amount of tax credit the individual will receive. Even with the restriction of these regulations, there are many vehicles that are eligible to receive these federal tax credits, see Figure 7: Federal Tax Credits for Hybrids.

	Hybrid Federal Tax Credit	
1	2009 Cadillac Escalade Hybrid 4dr SUV (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
2	2009 Cadillac Escalade Hybrid 4dr SUV 4WD (6.0L 8cyl gas/electric hybrid 4A)	\$1,800
3	2008 Chevrolet Malibu Hybrid 4dr Sedan (2.4L 4cyl gas/electric hybrid 4A)	\$1,300
4	2009 Chevrolet Malibu Hybrid 4dr Sedan (2.4L 4cyl gas/electric hybrid 4A)	\$1,550
5	2009 Chevrolet Silverado 1500 Hybrid 4dr Crew Cab w/1HY SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
6	2009 Chevrolet Silverado 1500 Hybrid 4dr Crew Cab 4WD w/1HY SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
7	2009 Chevrolet Silverado 1500 Hybrid 4dr Crew Cab w/2HY SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
8	2009 Chevrolet Silverado 1500 Hybrid 4dr Crew Cab 4WD w/2HY SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
9	2008 Chevrolet Tahoe Hybrid 4dr SUV (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
10	2008 Chevrolet Tahoe Hybrid 4dr SUV 4WD (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
11	2009 Chevrolet Tahoe Hybrid 4dr SUV (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
12	2009 Chevrolet Tahoe Hybrid 4dr SUV 4WD (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
13	2009 Chrysler Aspen Limited HEV 4dr SUV 4WD (5.7L 8cyl gas/electric hybrid 4A)	\$2,200
14	2009 Dodge Durango Limited HEV 4dr SUV 4WD (5.7L 8cyl gas/electric hybrid 4A)	\$2,200
15	2008 Ford Escape Hybrid 4dr SUV (2.3L 4cyl gas/electric hybrid CVT)	\$1,500
16	2008 Ford Escape Hybrid 4dr SUV AWD (2.3L 4cyl gas/electric hybrid CVT)	\$1,100
17	2009 Ford Escape Hybrid 4dr SUV (2.5L 4cyl gas/electric hybrid CVT)	\$1,500
18	2009 Ford Escape Hybrid 4dr SUV AWD (2.5L 4cyl gas/electric hybrid CVT)	\$975
19	2009 Ford Escape Hybrid Limited 4dr SUV (2.5L 4cyl gas/electric hybrid CVT)	\$1,500
20	2009 Ford Escape Hybrid Limited 4dr SUV AWD (2.5L 4cyl gas/electric hybrid CVT)	\$975
21	2010 Ford Fusion Hybrid 4dr Sedan (2.5L 4cyl gas/electric hybrid CVT)	\$1,700
22	2009 GMC Sierra 1500 Hybrid 4dr Crew Cab w/3HA SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
23	2009 GMC Sierra 1500 Hybrid 4dr Crew Cab 4WD w/3HA SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
24	2009 GMC Sierra 1500 Hybrid 4dr Crew Cab w/3HB SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
25	2009 GMC Sierra 1500 Hybrid 4dr Crew Cab 4WD w/3HB SB (6.0L 8cyl gas/electric hybrid 4A)	\$2,200

³⁸Hudson 2010

26	2008 GMC Yukon Hybrid 4dr SUV (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
27	2008 GMC Yukon Hybrid 4dr SUV 4WD (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
28	2009 GMC Yukon Hybrid 4dr SUV (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
29	2009 GMC Yukon Hybrid 4dr SUV 4WD (6.0L 8cyl gas/electric hybrid 4A)	\$2,200
30	2008 Mazda Tribute Hybrid Grand Touring 4dr SUV (2.3L 4cyl gas/electric hybrid CVT)	\$3,000
31	2008 Mazda Tribute Hybrid Grand Touring 4dr SUV AWD (2.3L 4cyl gas/electric hybrid CVT)	\$1,950
32	2008 Mazda Tribute Hybrid Touring 4dr SUV (2.3L 4cyl gas/electric hybrid CVT)	\$3,000
33	2008 Mazda Tribute Hybrid Touring 4dr SUV AWD (2.3L 4cyl gas/electric hybrid CVT)	\$1,950
34	2009 Mazda Tribute Hybrid Grand Touring 4dr SUV (2.5L 4cyl gas/electric hybrid CVT)	\$3,000
35	2009 Mazda Tribute Hybrid Grand Touring 4dr SUV AWD (2.5L 4cyl gas/electric hybrid CVT)	\$1,950
36	2009 Mazda Tribute Hybrid Touring 4dr SUV (2.5L 4cyl gas/electric hybrid CVT)	\$3,000
37	2009 Mazda Tribute Hybrid Touring 4dr SUV AWD (2.5L 4cyl gas/electric hybrid CVT)	\$1,950
38	2008 Mercury Mariner Hybrid 4dr SUV (2.3L 4cyl gas/electric hybrid CVT)	\$1,500
39	2008 Mercury Mariner Hybrid 4dr SUV AWD (2.3L 4cyl gas/electric hybrid CVT)	\$1,100
40	2009 Mercury Mariner Hybrid 4dr SUV (2.5L 4cyl gas/electric hybrid CVT)	\$1,500
41	2009 Mercury Mariner Hybrid 4dr SUV AWD (2.5L 4cyl gas/electric hybrid CVT)	\$975
42	2010 Mercury Milan Hybrid 4dr Sedan (2.5L 4cyl gas/electric hybrid CVT)	\$1,700
43	2008 Nissan Altima Hybrid 4dr Sedan (2.5L 4cyl gas/electric hybrid CVT)	\$2,350
44	2009 Nissan Altima Hybrid 4dr Sedan (2.5L 4cyl gas/electric hybrid CVT)	\$2,350
45	2008 Saturn Aura Hybrid Green Line 4dr Sedan (2.4L 4cyl gas/electric hybrid 4A)	\$1,300
46	2009 Saturn Aura Hybrid 4dr Sedan (2.4L 4cyl gas/electric hybrid 4A)	\$1,550
47	2008 Saturn VUE Hybrid Green Line 4dr SUV (2.4L 4cyl gas/electric hybrid 4A)	\$1,550
48	2009 Saturn VUE Hybrid 4dr SUV (2.4L 4cyl gas/electric hybrid 4A)	\$1,550

Figure 7: Federal Tax Credits for Hybrids³⁹

When purchasing a new vehicle, finances are greatly important, if not the most important aspect when the customer is making their decision. People generally look for numerous ways in which they can reduce the amount of money that they are spending. The government has capitalized on this and began offering incentives for individuals, influencing them into spending more money initially to purchase a hybrid vehicle in order to save money later. Through online sources, articles, and dealerships, the variety of incentives and programs can be analyzed. Through interviews with both sales representatives and customers, the effectiveness of these government incentives can be determined. Talking to individuals who have already taken advantage of these motivations determines if it was worth it for them to spend the extra money initially. Speaking with customers that haven't yet made a commitment helps to determine if the incentives are successfully influencing people into making the decision

³⁹ Hudson 2009

to buy a hybrid vehicle instead of a conventional car. The interviews with sale representatives should give insightful opinions on whether or not the programs are beneficial or deceiving for individuals.

When hybrid vehicles were first introduced on the market, many associated them with the Toyota Prius. Some individuals were attracted to the distinct style of the Prius as they considered it a statement to society that they were concerned about the wellbeing of the environment and the condition of the world in which we live. Since the Prius, much advancement have been made and Hybrid vehicles are now available in numerous different models to appeal to a wide variety styles and preferences of the target market, " 'One important decision is the size of the vehicle.' If you really, really need an SUV-sized vehicle, there are a number of hybrid SUVs that are on the market now or coming onto the market soon,' notes Berman."⁴⁰ Instead of the Prius that doesn't appeal to most, there are now more conventional looking vehicles available as hybrid models, providing people options and alternatives to choose a car that is best suited for them and their lifestyle.

Some may believe that the new hybrid vehicles are not as powerful as their counterparts, their engines being significantly smaller than the engines of conventional vehicles. When the hybrid was first introduced there were some reports of these new cars being somewhat sluggish, however, over time as improvements have been made, there are reports now that some hybrids are quicker than conventional cars, The engine in the hybrid car is powerful enough to move the car along on the freeway, but when it needs to get the car moving in a hurry, or go up a steep hill, it needs help. That "help" comes from the electric motor and battery -- this system steps in to provide the necessary extra power.⁴¹ With a smaller lighter engine, fewer cylinders, and lighter pistons and internal components, this makes hybrid cars more fuel efficient. Also helping bridge the power gap between hybrid cars and conventional cars are the materials that the vehicles are constructed out of, some hybrid cars are constructed with ultra lightweight materials like carbon fiber or aluminum. Hybrid cars are also designed to be more aerodynamic than most cars, allowing them to "slice" through air instead of pushing it out of the way. All these factors combined equate to a super efficient form

⁴⁰ Ransom 2009

⁴¹ Layton et al. 2008

of car that gets excellent fuel economy and helps the environment by cutting down on pollution.⁴²

2.5 Widespread change to hybrid/electric instead of gasoline/diesel

The adoption of hybrid technology continues to rise, but the pace is still too minimal for any changes in environmental issues or fuel demand to be seen. The market for hybrids is still lacking in the number of vehicles and models available. Manufacturers are still developing and improving on the hybrid technology that is still fairly recent. “It takes approximately fifteen years for the automotive fleet to turn over in the US.”⁴³ This extended period of time makes for a gradual change before a substantial amount of vehicles on the roads are hybrids.

With such a massive world population and high dependency on transportation, a significant switch to hybrids from gasoline and diesel vehicles must be met before any changes can be seen. In fact, we need “50-80% of the car buyers worldwide adopt these new “low carbon” technology automobiles to make a material difference.”⁴⁴ That number far exceeds where we are at today. It will take many more years for a difference to be seen in the large scale. Another goal of switching to hybrids is to decrease foreign dependence on oil. However the reality is “the development and widespread use of full hybrid vehicles by 2030 will only reduce world demand for transport fuel by 10%.”⁴⁵ A widespread change to hybrids requires an extended period of time and also may not be cost effective. Many of the outcomes are not worth all that goes into getting the advanced technology on the road.

2.6 Conclusion

Through our research on hybrid car technology, we explored many interesting topics. From studying information about environmental effects, emissions, production and marketing of hybrids we were able to understand a lot of the pros and cons associated with them, but it raised some questions as well, such as how hybrids’ emissions compare to standard combustion vehicle emissions, and at what point would the hybrid vehicles be worth the extra money, with and without the incentives that come with purchasing one. We also investigated the topic of

⁴² Layton et al. 2008

⁴³ Khosla 2009

⁴⁴ Khosla 2009

⁴⁵ Pickett 2008

widespread change to different types of hybrid vehicles and how feasible this plan would be. Our research has led us to look at the past, present, and future of cars on the roads, especially hybrids. Due to the large variety and amount of questions that we could ask on this topic we have had to cut down our scope a bit. We have selected a few main questions that we would like to answer by the closing of this paper. At what point does a Hybrid make up for its cost? What are people looking for when they are buying a car? What kinds of incentives are people offered when buying hybrids? What are the differences in emission variations between standard and hybrid cars? When are they recycled? What are the differences in materials used? Is widespread conversion feasible?

Chapter 3. Methodology

The objectives of our paper were to analyze the process of making hybrid cars to see if their production is as clean as their daily use, examine the various economic effects and routes for converting combustion engine vehicles with alternative designs to see if widespread change is feasible, and analyze marketing trends and changes associated with hybrid technology. We used many different methods to gain access to the information we need to fully study these topics. Secondary data, interviews, focus groups and many articles and online sources helped us make educated conclusions to our project questions.

3.1 Quantitative Data Analysis

Hybrid vehicles are very complex machines that require more materials and work to construct, compared to the standard combustion engine vehicle, due to the fact that they have at least two sources of power. This being the case, one could think that it is only natural that the construction of hybrids creates more harmful gasses than combustion engine vehicles, however by what margin is seldom brought up in many relevant conversations and statistics. We used the MIT study “On the Road in 2020”, which includes data on these topics, to help us make informed decisions about the ‘greenness’ of hybrids. Using this data, we compared amounts of different materials used in cars, the energy consumption and emission levels used in processing these materials, and the emission levels of cars. Series of calculations were made in Microsoft Excel spread sheets in a precise sequence in order to produce accurate analysis. This produced quantitative results that were used to generate graphs and comprehensive displays, showing timelines on when hybrids becomes ‘greener’ than a regular ICE’s.

3.1.1 Energy Consumption Calculations

Our data included what materials go into certain types of cars. The data gave the mass of each material per car as well as the total weight of the car. Our data also included how much energy, in mega-Joules, it takes to process every kilogram of each material. With this data we found out how much energy it takes to produce each type of car.

The first set of calculations was to take each material and multiply its mass/car (kg/car) by how much energy it takes to process each kilogram of that material (MJ/kg). This gave us

how much energy is used to produce enough of each material for one car. Next, we added up all of the material energy usages to get a total amount of energy used to make the car. In our data, we use two sets of energy consumption values; one for processing new raw material and one for processing recycled materials. Calculations were done for all vehicles in our study and both sets of processing data were used. By doing these calculations we were able to compare quantitatively how much energy, for both primary and secondary processing, goes into making each type of vehicle. An example of the calculation spreadsheet used for each car can be seen below.

Vehicle:	Current, SI ICE, Gasoline, Auto				
	Given Data			Calculated Data	
	Vehicle Mass(kg)	Energy Use, Primary (MJ/kg)	Energy Use, Secondary (MJ/kg)	Energy Use/ vehicle, Primary (MJ)	Energy Use/ vehicle, Secondary (MJ)
Ferrous Metals	886	40	30	35440	26580
Aluminum	81	220	40	17820	3240
Glass	35	30	15	1050	525
Magnesium	10	280	27	2800	270
Copper	9	100	45	900	405
Zinc	7	50	16	350	112
Lead	10	40	8	400	80
Plastics	100	90	45	9000	4500
Rubber	54	70	N/A	3780	#VALUE!
Wood, Felt, etc.	64			0	0
Paint, Coatings	5			0	0
Nickel	0	110	110	0	0
Others	9			0	0
Fluids	54			0	0
Total	1324			71540	35712

Figure 8: Calculation Spreadsheet for Energy Consumption

3.1.2 Breakeven Calculations

In today's car market, many cars have a standard ICE model as well as a hybrid model. In our study we compared many of these vehicles. Break even calculations let you know how many miles need to be driven in order to make the premium price of a hybrid model beneficial.

For these calculations we needed to know, for both models, the price of the vehicle, its gas mileage (both city and highway values were preferred), and then the price of gas (which can be arbitrarily picked and changed to match the current pricing).

To find the breakeven point we had to set up an equation that took into account all of our data at once. The equation compared gas mileage of the standard model to that of the hybrid model and compensated for the increased price. The equation was then solved for the mileage variable which was the same on both sides of the equation. This mileage was the minimum mileage a person would have to drive, in the life of the vehicle, to make it monetarily worth paying for the more expensive hybrid. This equation was used with different values of gas mileage as well as three different types of driving habits. Calculations were done for the following styles of driving: Strictly highway, strictly city, and a one to one ratio of both highway and city driving. The equation used can be seen below.

$$\text{(Mileage/MPG standard)} * \text{(Gas price)} = \text{(Mileage/MPG hybrid)} * \text{(Gas price)} + \text{(Price Difference)}$$

Equation solved for "Mileage" to give the mileage of the Breakeven Point.

Figure 9: Breakeven Point Equation

3.2 Consumer Attitudes and Selling

One area of concern in our hybrid research involves the sales characteristics. We specifically wanted to examine what points are stressed when marketing hybrids. Sales persons must have some tools and guidelines that they use in order to attempt the sales of vehicles. The marketing campaigns may be diverse for different manufacturers and sales divisions and that is something we have considered. Most of the data used stems from interviews. These interviews were done with sales people at car dealerships, as well as ones conducted within our focus groups. A guideline of questions was prepared in order to make each interview successful, providing us with substantial and useful data. Through examining the array of data received, any commonalities in the ways in which sales people and dealerships market their hybrids were determined.

Every individual buys a car for a reason. There are a vast amount of different styles available and people buy what is appealing to them. What people look for when they are

buying a car is a significant phase in their overall decision making process. Whether it is a hybrid or a conventional internal combustion engine, there must be a reason for the purchase. Data found using our focus groups that consist of people who have bought a hybrid and those who have recently bought an internal combustion vehicle was crucial to understanding what different individual's consider throughout their search. Once again, our questions were prepared ahead of time, ensuring our data stays consistent with regards to the questions asked. Using the data, we observed whether or not those who buy hybrids have similar reasons and whether or not those who buy internal combustions have a common theme.

It has been stated earlier that converting the world's population of combustion engine vehicles to hybrid vehicles is theoretically illogical if not impossible due to the lack of resources and time constraints. However, this does not mean that there are not areas or groups of people that cannot make a significant impact on the environment by switching to hybrids. By studying various public transportation statistics, such as the driving patterns of different households, professions, locations, and environments from various sources, we determined where hybrid cars could present the greatest efficient environmental impacts. Vehicles such as Taxis and public busses would be prime examples of high impact vehicles due to their high mileage. This way, people who are switching to hybrids can tell how much they are reducing their impact on the environment compared to others who are living in different conditions. This would also be an efficient way to determine where the optimal environmental areas to sell hybrids are, as well as the general number that would be appropriate to sell there.

3.2.1 Interview with a Car Salesperson

Valuable marketing information was gained through personal interviews with car salespeople and sale representatives. With numerous new models of hybrid and non hybrid vehicles available, there are many new tactics for selling cars. Car dealers are experts in understanding trends in car sales, whether they are hybrid or conventional vehicles, changes and fluctuations in sales rates, which vehicles suit particular lifestyles better than others, amongst many other important decision variables. The knowledge and information gathered from these retailers was essential in accurately understanding the purchasing habits and

desires of customers. We interviewed Ed Proko, co-owner of Mill Street Motors and local used-car dealer, using a semi-structured interview protocol.

Interview Questions:

- Do you default to trying to sell ICE's until someone asks about hybrid technology?
- Are the sales rates of hybrids changing as more and more models of hybrids are being produced?
- What are the ratios of hybrids sold to ICE's sold in the past couple of years? Are the yearly ratios changing?
- Are people starting to trade in hybrids?
- Do you have different marketing strategies for selling hybrids versus ICE's?
- What models of cars are currently selling the most?
- What depreciation rates have you noticed on different vehicles, whether hybrid or ICE?
- How do you anticipate what type of vehicles to stock your car lot with?

3.3 Focus Groups

The reasons why people do and don't purchase hybrid vehicles are as diverse as the number of cars on the road. For our research, it was imperative that we sorted out what the most prominent of these reasons were so that we gained a better understanding of the marketing of hybrids. In order to begin obtaining the necessary information we organized two eight person focus groups. One group consisted of individuals who purchased a hybrid vehicle within the last 12 months, and the other consisted of those who purchased a non-hybrid in the same time period. To make sure that things progressed as smoothly as possible, our IQP group worked in conjunction with another group who was also focusing on hybrid vehicles.

In order to gather participants for our focus groups, we sent out an e-mail to the faculty and students of WPI, looking for those who fit the criteria of our desired categories with an incentive to do join being a \$25 American Express gift card. Those who were interested in our groups were required to send us a reply email with some basic information about themselves including the brand of car they purchased, when they bought it, their name, age, and contact information. After going through all the replies, we selected people that we believed would be the most beneficial to our study.⁴⁹

The meetings lasted roughly one and a half hours, each one managed and supervised by members from each IQP group. Upon first arrival at the meeting, we greeted the visitors and explained to them the purpose of the meetings. Each group was asked a set of questions regarding their choice of purchase, what their initial choice of vehicle was at the time, what their driving habits are like, and what they were looking for when they started car shopping. The hybrid owners would be asked about their cars, the impacts it has or has not made in their driving lifestyles, and what they think are some of the differences between hybrids and combustion engines. The non-hybrid owners on the other hand would be asked a similar set of question geared towards why they chose an ICE car over a hybrid.

3.3.1 People who bought a hybrid in the past year.

1. How much, on average do you drive a year? What is your daily commute like?
City/Highway/Off-road.
2. How much do you spend on gas per week/month/year?
3. How much did the car cost? How much was the last car purchased?
4. How long do you keep your car? How did you go about getting rid of it?
 - a. Junk, Sold, Trade-In.
5. What factors go into making a decision to buy a car, hybrid or not?
 - a. How did the interior size/comfort factor affect your decision?
 - b. How does output performance (acceleration) affect your decision?
 - c. How does your lifestyle/geographic location affect your decision?
 - i. For instance, do you need a truck for towing purposes, 4WD for winter reasons?
6. Was there anything about hybrid's that may have had a critical influence on you decision making?
7. How does the economically unstable foundation of the GM Company affect your decision making?

3.3.2 People who bought a new car (non-hybrid) in the past year.

8. How much, on average do you drive a year? What is your daily commute like?
City/Highway/Off-road.
9. How much do you spend on gas per week/month/year?
10. What type of car did you buy? If there is a comparable hybrid on the market, did you consider purchasing it?

11. How much did the car cost? How much was the last car purchased? When did you purchase it and did you ever consider buying a hybrid then?
12. How long do you keep your car? How did you go about getting rid of it?
 - b. Junk, Sold, Trade-In.
13. What factors go into making a decision to buy a car, hybrid or not?
 - d. How did the interior size/comfort factor affect your decision?
 - e. How does output performance (acceleration) affect your decision?
 - f. How does your lifestyle/geographic location affect your decision?
 - ii. For instance, do you need a truck for towing purposes, 4WD for winter reasons?
14. Was there anything about hybrid's that may have had a critical influence on you decision making?
15. How does the reputation of the car company affect your decision?

Chapter 4. Findings

We used many different methods to gain access to the information we required to fully study and answer the questions that we chose. Secondary data, interviews, focus groups and many articles and online sources helped us make educated conclusions to our project questions. As we progressed through our research, our answers became more apparent, clear and certain until we were confident with the results that we had obtained.

4.1 Emissions and Efficiency

After looking at many different types of cars, their components, and how they are made we saw that every car is not equal. They all vary in how much energy goes into making them, how much pollutants are produced while making them and how efficient they actually are when driving.

4.1.1 Energy Consumption for Manufacturing Vehicles

After all the calculations for energy consumption had been made, the values were graphed as a means of comparison, see Figure 10. The graph shows that, for primary material use, all of the hybrid cars studied consumed more energy in their manufacturing processes. In some case the hybrids consumed 40% more energy than the baseline ICE. This is because of the high amounts of energy needed to process larger amounts of materials such as aluminum, copper and things that would fall into the 'Other' category. It takes five and a half times the energy to process aluminum compared to steel. The steel to aluminum ratio for an ICE is almost 11:1, while some hybrids have a 1:1 ratio, leading to very high energy consumption. Higher amounts of magnesium and nickel in hybrids also add to the increased levels of energy needed.

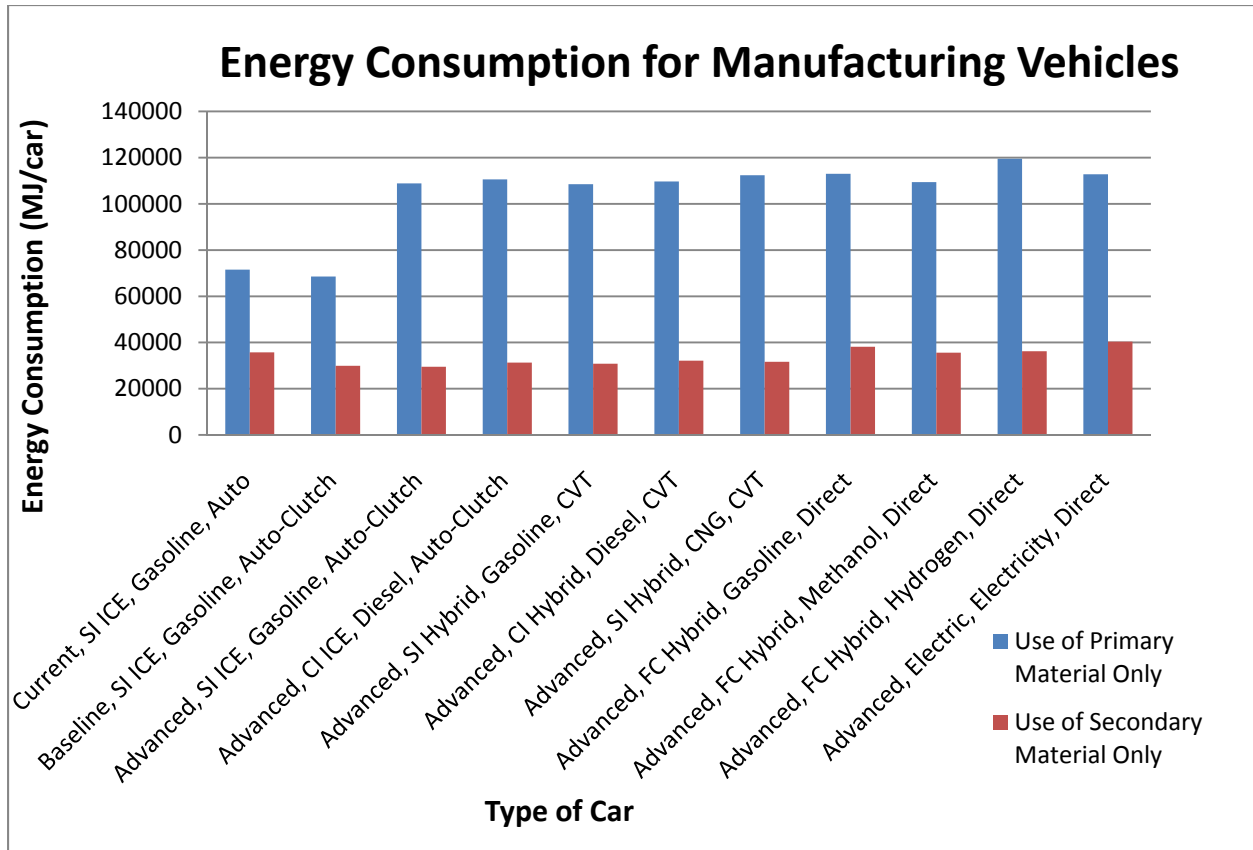


Figure 10: Energy Consumption for Manufacturing Vehicles

The graph shows that the use of recycled materials is a much more feasible way to make hybrids efficiently. If possible, using 100% recycled materials would lead to all of the cars studied being close to equal in energy consumption. This is mainly due to the fact that all of the main energy consuming processes which caused hybrid to use so much energy are much more efficient when using secondary material. For example, secondary processing of magnesium only consumes 10% of the energy needed for primary processing.

4.1.2 CO₂ Emissions Resulting Manufacturing Vehicles

The amount of CO₂ emissions associated with vehicle manufacturing is directly related to how much energy is consumed during their production. Many of the primary ways of producing energy emit large amounts of CO₂ into the atmosphere. Again, the use of secondary materials proves to be much better for the environment when compared to using fresh raw material. Figure 11, below, shows the CO₂ emissions related to manufacturing vehicles. Note the similarities to Figure 10 in the previous section.

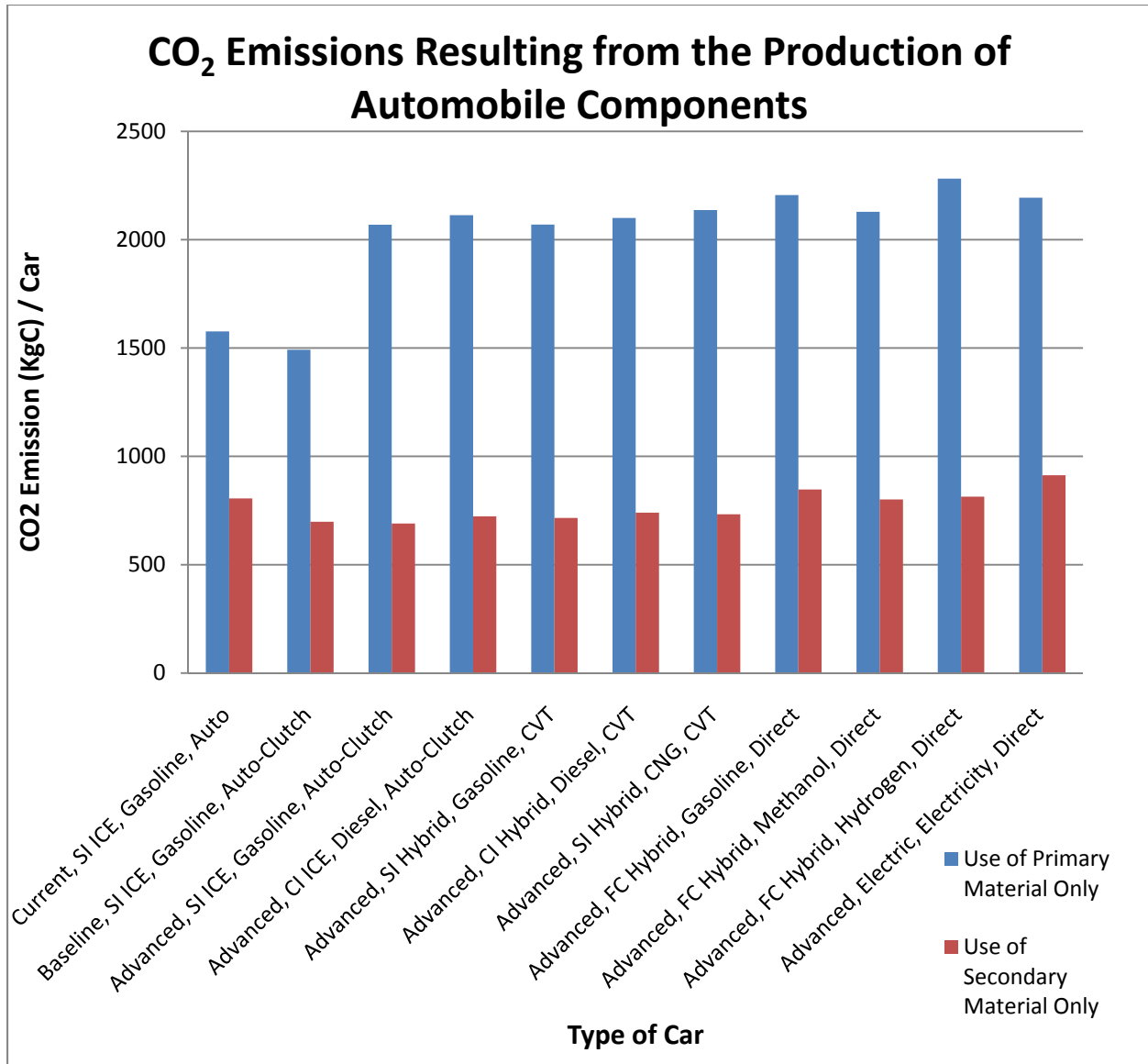


Figure 11: CO₂ Emissions Resulting Manufacturing Vehicles

4.4.3 Break Even Points

The break even point calculations for three of today’s popular cars told us a lot about both their efficiency and their consumer value. The data shows that the best performing car was 2010 Ford Fusion Hybrid, however, we are not comparing this car to others, but to a non hybrid model of itself, see Figure 12 below.

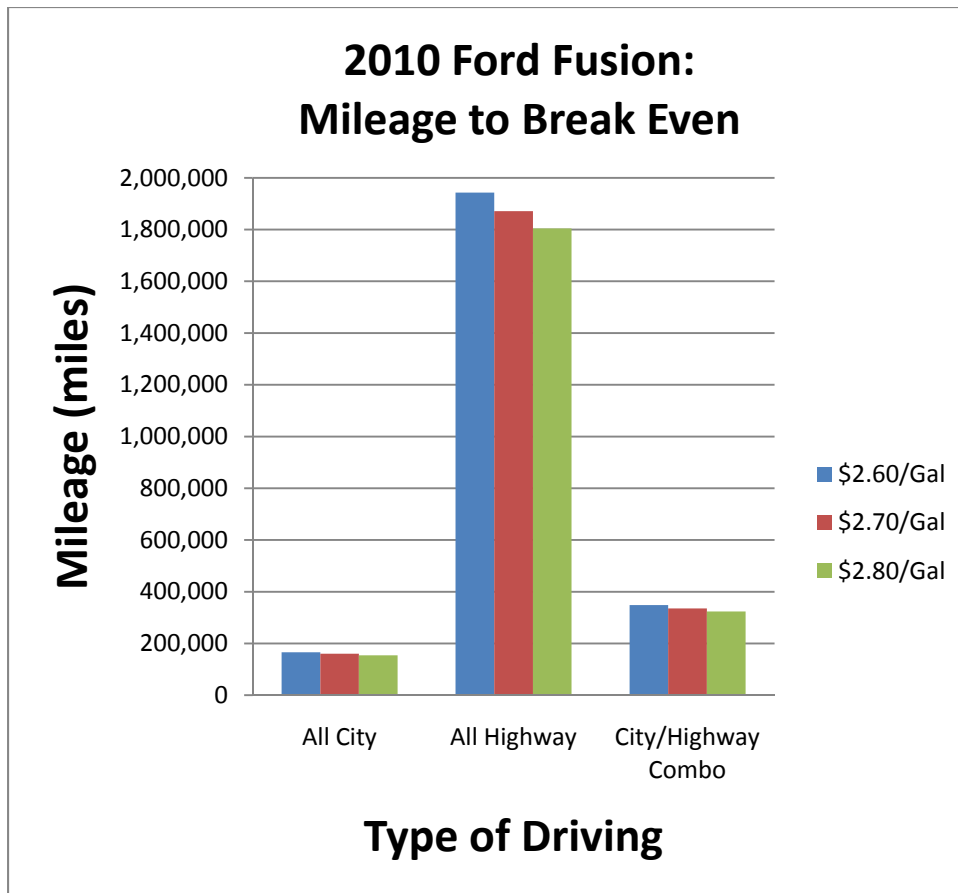


Figure 12: Break even Point for the 2010 Ford Fusion

With the current gas price hovering around \$2.80 per gallon, a consumer would have to drive Fusion Hybrid over 150,000 miles, only in the city, before they started saving gas money. Conversely, if all of their driving was done on the highway, they would have to drive nearly two million miles before saving any money. If we compromise and split the driving evenly between the highway and the city, the consumer will have to drive over 300,000 miles until the extra investment was worth it.

Different types of cars are going to perform differently, which is why a mid-sized car/small SUV was analyzed. The 2010 Ford Escape Hybrid will have to be driven over 200,000 miles through cities before it will put the consumer on the plus side of the investment. Highway driving will need close to one million miles and the average combination of city and highway will still be a staggering 350,000 miles before the car starts to pay for itself. See Figure 13 below for the full graph.

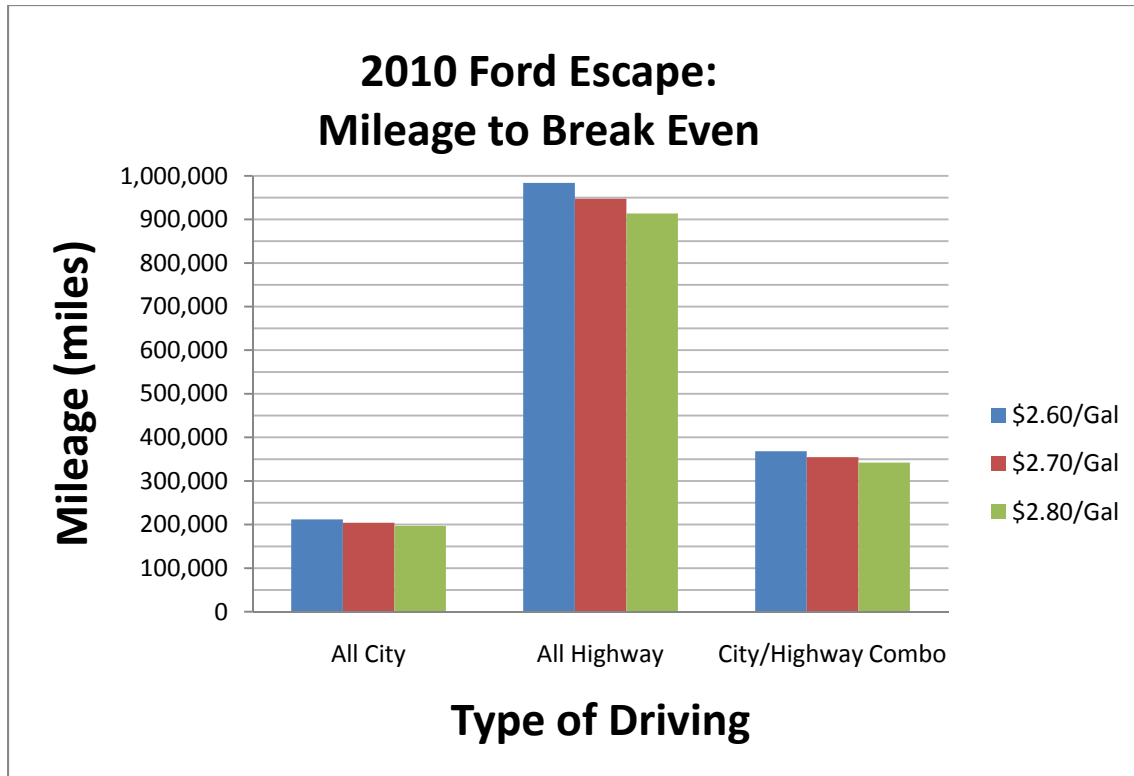


Figure 13: Break even Point for the 2010 Ford Escape

The data for the final car was very interesting, a hybrid car that will never make the consumer's money worth it. The data for the 2010 Toyota Highlander, see Figure 14, showed that if the consumer has an all highway commute the hybrid model will never pay off. This is because the highway fuel efficiency is worse in the hybrid than in the ICE model. All city driving will provide for a break even point of approximately 250,000 miles and a mixed commute will lead to almost 800,000 miles before breaking even.

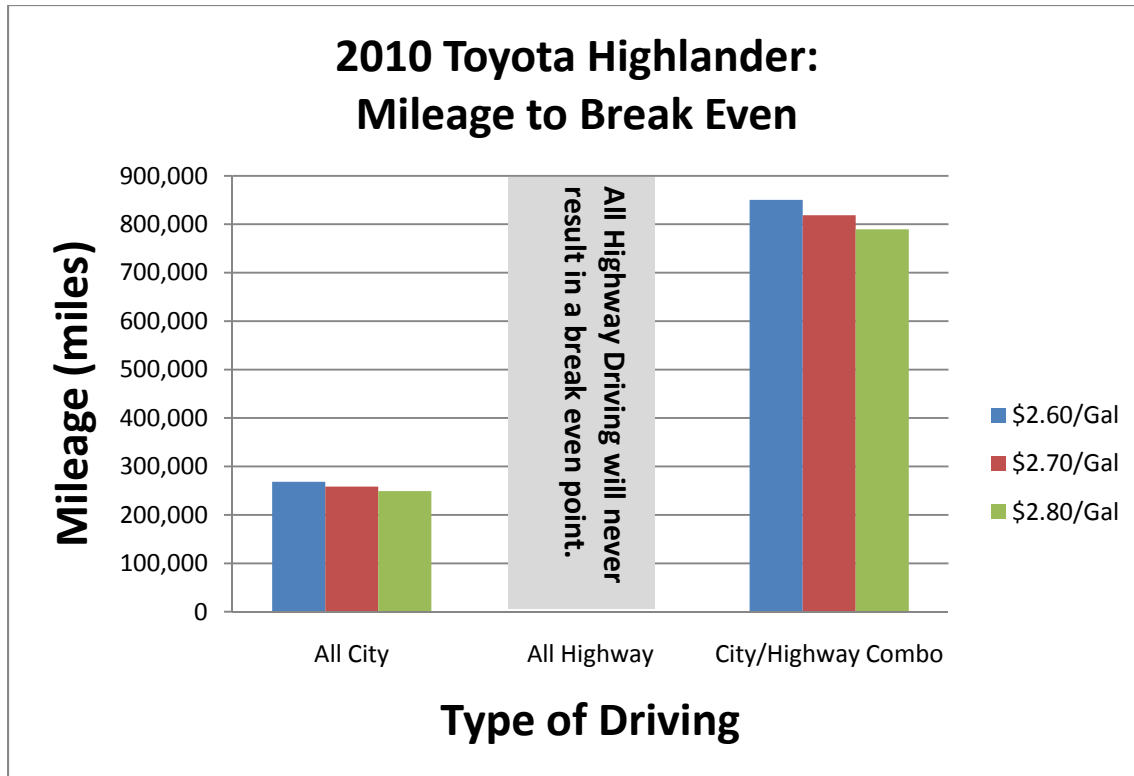


Figure 14: Break even Point for the Toyota Highlander

4.2 Public's View on Purchasing Vehicles

What specifically people are looking for when they are searching for a vehicle that best suits them was an important question brought up throughout this entire project. We thought about lifestyles of individuals, for example families, couples, single individuals, we considered those that viewed cars as status symbols, where a person lives demographically, how much the person travels on average, among many other things. Through interviews and further questions, we found that there are a variety of different criteria that people look to fulfill, many of which were things that we had previously addressed.

Families tend to look for vehicles that have a lot of extra space and that are high among current safety ratings. Some people that are interested in traveling look for vehicles with space and towing abilities. Due to New England weather conditions, many of the volunteers were in search of a vehicle equipped with four wheel drive. Some individuals are passionate about

their cars and particular about performance and exotic appeal, while others are just in search of something to successfully take them from one location to the next.

“We needed an SUV because of the terrain and hills that we have to commute.”

(Participant #5, Question 10)

“The number one for us is safety ... size and ability to transport strollers and pack and plays and the amount of stuff that two children under four require. We needed trunk space. So for this one with two car seats and I have parents that are local so we are often traveling with them. That is why finding a third row was also ...we wouldn't have bought a new car without a third row. So we wanted to be able to have the car seats and other people come in the car, have me get in the back seat with the kids...so it was all about functionality with being a parent with children...so safety, functionality, and then from there probably went price, to style...”

(Participant #2, Question 13)

“When it came down to my purchase, it was between three cars and I am very, very particular about what I get. You know I'm an engineer, an automotive engineer, and I gotta have the right stuff... And so I think that the performance and exotic nature of a car really appeal to me and but one of the trips for my wife was that we wanted something that would be comfortable for people to travel...” (Participant #1, Question 13).

Another important question that was raised throughout this study was why people would chose to purchase a conventional vehicle rather than a hybrid vehicle. We wanted to know what would deter them from buying a vehicle, whose hype was advertised to have such an immensely positive impact on the environment and also to be so outstanding on gas mileage. We thought that price was a major contributor in this decision.

We found that the major contributor to the participants' decisions to not purchase a hybrid vehicle was the price of the vehicle and the thoughts that they would never make back the difference in price. Some people needed a car that was not a hybrid for lifestyle reasons. And others had strong feels against hybrids, not believing all of the recent publicity about their benefit to the environment.

“I would have loved to get a hybrid but you can’t get a hybrid that will tow a trailer” (Participant #6)

“hybrids are just a stop gap so I’m not too excited about them unless they happen to perform well and happen to give the tax incentives to make them pay off before you end up throwing it away”

(Participant #1, Question 14)

“... you realize like they never really pay off in the long run” (Participant #2, Question 14)

“it was just too priced out for us and as we talked about it, it would have taken us too long to make that difference back” (Participant #3, Question 14)

“Pretty much price range. We would have been prepared to buy the hybrid highlander but just...we knew we wanted the highlander...we couldn’t afford the hybrid” (Participant #5, Question 14)

“I looked at the Highlander Hybrid but it was about \$10,000 more and I looked at what it would take to pay that back, the return on the investment, and it wouldn’t work, I would get rid of the car before it paid off.” (Participant #5, Question 10)

For individuals that purchased hybrid vehicles, we were very interested to know their reasoning behind their purchase. We thought that many of the individuals purchased the vehicle as a statement in support of the world “going green”. We also suggested that the better gas mileage was a major contributor, especially with the drastic increase in gas prices.

Through the interviews in the focus groups, we found a variety of different reasons for individuals purchasing their hybrid vehicles. We were surprised to find such little talk about the gas mileage that these cars receive, and more discussion about the actual physical appearance of the vehicles and their status within our society. The cars were attractive to these individuals, but were also seen as a message to those surrounding them that they are making an effort to help the environment.

“I went down to a meeting with Toyota with the Mechanical and Electrical engineering professional societies, and all they had was a right hand drive Toyota Prius, and I saw the design of this earliest Prius, they were already selling them in Japan, and I came away saying my God that thing is so beautiful...” (Participant #7, Question 1)

“So, they had a design that looked beautiful, almost as if I was a human looking at a painting. For me I was looking at a piece of technical beauty. My wife is not an engineer, but we both agreed that that car was an amazing car... the technology of the Prius seemed to be the most advanced, and that’s where I felt that splurging and paying the extra expense was worth it.” (Participant #8, Question 1)

“I was looking for a car because I have an 1.5 hr commute from western Massachusetts, and I needed a car that got better gas mileage than my old Volvo.” (Participant #9, Question 1)

“it was commuting and I think it’s useful to talk about the symbolic reasons that people buy Prius’ over other hybrids out there because people see the car and know it’s a Prius and know what it stands for... the Prius is symbolically sexy in the academic world.” (Participant #11, Question 1)

“I think there is a brag factor that you want that image of driving a hybrid to attach to you. That it’s good for the environment, but you do feel good about driving it and advertising that too.” (Participant #12, Question 1)

Many respondents of the hybrid focus group said their driving habits had been influenced and altered once they switched over to hybrids from conventional vehicles. Those that purchased the Toyota Prius especially noticed this fact. The New England winter weather was a main reason respondents felt this way. Some were used to driving SUVs, which are clearly better for driving in the winter than the Prius. On the other side, the Prius is a front-wheel drive car, which is better than rear-wheel drive in snowy conditions. Another factor that resulted in modified driving habits was the decrease in power of the hybrids. Some respondents had been used to a sports car feel. Once driving a hybrid, more specifically a Prius, they were not able to accelerate as quickly or buzz up hills like a conventional sports car is able to do. Some dealt with these issues by having a second vehicle, conventional, that they could

use when necessary. Others reacted by simply avoiding driving in these conditions. These were all decisions that respondents of the focus group had to confront when choosing whether or not to purchase a hybrid.

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4.3 Sales Approach:

During an interview conducted with Ed Proko, co-owner of Mill Street Motors, the questions involving what types of vehicles sell the most and what does the general public want for a vehicle were issued. The interviewee had much firsthand knowledge on the subject. However, this knowledge was limited because Ed Proko is a used car dealer. He only knew which used cars were being sold and purchased. He was unable to discuss the buyer and seller perspectives of brand new vehicles. It was verified that hybrids are not one of the vehicles that most people seek. Throughout the interview, it was told that Mill Street Motors had only sold one hybrid, in the recent year. The owners do not keep hybrids in their inventory because it is a waste of money for them. If a customer desires a hybrid, one of the owners will find one for their customer. This is how they deal with many other small, fuel-efficient vehicles. According to Mill Street Motors, the current vehicle market is substantially for trucks and SUVs. Whether it is because of kids and large families or for the sense of greater safety, the general public still

feels the need to have larger vehicles. The only period of time when smaller, efficient cars were ruling the industry was during the extremely high gas prices. Once prices fell back down, people started to purchase less efficient vehicles once again. From this interview, it was verified that hybrids still have not been widely accepted and they do not fit the needs of the lifestyles of most people.

4.4 Incentives

During the interviews and focus groups conducted, multiple examples and experiences, as well as various perspectives on incentives were recorded. First and foremost on the list were the tax incentives that the government gives to hybrid owners, which was viewed by some in a poor light due to the belief that the incentives are an attempt to cover up some of the negative and not well known facts about them. There were several articles on the internet that listed and discussed many potential incentives in significant detail. This list included the Energy Policy Act of 2005, which replaced the clean-fuel burning deduction with a tax credit. A tax credit is subtracted directly from the total amount of federal tax owed, thus reducing or even eliminating the taxpayer's tax obligation. The tax credit for hybrid vehicles applies to vehicles purchased or placed in service on or after January 1, 2006. There are many rules and requirements that must be met in order to be eligible for these tax credits. Some of these being that the hybrid must be purchased new, not used, the car must be used primarily within the United States, the vehicle must be purchased within a certain time period, and the date that the vehicle is bought is somewhat a determining factor in the amount of tax credit the individual will receive. Even with the restriction of these regulations, there are many vehicles that are eligible to receive these federal tax credits. By looking at the statistics and the numbers, we determined that the tax reliefs were saving the hybrid car owner's more money than the amount they were accumulating from not paying for the extra gas.

In the non hybrid focus group, pricing was a major contributor in the volunteer's decisions for purchasing a vehicle. Each of the contestants stated that the price was either too high, the breakeven point was too high, or the tax incentives were not always worth the extra investment. In one instance it was actually the deciding factor against the hybrid vehicle. In

the hybrid group, the major contributor was the exceptional gas mileage that most of the hybrid cars were getting and their reputation of being helpful to the environment.

“I have a problem theoretically with hybrids and that the research shows of course it’s just a stop gap measure. The real reason for buying them would be the tax incentives and a few things like this because when it gets right down to it the technology is not the way we should be encouraging people right now actually. On the other hand the tax advantages make it significant...and so I would much rather buy something which is a longer term look at fuel economy...certainly there are a lot better options than hybrids” (Non Hybrid focus group, Participant #1).

4.5 Feasibility of Mass Conversion

During our research to determine the possibility of a great global change from combustion to hybrid, we saw there the adoption of hybrid technology continues to rise, but the pace is still too minimal for any changes in environmental issues or fuel demand to be seen. The market for hybrids is still lacking in the number of vehicles and models available. It also takes a great amount of time in order to convert something as large as the world’s automobile population from one brand to another. It takes approximately fifteen years for the automotive fleet to turn over in the US alone. This being said, a mass conversion of the world’s car population would take even longer. A significant switch to hybrids from gasoline and diesel vehicles would have to be met before any changes could be seen when dealing with massive world population and high dependency on transportation. Unfortunately, we discovered that we require 50-80% of the car buyers worldwide adopt these new “low carbon” technology automobiles to make a material difference. That number far exceeds where we are currently at today.

As we investigated the subject, we also looked into the additional materials that went into hybrid vehicles that were not used in standard combustion engine vehicles, such as copper and nickel. We discovered that due to the large population of cars in the world, it would be impossible to do an absolute conversion. It would require building batteries that all together contain more nickel than the world currently has.

A widespread change to hybrids requires an extended period of time and also may not be cost effective. Many of the outcomes are not worth all that goes into getting the advanced technology on the road. Even if hybrid vehicles are a possible advancement of transportation technology, the issues that come with changing the world's population of standard combustion engine vehicles to hybrids pose too large of a task to be completed within any given amount of time.

Chapter 5. Conclusions

Do hybrids meet the expectations that society has suggested of them in the past decade? That is the main question that we set out to answer in this paper and it has many factors that have to be taken into account to answer it. People that buy cars need to know what they want in a car, choose the right car, and be aware of the investment that they are entering into. Car manufacturers and dealerships need to understand the consumer needs and habits before trying to sell hybrids. Yes, the technology is advancing and has potential but it has to be used correctly to work effectively. Overall, hybrids really do not live up to their expectations.

First of all, for cars that are supposed to be more environmentally friendly hybrid create much more emission before they even hit roads. The production of hybrids is far more harmful than the production of today's regular ICE's. In some cases, hybrids consume four times as much energy in production, and in turn are responsible for four times as much harmful pollution that is released into the atmosphere, when compared to non-hybrids.

It is easy to jump to the conclusion that a hybrid which gets better gas mileage than a non-hybrid will save the consumer money, but initial costs must be taken into account. If the increased initial cost of a hybrid is too much, the investment will be very hard to break even with. Hybrids must be driven to high mileages in certain conditions to really be worth paying for. These mileages are often even with, or many times higher than, the average mileage that a consumer keeps their car for. The specific driving condition in which a hybrid is effective is in all city driving. This makes it even harder for a consumer to rack up at least 150,000 miles to justify the high cost of the car. Anyone whose driving exceeds the low speeds of city driving is substantially increasing the mileage in which they will have to drive in order to break even.

Most consumers probably do not take the time to actually do out the calculations to see if a hybrid will save them money, but money is something that they do think about a lot when considering buying a hybrid. Some hybrids are close to \$10,000 more than the non-hybrid model of the same car. Many people cannot justify spend that large amount of extra money for something that is supposed better for both their wallets and the environment. Many consumers who want to buy a hybrid vehicle will not because of their price alone. There are

however, many other reasons why people opt out of the hybrid option. In the northeastern U.S. especially, people need vehicles that can perform in harsh conditions such as snowstorms, or that can handle rough, unpaved roads. Many hybrids simply do not have the power or capability to fulfill the needs of certain geographic areas. Although the trend of hybrids being small is starting to change, many consumers find them to be too small for their need as a family car. Hybrids are growing larger to meet this demand, but as they become larger their efficiency decreases. Small, efficient engines are for small, lightweight cars, not large SUV's.

This leads to the question of when hybrid technology will actually meet its expectations. We cannot say for sure what will need to happen, but we can make some recommendations. First, steps should be taken in the areas of production. Industry needs to find cleaner and more efficient way of producing lightweight materials such as aluminum and carbon fiber, which is used in the car bodies. More effective and increased levels of recycling would lead to much lower energy consumption and would add to the clean image of hybrids.

The next issue that should be addressed for hybrid technology is using it effectively. Using hybrids as taxis in large crowded cities would be a very effective use. Taxis are abundant, constantly in use, and stuck in traffic in large cities such as New York. This would be the ideal situation for a hybrid as it would not be sitting at red lights idling and producing harmful emissions and it would rarely have to be used at speeds above the effective electric engine range. With taxis constantly in use they would reach their break even point much quicker than a family car that is used for only daily commuting. The sheer number of taxis in large cities would play a large role in their effective implementation, and would be a good first step for widespread change.

Widespread conversion to a hybrid technology, such as fully electric or hydrogen driven vehicles is still a long way off and is not feasible at this time. The production of equally efficient hybrid vehicles is not great enough to compete with non-hybrids, both economically and numerically. These kinds of hybrid cars are expensive right now and are produced in small numbers compared to other consumer cars. If enough of these vehicles could be manufactured and sold then a new source of fuel would have to be implemented. Converting gas stations to new refueling stations would be extremely time consuming and expensive. If in

the future these plans were to be fulfilled, it would be best to start with a few very populated centers and spread outward, but again, these plans are far in the future.

Overall hybrid technology is heading in the right directions, but a lot of work must be done to refine it. Industry needs to be able to produce hybrids with the same or lower levels of emissions and energy consumption as conventional cars. Engineers need to develop more effective electric engines with a greater speed range. Hybrids need to be comparable to conventional cars pricewise and performance for consumers to start purchasing them in a larger scale. Until these issues are addressed hybrid vehicles will not meet the expectations set forth by today's society.

Appendix A: Focus Group Transcript

Focus Group Transcript for: People who bought a new hybrid car in the past year.

Gove: My name is Brendan Gove I am a junior at WPI mechanical engineering major. This focus group point is to support research that we are doing for an economical and environmental analysis on hybrid technology and different impacts that technology can have on our nation and on the world. The goal of this group is to try and inspire you guys to talk to one another and find out what reasons went into you purchase your decision to buy a hybrid vehicle. Starting off on that, what were the major factors that went into purchasing a hybrid vehicle?

Participant #7: My wife and I have been driving hybrids for 10 years. We purchased the first Toyota Prius, a 2001, purchased in 2000, and we did because I went down to a meeting with Toyota with the Mechanical and Electrical engineering professional societies, and all they had was right hand drive Toyota Prius, and I saw the design of this earliest Prius, they were already selling them in Japan, and I came away saying my God that thing is so beautiful, from an engineering standpoint, that on the drive home I told my wife we were getting one of those things as soon as they are available and if they are at a reasonable price. I think we waited at least 2 years until it was introduced, and we bought nearly the first Prius ever sold in Massachusetts, and we still own it. Three years later we purchased a 2004 in 2003 and we have been driving that and typically we keep cars 12-14 years, so we are on the 10th years of our 2001 Prius. I am looking at the possibility of a plug in car. So we have been at this for years. Prior to that, part of my retirement of WPI, I helped create the electric car and solar car program 20-25 years ago. We designed developed and manufactured and raced solar powered race cars. I had the background of helping WPI students create a solar powered racing car that we raced from Florida to Michigan. At times we moved the car at 60mph, but due to energy conservation issues, we often moved slower than that. Then I lead projects with WPI students' immersing students at GM in Warren, Michigan looking at the cars they made. I had students who thought they could do a better design than GM, so we did it, we tried it. That was one reason why we bought the Prius.

Gove: I think the key thing I am going to take form that is you said it was an amazing vehicle, that aspect you are referring to is the advantage of having a dual power system the car provided for you right?

Participant #7: Right that's what the car was, but I was seeing some of the details, but understanding some of the details, the details looked very substantial and very real. So sure, we were there to see the concept, but what I was convinced about was Toyotas ability to design a vehicle with reliability, regardless of the recent happenings that the media is blowing out of proportion. So, they had a design that looked beautiful, almost as if I was a human looking at a painting. For me I was looking at a piece of technical beauty. My wife is not an engineer, but we

both agreed that that car was an amazing car. The problem I had was trying to teach salesman how these vehicles worked.

Gove: Because it was so new, right?

Participant #7: Yah, I had to teach these guys what they were all about and how it worked. It was unfortunate because the last guy who sold us the Prius didn't even know how to sell cars. I had to teach him how to sell cars too!

Gove: So any other thoughts? Any one jump right in? Similar thoughts?

Participant #8: I can follow up on that because I did a lot of research looking and comparing the Hybrid Toyotas to fords. I felt the same way, doing the research I knew I wanted to replace my 10-11 yr old SUV I was driving at the time. So I looked at the Honda Insight, and the Ford escape, and the technology of the Prius seemed to be the most advanced, and that's where I felt that splurging and paying the extra expense was worth it. I am still paying off the stupid thing because that's expensive for me. I do not have the ability to pay the sticker price of the Prius.

Gove: Right because that's a huge thing that goes into consumer trends because you pay an extra X amount of dollars so you have to ask yourself if its worth it

Participant #8: I didn't know if it was worth it but I realized I could save costs in comparison to the gas guzzler I had before. So I ran some numbers and talked to some ECE students who supported me getting the car. Not only from an environmental standpoint but an economical standpoint, it was funny that these grad students were selling me. And I am still going to be paying for this car for the next 2.5 years.

Participant #7: We came in at 20,000 on both of them. The 2003 was the same as the 2001.

Participant #8: Well I had the upgraded radio system.

Gove: So one of the things that we are finding on our studies is that people are buying these hybrids for what you guys are telling me. Environmentally there are benefits, doing your part, saving gas. In the same sense, we are finding that the Prius technology is more of a stepping stone because we are still running into problems. This is also a similar type of problem with petroleum shortage. The same thing occurs with the chemical make up of these batteries, being of an even greater shortage than petroleum. Another problem is how do you recycle these batteries, something we do not currently know how to do. So, talk about weighing the benefits of gains in one side but maybe a loss in another side.

Participant #8: The battery recycling was a question for me. I usually keep my car 10 years. I felt that by then that this problem would be solved by then.

Gove: This makes sense because the life span is about 8-10 years.

Participant #9: That was a concern for me too because I was looking for a car because I have an 1.5 hr commute from western Massachusetts, and I needed a car that got better gas mileage than my old Volvo. I was concerned about the battery issue which turned me away from hybrids Prius. I went with the Jetta diesel which at the time was billing as a new clean burn diesel so it didn't have supposedly that same type of particulate emissions as other diesels and it gets 48mpg highway. My objective was to, without understanding the tech very well, to make it into a grease car that it, well, because it was so new and well designed that my mechanic who installs grease car conversions refused to put the conversion kit into the new vehicle because it was untested and uncharted terrain.

Participant #10: What is a grease car?

Participant #9: It is a car that you convert so it can burn vegetable oil; they smell great, like French fries. SO, I obviously didn't convert it to a grease car, but where I live I can buy biodiesel out the part, and the car manual says I can use a certain % of biodiesel, which I do sometimes but it is more expensive.

Gove: So, a 1.5 hr commute is well over 600 miles per week right?

Participant #9: This car is about 1.5 yrs old and has 40,000 miles on it...

Gove: So that's the biggest thing you guys are giving me is that you bought the hybrid because of the large amount of driving you life style brings. People that buy the hybrids are driving a lot of miles.

Participant #8: Yah, I drive 20,000 miles a year.)

Participant #9: I would take the train if I could but it's terrible.

Participant #11: I know, I moved from the west coast to Worcester and 3 weeks before we moved our second car hit a deer, so when we came to the east coast we were under the impression that the public transportation was amazing, but it isn't. We tried having a 1 car family for a while, taking the bus. I live near Webster square in Worcester, and we purposely lived in Worcester so I could commute and stay a 1 car family, and it took my 2 hours to take the bus 4.5 miles, using three different bus routes. So, we had to buy a second car which was the Prius. One of the reasons was that my husband got a job in Westborough for the commute. The other reason was that I'm an academic and the Prius is symbolically sexy in the academic

world. We are a weird group we like that. Part of the purchase reason was also due to the timing that car sales were at an all time low and car prices at this particular dealership was 1/3 the price. So we were able to buy a used Prius for less than 10,000, which was an awesome incentive. I feel very strongly about buying used cars as well, I guess I should throw that out there too. SO yah, it was commuting and I think it's useful to talk about the symbolic reasons that people buy Prius' over other hybrids out there because people see the car and know it's a Prius and know what it stands for.

Gove: Absolutely, we have seen marketing trends that people like their brand name products

Participant #8: I don't know I liked the look of the Honda insight better, I liked the ford escape, but to me it wasn't about the status of having a Prius. Now when I got it people were all, "Oh my gosh you have this car," but I don't feel like I have a symbolic mindset of being proud of this car.

Participant #12: On the subject of status I can tell a very funny back story about my first Prius and now my second Prius. I bought my first Prius in 2002, not quite as much as an early bird as you. But I definitely recognized that the earlier models would have certain costs associated with them, but I felt it was important to affiliate myself with a product that had a part of a larger narrative of transformation of the auto industry, toward attempting to deal with these larger issues. It was the first car I had ever bought just because of my lifestyle. I was teaching at a private school in California. In my early days of teaching at this school I was driving a broken down SUV and was getting some smirky looks from parents and peers. Then I was able to complete the transaction and purchase the 2002 Prius. I then got different looks, not any less smikry but more towards a lack of understanding about the technology. SO I think that the symbolic nature of the Prius definitely has weight in why people get them now however.

Participant #12: That car was totaled in 2004 and at that point I was faced with a decision what I do, because at that point, the Prius had become visibly enough so that there was a 6 month waiting list to get a replacement, new Prius. They had just shifted from the first US generation to the second US generation. I decided to wait out those 6 months. It was important enough to me to still have a Prius and to continue on this, sort of, trend toward the newer technology that was moving in an improving direction with regards to ecological concerns that I decided to wait. So I went 6 months in graduate school without a car, and bought a 2004 in, I guess it was, early 2005. That's the car I continue to drive today. I only put, probably, 8000 miles a year on a car. And really try to minimize my use of the car as well.

Gove: So that product reliability, your loyalty to that product, excuses me, which originated from what? That experience you had at that private school?

Participant #12: Well, it's a great car. I'm not an engineer. I'm a human, but just as I'm enthused about looking at paintings I'm also enthused about, you know, engaging with this car because I think it is an important thing. And...also I hate to drive, like I really don't. I would rather my wife drive..And I find the car relatively pleasant to drive on those occasions when I absolutely have to. I do try to avoid driving but I find that the way that it handles means that I'm actually more conscious about the choices I'm making when I am driving it, in terms of laying on the gas, how I break, how I take elevation. All of these things, I notice them much more when I'm driving my own car than when I'm driving my wife's car.

Gove: your wife drives a...?

Participant #12: Drives a Honda Element, much to my chagrin, and will probably upgrade to a minivan when our second baby arrives in the near future. So ya, part of that product loyalty is the, sort of, that way that product turns me from a very ornery driver to a driver that is at least willing to go out on the road when he has to.

Participant #12: My experience is somewhat similar and a little bit different. I enjoy driving and had a driver's car, the Subaru WX Wagon. It was a ton of fun to drive, but it was a little car, 4 wheel drive, and you were lucky to get 24 miles to the gallon. So when that car was old enough that I was going to trade it, I decided I did prefer to get a hybrid for a variety of reasons; long weekend commutes-so a lot of miles, and something that I could feel good about driving. I really felt like, and still feel like, at least for the car I bought, I'm not sure all the economic benefits are there but the more miles you put on, the more you save. So if you're driving long miles anyway, at least you're saving something. I'm not sure if everyone feels this way, but there's an element of you are doing something better for the environment too, by if you're going to drive you're better off owning one of those cars. I got a Ford Fusion Hybrid because I liked how it felt on the road better. But I think another factor that we've heard from a number of other people is the Ford, Prius, I'm not sure who else; the cars are reliable. So the low maintenance, high mileage, and car that felt good driving; all those things were important to me. I did think a little about that fact that I wasn't advertising a darn hybrid and that was ok to me. But I do find myself when people say, 'Oh, you got a new car.' And I do say, 'It's a hybrid.' So I do think its something I'm...

Gove: Conscious of?

Participant #12: Well, not just conscious of. I think there is a brag factor that you want that image of driving a hybrid to attach to you. That it's good for the environment, but you do feel good about driving it and advertising that too.

Gove: Now one of the biggest things that we came across, we were wondering, why is it that companies like, we'll talk specifically about General Motors, why is it that a company in a

country, that its claim that they are intelligent above par from other countries, why is it that such a high class company would allow itself to get into the situation it did with regards economically. How is it that they could foresee in the 1970's when there was a similar gas crisis, an even worse gas crisis, how is it that a company like this could let itself get so far behind in technology such as hybrid technology?

Participant #7: I have an answer for that if you want an answer. I know the whole history of General Motors, why they ended up the way they did. It's very clear. Well it started out with General Motors. The first world solar challenge, a race of solar cars across the outback of Australia from Down Attalaid, took place in 1987. And General Motors put two vehicles in place to take part in that race of solar powered racing cars. They invited me to come along with them to the race in Australia and they won the race 2000 miles handedly. They had really tremendous technology. Much of it came from a skunk works, a small company called Aerovironment in California. They were closely linked. When they had that success with solar powered racing car in Australia they basically tuned to this skunk works and said, 'Hey lets create a vehicle for the public, an automobile, electric automobile, and they took everything they learned in terms of efficiency from that solar powered racing car and put it into this crazy car named, the Impact. Why would you give name to an automobile, the Impact? But that was the name of it, Impact. It was the finest pure electric, not hybrid. It still may have been, today, if I can see other electrics coming along, that GM Impact electric car was the finest electric car I have ever been aware of. It may still exceed, even now 20 years later. So it turns out they had to take care of the name so they changed the name to EV1. And that had a lead acid battery, and then they went to EV2 with a nickel metal hydride battery. They were in absolutely great shape. The chief executive officer, the CEO and chairman of the board was a WPI alumnus, Bob Stemple, was a good friend of mine, although I don't see much of him. General Motors was absolutely tops, way ahead of Japan, way ahead of everyone. They were bleeding money. There was a serious problem with the company losing money in spite of the old things they were doing. So they actually brought in a new chairman of the board. They didn't replace Bob Stemple, our WPI alumnus. They didn't replace him as CEO but did as chairman of the board. And they replaced him with the CEO of Proctor and Gamble, which puzzled the daylight out of me. But it didn't puzzle me for very long. That new chairman, full time CEO of Proctor and Gamble now brought in, and he's still doing Proctor and Gamble stuff but he's part time chairman of the board at General Motors. He tuned to my friend, Bob Stemple, and said, 'Bob I'm going to have you do two things. First all I'm going to have you fire 40,000 people. And the second thing you're going to do is get rid of this nonsense of electric cars. And General Motors was the tops in the world at that moment. They had a fantastically capable group of 300 people doing their electric car work. Bob Stemple faced the new Chairman of the board and said, 'I will not.' So they fired Bob Stemple and then they proceeded to fire their 40,000 people and immediately got rid of this amazing group of 300 pioneers in electric vehicles. That was not the

choice of General Motors. That was the choice of an idiot that they had brought in from Proctor and Gamble, a man who knows all about Ivory soap, pampers, Pringles and a few other things. But apparently he knew nothing about automobiles.

Gove: Right, so his lack of understanding, all he saw was loss of money.

Participant #8: However, with any innovative you have to put a lot of money into research and development in order to be an innovative company.

Participant #7: At any rate, the man from Proctor and Gamble had no vision of the future of any kind, so when we talk about General Motors I like to distinguish General Motors from Proctor and Gamble. Now, there was a mistake made by the board of directors of General Motors to bring this guy in as chairman of the board. That was a serious mistake. It cost, the board of directors are largely outsiders. So, if I were to blame anybody, I would blame a bunch of outsiders who came in and took command of General Motors and messed it up.

Participant #12: can I actually connect Proctor and Gamble to General Motors, just in terms of my own choices as a consumer because hearing this story, to me, is extremely interesting. It speaks to the notion that once you have a commodity you must continue to monetize it in order to maximize profit, whether it's a diaper or a car. Now as the parents of a 15 month old, we made a decision upfront to purchase cloth diapers. We wash those and that was extremely expensive upfront but it is also a commodity that doesn't continue to be monetized in the same way that disposable pampers would be. And in the same way you pay a certain price upfront for the hybrid car, and then it's not as much as an expense later in the game.

Participant #7: I was the first person who did not work for General Motors who test drove, when it was called the Impact. Eventually, they changed the name to EV1. I was the first guy outside of General Motors to test drive one. It still had potentiometers; it wasn't firmly imbedded with its control panels. You could still jiggle things, and it was the most beautiful car I have ever driven. When they finally came out into the market place, they were very cautious. Now this is before what I just described happened, while they were still trying to make it happen. They decided to have two limited markets; one in Phoenix, the Phoenix area in Arizona, and one in southern California. They were not going to sell them right away. They were going to lease them. So I happened to be visiting one of my sons, my wife and I have a very large family-4 kids, 12 grandkids, 10 great grand kids, and this sort of thing. We were visiting part of our family in Phoenix and he brought me to the particular outlet for the General Motors Impact. They said, 'Hey, get in and drive a real one now that it's all fixed up. You don't have diddling of potentiometers; you just go in and drive it.' And it was marvelous; absolutely beautiful car. Great acceleration, great everything. I had to calm down a little bit because as soon as I got in that car in Phoenix, there was a Phoenix policeman behind me. I wanted to

really try this car and see the acceleration and speed, but I was limited by the guy tracking me the whole distance. So I was somewhat limited. But that's sort of the story. With respect to the hybrid car, one of the first questions that people ask me when I bought the first one in the year 2000, first question I'd get was, 'Ya what about the power battery? Isn't there a problem with that?' Now the end result of that is, we still use that 10 year old car. It's our second car. It still has the same power battery. It just goes on. It keeps going and going and going. I had asked that question to the Toyota people in those early days and they said, 'We think it will last the life of the car.' Now, I think a traditional definition of the life of a car is about 12 years. I thought, well, they were being quite honest with me. I was a knowledgeable person and a knowledgeable customer. They said, 'We don't know. We haven't tested it. We think it will last the life of the car.' Well, we have a 10 year old Prius and it still cranks along quite well with its old power battery. During that time, I happened to be a downhill skier, mostly at Mount Wachusett and I'd have the only Prius, of course, parking at the parking lot of the ski area, Mount Wachusett.

Participant #11: You have to look at the tax structures. They had taxed luxury cars so that the people who wanted luxury cars switched to SUVs. So it's not that gas was cheap, it was that to buy the old symbolic cars became prohibitively expensive. And now there is this new class that gets out of the tax structure that can give you the symbol, right? I think now the tax structure is switching to the hybrids, when really it should be switching to the electric car or the air cars or a billion of the other energy efficient- the biodiesel or whatever because they are better. However, our symbolic imagination is about the hybrids right now because that is very sexy right now. And it is affordable. It's more affordable than a lot of the other options- like I was pricing the Tesla air cars. I was leaping because I really want one those, right? So to divorce it from the cultural aspect I think is dangerous. Also the monetary aspect- the tax structure, it's not just now much does it cost to buy the Prius, but what in the tax structure allows that to succeed and other things to fail, an Because there are massive shifts that are happening all the time.

Participant #10: In terms of the power, um, I did think about going from four wheel drive to front wheel drive, but it wasn't that big of a part of my decision. But the Prius, the Ford Fusion- they have as much power as small, midsize or compact cars. It didn't play that much into my decision at all. Oh I forgot- my first long ride in a Prius was in the Rocky Mountains. And um, that was with somebody who was looking at the Honda Civic when it was the Civic Hybrid or the Prius. And it was a little noisy going up the steep hills, but we got up them and it wasn't a problem. I was quite impressed with every aspect of that vehicle. That probably kind of laid the ground work. So I was thinking, "yeah I'm gunna, I could drive a hybrid for sure."

Participant #12: I like to go downhill with the Prius. The Prius itself taught me how to drive. My driving habits are actually geared to the Prius. Going downhill I put it into engine braking which happens to optimize the amount of energy going back into the battery and I often will go as far as I can with just the electric motor. With the original 2001, which we bought in 2000, Prius- it could go with the electric motor alone only 30mph. Beyond that the gasoline engine would turn on. With the 2004 model I could go, for short distance, at 40mph with only the electric motor alone. So it taught me- I don't think I could drive a regular- I've been driving these too long. I'm tuned into these things. Ford, Ford Motor got started with hybrids by being licensed to Toyota. Toyota sold them something like 70 patents, but not on their newest design. They would only sell Ford the original design so all of Ford's early hybrids were Toyota designs.

Participant #8: Anyway the power is OK. I went from a 6 cylinder which has a lot of power. The Prius is not very good in the snow, at all. I dislike that. Coming from, I lived in upper Wisconsin, and I bought an SUV and I bought it because I needed to be able to get around. It made sense there to have four wheel drive. You know now that I live in the Worcester area I don't really need that, but I have to say when I get into an old stick shift, you know, my friend's mini cooper, I feel like I'm in a sports car. I miss the sort of stick shift and the ability to control a car and really zip around. Its different and I think I drive much more reasonably than I did before. I have changed my driving habits, probably for the safer side, but I still love getting in a friend's car and zipping around in a stick shift every once and a while and it's so much fun.

Participant #7: We drive regularly into New Hampshire, so we are a little accustomed to snow and hills and things. It still works ok.

Participant #8: It works but it's not great.

Gove: Do you find your car- how is that in the snow?

Participant #10: I will admit with pure gasoline cars in the past, I would always prefer to drive after the street has been plowed.

Gove: Right, right.

Participant #10: I never enjoyed driving in snow. So that hasn't changed. But with the front wheel drive on the Prius, it is pretty decent.

Gove: Ok

Participant #11: I learned to drive in upstate New York and so I have probably less fear in driving in snow than I should. I find that you do lose a little bit in the Prius in certain weather conditions.

Gove: In terms of handling?

Participant #12: In terms of handling- yeah, you can, especially up hills. You can lose a little bit of handling. But as long as you are aware of that and account for that circumstance, I don't- it very rarely affects where I chose to go. And on the rare occasion I chose to take my wife's car for some specific purpose in some specific climate situation that's a luxury we have in being a two car family. But in terms of the question of power, that goes right back to what Jennifer was saying about the symbolic issue.

Gove: Its cosmetic.

Participant #12: I'm not going to pass a sports car going uphill at 80mph in the Rocky Mountains, nor do I wish to.

Participant #10: Does the turbo diesel, do you feel the lack of power in that?

Participant #9: In the snow? Or just- I mean it has an incredible amount of power on the dry pavement.

Participant #10: It's very torquey, its very torquey.

Participant #9: It's crazy, but it's not fantastic in the snow either. Again, it's a small-er car than I'm used to driving. It's a lighter car than I'm used to driving. And I did specifically not choose a Prius for that reason because I knew I had to drive through snow and I had heard from friends who live in western Mass who had Prius cars. They said, you know, they take out the Subaru in the winter, you know, because where we live its unpaved roads and deep snow and you can't drive a, they say, that you can't drive a Prius.

Participant #11: I can't get out of my driveway sometimes. If I have 6 inches I have to shovel a path. I mean I have a plow that comes, but he comes at the end of the storm. I have a hundred foot driveway and I can't get out.

Participant #9: I had to be able to get to work.

Participant #8: I used to be able to get out with my SUV, now I gotta get the shovel out.

Gove: Well I guess the point of that is just that having that hybrid, even though you have to deal with the snow, it's worth having the hybrid.

Participant #8: It is, I'm not going to go back to getting, I mean I might consider getting a diesel when biodiesel becomes more available where, you know, where I get my gas and live. Right now that's not as readily available as, you know, Greenfield wherever you are.

Participant #9: Yeah, there is a whole plant out there.

Gove: Really?

Participant #8: It's possible that because- you are saying you get better gas mileage. I mean really when it comes down to it, that's what makes most sense to me is getting the best gas mileage. Electric cars- I drive too much, I drive too far. I'm going to get into my car on Friday and I'm going to drive to Maryland. An electric plug in is probably not going to work for that unless there is high speed plug in stations that they are talking about building. They are not there yet. Maybe someday when they are there, I would consider that, but then I'm relying on the coal infrastructure of our electric system in the United States, so I don't know. There are a lot of decisions to be made.

Participant #9: The problem with diesel is that, you know, they say that this is a better- these models, these 2009 models, are a better clean burn. And they also say that if you use a biodiesel mix it encapsulates a lot of the particulate matter in a way that you don't get with a regular diesel mix, but I haven't seen the data on it either, so I don't know if it's really just spewing particulates, and um, yes getting good mileage but what's the, you know, emission from the vehicle. I'm not sold or sure about that yet, so...

Participant #8: But if there is a hybrid convertible that comes out I'd tell you. That's when the sort of culture, what is Jennifer talking about, you know, status. I want a convertible, but there is no hybrid convertible yet.

Gove: From the recent research we have done, you know what Jennifer is talking about, you know, is very real, um, pretty interesting stuff. Any closing arguments, anything...

Participant #7: I think, something that is sort of critical maybe. Everything, you know, I've heard about ethanol vs. fossil fuels, alcohol fuels vs. gasoline. I was negative on those things because I kept hearing that if you turn corn into ethanol and use that somebody is going to lose food or the price of food goes up. And, uh, there were arguments of that, and also that it took more energy, uh, to create ethanol from corn than the energy you finally get from ethanol as a fuel. It didn't seem to make a lot of sense. I'd listened to a lecture, I've forgotten the guy's name, I'd listened to a lecture about three weeks ago and I'm beginning to change my mind. He was pointing out that much of the data we have been bombarded with concerning ethanol is incorrect. That these claims are not correct, that in fact ethanol can be made- and he showed data which indicated that, you know, you can increase the amount of food from corn even though you may be using the corn for ethanol. All kinds of things that I thought were true may not be true. And he was putting on a very strong pitch for us to get off the bandwagon- better than a hybrid could do. Get away from imported oil. He was concerned very much for the fact that China and Saudi Arabia and all these other people are getting our money, and with our

money they are slowly buying into us and buying our country through companies and things. They are beginning to gain major components of our own US companies. So he was, he was talking from the point of view of a long range problem. What is, you know, what is it going to do to the freedom of this nation if suddenly we find Saudi Arabia owns 30% of our companies or China owns another 30%. But his argument was that ethanol really is quite good and all he is asking for is that the American companies build all gasoline engines flex engines, so they can use either ethanol, 85% ethanol/ 15% gasoline. We all use 10% ethanol now , 90% gasoline. He was arguing, "Look for the price of creating flex engines, and put 1 pump 1 tank 1 pump at each gas station with 85% ethanol/15% gasoline." And he feels that that will build it. The speaker had very high praise for hybrids, but he pointed out what we know. It costs \$3-4-5000 more to buy a hybrid compared to a comparable gasoline car and he's pointing out that to build flex engines will cost only another \$2-300. And so he has a strong argument and I am wedded to electric cars of hybrid cars and I was opposed to alcohol fuels thinking that what I was reading was fully correct and apparently it wasn't. So I'm about to do some really deep study to what he was saying and he may be right, and therefore keep in mind that perhaps the future of the company might very well depend on our willingness to pay a couple hundred for a flex engine, try out the 85% ethanol/ 15% gas and see how we like it. And he is pretty certain that if we took that 1 brief step we could break the back of Saudi Arabia and break the back of China with respect to the great, powerful impact they are beginning to have on this country. And, uh, I'm one of the guys who helped win World War II and I'm one of the guys who helped win the Cold War. I provide, I helped to build the minuteman into continental ballistic missile when I was in industry and I'm a patriot and, uh, if you tell me if there is some way to break the back of Saudi Arabia and OPEC and break the back of China- I'm in favor of that. So I'm about to launch into a study into alcohol fuels and flex engines- see if I can understand what they are doing and maybe I have another 15 years, I'm not sure. My father lived to be 100- maybe I've got 15 years, maybe, in which to, uh, still has some impact. But I'm about to move in that direction. So it's just a comment that I think should be said. Look at the idea of flex engines and alcohol as the fuel- 85% ethanol being the fuel. And a couple hundred bucks compared to a few thousand. I love hybrids and I love electric vehicles, but there are some real problems. Every pure electric vehicle is very expensive because of the batteries. Every plug in is very expensive because of the batteries. So if there's a way to think in terms of pulling away from OPEC and pulling away from China and if it happens to use a different technology, I don't care. I'm for it because my concern is for this country.

Gove: Right my head is exact- this weekend I was talking to my grandfather, he's 86- the exact same, you know, conversation. Was that he fought in World War II and he has resentment towards companies, towards other countries who are gaining, uh you know, power. Things he, you know, fought for is relapsing, is what he was saying. So that is a very interesting point. Did you want to say something?

Participant #12: That's a tough act to follow man, I don't know, um. I mean the only point, the very limited point that I wanted to make, but I think an important one. In the same way Jennifer talked about, um, the symbolic power of the hybrid car. When you talk about the American people wanting SUVs. -well where does that come from? In part that is manufactured by advertising appeal to consumers, and so part of the equation here is, you now, what gets advertised, and presented, and marketed, and product placed in TV shows and films to consumers as things to be desired. And I think that is a really important part of the equation that we haven't touched on yet.

Gove: Consumer demand is a reflection of media.

Participant #8: And I guess the other side of it too is how the sort of environmental side, how many people are choosing it for the environmental reason, and I just read, I think in the Boston Globe yesterday, that in 2000-2009 people haven't changed their recycling habits at all in Massachusetts.

Gove: Right, its flat lined.

Participant #8: Its flat lined so are there certain people, and we've reached the threshold of those people who are environmental in buying cloth diapers and hybrid cars. You know where, is there a threshold, or can we convert other people to buy more environmentally friendly products in general. So there's a bigger question I think, it's beyond the car, it's a lifestyle.

Gove: Which is becoming a huge issue with you know, but that's another whole discussion. Ok great, I mean I don't want to hold you guys up. The deal was from 4 to 5.

Focus Group Transcript for: People who bought a new car (non-hybrid) in the past year.

8. How much, on average do you drive a year? What is your daily commute like?
City/Highway/Off-road.

Participant 1 - I drive my car, my primary car was bought, probably only about 10,000 miles a year. My commute is 20 miles round trip, mostly freeway.

Participant #2 - I mostly don't commute to work and I have only had my car for about two months so I don't have any idea of how many miles I commute a year but when I travel home and stuff, which is generally once a week, its mostly back roads.

Participant #3 - I probably put on, it's our main family car, and we've had it for three months and have put on about 4,000 miles already so probably about 13,000 to 14,000 a year. I commute to work probably about 30 miles round-trip, about 25 minutes. It's

back roads and most of the driving I do is non highway which makes things with fuel a little more difficult. Large trips are all highway but the general use is small roads.

Participant #4 - I think, well I get my oil changed twice a year so, probably around three to four thousand miles. I would say. I do a lot of driving but it's all city, [my commute] has gone from 5 minutes to one and a half minutes of driving, so I just walk sometimes. But the majority is when I start driving in the summer and that gets me to about 4,000 miles a year.

Participant #5 - And I went from 1800 feet, when I used to walk to work, to actually the car that we bought, my wife is the primary user and she puts about 20,000 miles just for commuting to work, and bring the kids back and forth to school. We bought the car at the end of March last year and we've got over 35,000 miles on already. But a little more than half of it is the commute, the majority of its highway.

9. How much do you spend on gas per week/month/year?

Participant #1 - about \$50 a week for me.

Participant #2 - I think mine's about \$35 a week.

Participant #3 - I probably fill up once a week and it's about \$40-45 a week.

Participant #4 - I fill up every two weeks and it's around \$35.

Participant #5 - It's about \$40 a week.

10. What type of car did you buy? If there is a comparable hybrid on the market, did you consider purchasing it?

Participant #1 – well I bought a 2003 Audi S8, because you know the was only 300 of them made and I wanted to get one but I did actually look at a Honda Accord Hybrid, which surprisingly has similar performance, but they quit making that as well. But there is no hybrid right now that has the performance that these S8's have.

Participant #2 - I bought a 2004 RAV4. I looked at some hybrid but I really want four wheel drive and something bigger, slightly bigger car than my Chevy Aveo, which I used to have, so I didn't really look into hybrids that much.

Participant #3 - I bought the 2010 Mazda CX9. I wanted a hybrid originally, but the only one that I really compared it to was the Toyota Highlander Hybrid but it was just priced out for us, but I would have liked to get one but for our needs there weren't a lot of choices. It was just too highly priced and there weren't that many of them available either.

Participant #4 - I bought a 2009 Honda CR-V. I don't think I really looked at hybrids, the only one I think I might have looked was the Honda Accord. The reason I got it honestly was the place I used to live, you needed a donkey to get up there, it was all hills and I actually need four wheel drive. I didn't want an SUV, like I was driving the Mayflower, so I wanted something a little bit smaller.

Participant #5- we got a 2009 Toyota Highlander and I wanted a hybrid. We needed an SUV because of the terrain and hills that we have to commute. I wanted the, I looked at the Highlander Hybrid but it was about \$10,000 more and I looked at what it would take to pay that back, the return on the investment, and it wouldn't work, I would get rid of the car before it paid off.

11. How much did the car cost? How much was the last car purchased? When did you purchase it and did you ever consider buying a hybrid then?

Participant 1 - I always buy collectible, used cars. So I paid on eBay 15,700 dollars for this car, but it sold for 82,000, when it was new. And then my car previous to that, sold for 51,000, but I bought it for 11,000. So I always buy them when and I look around for used when they are a few years old.

Participant #2 - I bought my car for 25,500 and my previous car for I think 12,500.

Participant #3 - Oh gosh, I don't even remember. I don't know. I will give you an approximate cause it gets so who remembers what you finalized. I don't remember. I think we bought it for about 29,000. I think that's about what it was. And the previous car we had a Subaru Outback that I loved, but it was too small, was umm I think maybe 24,000. They weren't that different. I needed a third row. Oh yeah. And I looked at the Tribeca, but there third row was a joke.

Participant #4 - So, I bought my 1997 used Saturn for around 8,000 dollars. It was the best investment ever. I love my Saturn. It was a standard. It had a ton of miles on it. It exploded and well I basically drove it to the ground. So the Honda was I think 24,000. I think right on the dot.

Participant #5 - I loved my Saturn. I had two of them. I loved them. Umm I believe we paid about 27,000 and the last one we had a Honda Odyssey that I think was 23,000.

12. How long do you keep your car? How did you go about getting rid of it? Was it junk, did you sell it, did you trade it in when you got a new car?

Participant 1 - I still have the first car I ever bought new, I bought a new 1973. It is still in my garage. So it has 300,000 miles on it. So I don't normally get rid of cars. The car I got previously to this one, I sold it with 210,000 miles. I had it for about ten years. I bought it used. And I will keep this one for at least ten years. Uh normally if it is a German car I will go for at least 200,000 miles before I sell them. And I do sell them, at that point. But my Fiat I will keep forever. It won't be sold.

Participant #2 - Um previously I had bought a lot of crappy, used cars, so it was probably under three years, but I did trade in my car with this purchase and when I bought my Chevy Aveo I also traded in the car I had. And previous to that, I just drove them until they died completely and then just gave them away for parts.

Participant #3 - I would say I keep cars for average five to seven years. We've sold, we had prior to, you know we've sold a car on our own, we have traded in, and we have done kind of everything. But um this last one, the Subaru, we traded in for the Mazda.

Participant #4 - I kind of used to keep them until they went into the ground. Umm, but it is kind of my idea, I basically, I don't look to upgrade my car, unless I absolutely have to because of the terrain. I am not really in it for status or anything. I just need to move.

Participant #5 - We used to have a, it's an American made, vans that I didn't want to go over 100,000, so it, we wanted them longer, but we had been burned on it once, so we avoided that. When we got the Honda, we intended to be able to go quite a ways, and a year ago the amount of miles we had put on the car and the incentives that they were offering for buying a new car basically we could lower our payment and get a new car that was six years newer. It wasn't a clunker, but we did trade it in. And there wasn't anything wrong with it per say, it was getting up in miles. But it was more driven by the state of the economy and trying to help the economy by making a purchase and it worked for us because as long as we could keep our payment the same we were willing to do it and I think it actually saved us a few dollars.

Participant #3 - I don't know if you are going to ask this, but I would say to, it is a hard question circumstantially why we have kept our cars. I would have kept, we have moved every car because we had one kid and then we had two kids. So safety became a factor, space became a factor, so I think it is just circumstances. You know? The idea with this new one according to my husband is that we are staying in it for a long time. So, but I think, as our lives have changed, I also used to live and work residentially, so I never needed a car. And then I got a new job where I had to commute. So it has always been circumstantial for us, getting a new or changing a car.

13. What factors go into making a decision to buy a car, hybrid or not?

- g. How did the interior size/comfort factor affect your decision?
- h. How does output performance (acceleration) affect your decision?
- i. How does your lifestyle/geographic location affect your decision?
 - iii. For instance, do you need a truck for towing purposes, 4WD for winter reasons?

Participant #3 - The number one for us is safety, since this was the car that I was going to be driving with both of our children. So safety was number one, without question, size and

ability to transport strollers and pack and plays and the amount of stuff that two children under four require. We needed trunk space. So for this one with two car seats and I have parents that are local so we are often traveling with them. That is why finding a third row was also ...we wouldn't have bought a new car without a third row. So we wanted to be able to have the car seats and other people come in the car, have me get in the back seat with the kids...so it was all about functionality with being a parent with children...so safety, functionality, and then from there probably went price, to style, and what factors in for me honestly was the people at the car place. I won't buy a car from someone who I think is a jerk. There were some places that I ruled out because I didn't like their attitude. I was like I don't need to give you my money, and I left. That is way down on the list because there is always a million dealers and dealerships if you don't like the people. That is what I would say for me.

Participant 1 - When it came down to our....the reasons why we bought another car is because my 220,000 mile previous Audi...it was time to sell it. 220,000 miles is my limit – not 100,000. Although seriously now we have four cars. The lowest mileage one of any of them is 110,000. That is what my S8 has. I have with 300 and one with 200, and one with 120, and my wife's Audi has 120,000. But at any rate, when it came down to my purchase, it was between three cars and I am very, very particular about what I get. You know I'm an engineer, an automotive engineer, and I gotta have the right stuff and so it was either gonna be an exotic, affordable car which is the Audi S8, which is incredibly exotic. It was appealing to me because there are only 100 of them made that were that color....300 altogether and it had the performance that I was looking for, but I was also intrigued by small comedic cars so I came close to some others. The second car in consideration was the super charged cooper...the little mini cooper because I had one of those...the real one when I was in college, and the third again was the four year Accord v6 hybrid, and they were all about the same price and the used price range that I am doing it. The answer came down to....my wife said you're not buying the mini because we needed a full size car and we cannot have two small cars, and so ultimately I said oh yeah because I wanted to buy the S8. And so I think that the performance and exotic nature of a car really appeal to me and but one of the trips for my wife was that we wanted something that would be comfortable for people to travel and obviously you can't in her two-seater or my 300,000 Fiat, our Toyota appliance that we keep.

Participant #2 - Previous to this car, I just bought cars to get me from one place to another and...but I spent most of my life living at the bottom of a hill so I could not drive up it in the snow, so I wanted a four wheel drive car. I mostly bought this one because my brother did all of the research. He told me that that's the care to buy...and I did actually leave a dealership because they were a jerk and drove all of the way to Wellesley and

paid \$2000.00 and they were the nicest people that I ever met....and so I could afford it finally for the first time in my life.

Participant #4 - I think the factors to be honest I look right at the price, to start off with, because I know my budget, so I eliminate more cars then I try to research. Living in Worcester and New England I've come to the rationalization that I'm just tired of being the best maneuver of a two wheel drive car in the snow and hills. So I do need that flexibility. And then I prefer to drive a standard. Only because it just feels like I am actually driving, and it saves gas. but unfortunately my ex wife at the time couldn't...I was like a valet parker I would move it because she didn't know how to drive it so one of my motivations was to get an automatic so whoever had the car that I was behind could just take it and leave and go to work. But that's what it comes down to. And I am not one of those people that goes into a dealership and is looking to barter I want to go in and out within 2 hours and leave.

Participant #5 - Again hill wise we needed a four wheel drive, that was essential. Size wise I would have preferred something smaller but I had a small Saturn that I used for commuting so we couldn't get a second small car we needed something larger to be able to haul the kids and their friends and all that around and then be able to fill it up to get kids moved to college...try to do it in one trip. And then the price and also spent a lot of time with consumer reports...going through checking the repair histories and the reliability and all that...the different models.

14. Was there anything about hybrid's that may have had a critical influence on you decision making? If you were at one point looking at a hybrid was there anything that critically influenced your decision to not get one?

Participant 1 - I have a problem theoretically with hybrids and that the research shows of course it's just a stop gap measure. The real reason for buying them would be the tax incentives and a few things like this because when it gets right down to it the technology is not the way we should be encouraging people right now actually. On the other hand the tax advantages make it significant...and so I would much rather buy something which is a longer term look at fuel economy...certainly there are a lot better options than hybrids, hybrids are just a stop gap so I'm not too excited about them unless they happen to perform well and happen to give the tax incentives to make them pay off before you end up throwing it away.

Participant #2 - I did a project in a grad class where I always thought great things about hybrids and then you realize like they never really pay off I the long run so other than

the feel good nature of it...which in that case I would just move closer and drive it less, which has a similar thing. And then when I want to and need to drive in the snow I get...I can get where ever I want...so...

Participant #3 - Yeah as I said I originally wanted the Toyota highlander hybrid that was my initial thought but um A.) It ended up being too small in the middle row, I couldn't fit myself and two car seats and then really it just came down to price. And that there wasn't really another option in a hybrid that fit our needs and the cost was really the main thing, we were just...it was just too priced out for us and as we talked about it, it would have taken us too long to make that difference back.

Participant #4 - Um, I never really looked at them. I guess to be kind of vain I thought they looked like golf carts. Not that I care that much about it. But I got to admit...it looked flimsy, I'll put it that way, it didn't look safe I guess you could say. But the other thing is, is that I'm all pro environment but to me it kind of felt like I could just get a car that does well on gas and I'm helping the environment...then having to use something else...so spending less...driving less...conserving gas...is kind of the same and like she just said it was out of my price range...beyond that...

Participant #5 - Pretty much price range. We would have been prepared to buy the hybrid highlander but just...we knew we wanted the highlander...we couldn't afford the hybrid.

Participant 1 - If you look at the highlander especially the Lexus SUV hybrid all the studies show that is a 200,000 mile break point for cost. In fact I think on the Lexus...the 478...you never come out ahead on it...so there's a little hype.

Alyssa- And my last question is does the reputation of the car's manufacturing company affect your decision? Like if it's foreign or American?

Participant 1 – I definitely don't mind. The ad that most automotive makers will spout on is you buy American if you want the biggest and best value, you buy Japanese if you want something which is the automobile appliance, you go there, you push a button and it goes, push a button it stops. Then you buy German cars if you're an engineer because the German cars have a certain engineering exotic nature that appeals to me and so I'll almost buy a car in spite of the fact that it's important and it doesn't rate well because I don't see eye to eye on some of the features that are important so I think I do base reputation quite a bit about cars and if you can afford something which meets your standards then I guess I would say I influenced it...

Alyssa – I bought a Toyota because I heard they last a long time and I did buy it on the day they stopped selling round fours as well so, mine was made in Japan, it's all good. I had a

Volkswagen before which lasted forever and then I owned a Chevy which was only 3 years old and it sucked. I put more money into it than I ever paid... I definitely have a bad view of American cars after driving them.

Participant #3 – We looked at, um, we narrowed it down as the Mazda CX9 and the Chevy Traverse and the GMC Acadia, that's what we narrowed it down to, and we were definitely influenced by the fact that Mazda, we were happy with that company and we heard good things. The problems that the companies were having like looking at GMC and looking at Chevy, it definitely gave us some pause and with all things made equal it may not have mattered but there were a bunch of little factors and that definitely swayed us a little bit. We had heard good things. My father is a Mazda guy. We're a Mazda family so we've had good luck with them, we've all enjoyed them and we've heard some things going into a GMC or going into a Chevy. When you mention it to some people they give you a (insert negative sound) but when you go to a Mazda people go "oh I love my Mazda we've heard good things and are happy with the company" and so...

Participant #5 – My father was a Dodge and Chrysler guy all the way through, and so was I. I guess I tried to live the, support American car but I've come to find out the Honda engine is made in Kentucky so... I really wasn't too influenced too much but I guess it was just by word of mouth, the people that I saw that owned Hondas had them for a very long time and seemed to have no problems with them so...

Participant 1- The last Chrysler product that we had which was the minivan was made in Canada and had a Japanese engine, so it's a very good car.

Participant #4 – We had a Honda and would have preferred to have gone with the Honda SUV but it didn't have 4 wheel drive and prior to that all our vans had been American, and our previous new cars had been American. We just had a used Honda Accord several years back, but this was our first Toyota and between its ratings and all that we felt comfortable. I don't know how I feel about Toyota now but...

Participant 1- You shouldn't worry about that. They'll be right on top again.

Alyssa- Hi, I'm Alyssa.

Participant #6- I'm (Says name) sorry I'm late.

Alyssa- would you like to tell us about your car?

Participant #6- Yeah. In January I bought a Hyundai 2008. It came off of a lease. My wife and I have a pop up tent trailer and I would have loved to get a hybrid but you can't get a hybrid that will tow a trailer, and this trailer is not a heavy trailer, it's about 1500 pounds without

any load in it. I could have gotten a Subaru I think it's an outback with a 6 cylinder engine but it takes premium gas. I looked on consumer reports, I looked on Edmunds, I also read comments on people who bought Hyundai's and I found out that they were built in Alabama and that made me feel better about it. We had a Ford station wagon for 8 years and had about 137000 miles on it and it was starting to, every other month I was going into the garage with it but up until 100,000 miles on it had been a great car and I was very interested in the Ford Fusion but again, 4 cylinder so... this car is 6 cylinder and it also gets very good gas mileage, not so much in the city. It gets about 18 miles to the gallon, but on the highway I actually get over 30 miles to the gallon. The quality from that from what I've read is that they're right up there with, I wanna hesitate to say Toyota but, Toyota and Honda and some other cars. The market hasn't quite recognized it yet but the price on them is a little bit lower but I think now that with the problems that Toyota are having people are actually looking at these Hyundai's because their quality is very good and I've been satisfied with them. Again I would love to be able to buy a hybrid car if we were going to buy another car that we weren't going to tow I probably would have gotten a 4 cylinder and a hybrid. Note the one question I haven't thought of is what to tow with a Toyota Prius, if you buy it used, what the life cycle going to like. The battery that you have there. And I think in the next couple of years, that technology is gonna change quite a bit. I was hoping I could wait another couple of years to buy a car but, it's just this car was not gonna hold out for me.

Alyssa- Do you do a lot of driving?

Participant #6- Not really a lot, but enough that, you know I drive back and forth from work, it's about 8 to 10 miles or so but I'm driving around the state or down to Connecticut to visit relatives and then when we go on vacation we usually drive so...

Mike- How much do you put on for mileage per year?

Participant #6- about 15000 or so.

Alyssa- Did you trade in your last car to get this car?

Participant #6- No I gave it to my son.

Mike - That brought up an interesting thing. What do your cars take for gas? I know that my WRX takes premium. I have to add 91-93 in it, for octane.

Participant 1- 93

Alyssa - Regular. Whatever, I'm cheep.

Participant #5 - Regular

Participant #2 - Regular

Participant #4 - Regular

Mike - You and I take the hit.

Participant 1 - I don't drive much.

Mike - I think that's all we have. Anything else interesting facts or figures about hybrids that anyone has? Concerns or issues?

Participant 1: I think that the whole, once we go to plug in hybrids the equation does change a bit. Because when we don't have to put gasoline to charge the battery through the inefficient reciprocating engine and through inefficient generators and inefficient transmissions when you're actually able to use the central grid to charge your batteries then it becomes much more attractive. But again hybrids by their nature, are never going to be as efficient as a purely direct motivator whether it be a high tech diesel or pure batteries, so I just... it bothers me when I personally people promoting hybrids as if they were the last bit when it's just a stop gap technology. Stop gap technology.

Alyssa - I would agree with what Participant #1 said that I think there's a lot of hype, and everyone's feeling this need and this pressure to do something but when you really look into it, it doesn't seem to have the results that I think you were expecting. Like you think, well I'm gonna get a hybrid, like that was my initial thought and then I looked into it and I did the research and looked at everything... well it's not quite there yet, I agree. So...

Participant 1- It's funny, one of the reasons why Honda said why they were unsuccessful and dropped the Accord Hybrid was because it didn't look hybrid enough. It looked just exactly like a regular Honda Accord, in fact even the industry panel just had one additional extra gauge. And yet car and driver would say it's the only hybrid they would ever recommend because it did get remarkable gas at 38 miles per gallon on the highway and 30 miles per gallon in town, and yet it's the fastest Honda ever sold, faster than the S2000 because it had a 240 horse power V6 plus about another 130 horse power hybrid and so it was faster than my S8, 0-60mph.

Alyssa - But then were they just not selling?

Participant 1 - Nope. They dropped after 2... 3 years.

Alyssa - Cause I didn't even know they made one.

Participant 1- It was also the worst looking Honda accord for a long time. It didn't improve by doing that. And it's funny because a lot people buy hybrids because they look like golf carts.

It is proven that there is a certain niche that likes to buy something that looks the part and then there's these other people that say "ahh make it look like a normal car and maybe I'll buy it" but those people aren't buying them. Because the Toyota Camery looks like a regular car and most of the Lexus hybrids look just like regular cars and they're not selling like hot cakes.

Participant #6 - But the Prius...

Participant 1 - The Prius and the new Honda insight...

Participant #6 - The Prius has a definite look...

Participant 1 - Right.

Participant #6 - ... And people can recognize it from way off... in the distance...

Participant #4 - My last two cents it became too much of a status symbol of hey I'm doing my part, I have a hybrid sticker in the back. Great, you get a parking space, and you get a tax reduction, what about me? I can't afford it. Congratulations. And, I come to find out that they can sit outside with their car running, I turn mine off and I'm doing my part so...

Participant 1 - The new Subaru has got a partially zero emission vehicle which is a hybrid. They simply have a bigger battery and a bigger starter and they shut off the engine every time you come to start so therefore it qualifies for the partial zero emissions as electric backup for the air conditioner, all this kind of stuff, but it's not a hybrid and so there's lots of ways you know and the problem with, as we all know the problem with throttled engines, gas engines is that they're just woefully inefficient at partial throttle, and that's the reason why hybrids are so much better in town cause they shut the engine off. But a diesel is remarkably efficient idly. Remarkably. The high performance 8 series Audi's with the diesel 310 horse power turbo diesels get 40 miles per gallon in a car that does 170 180 miles per hour. But they're not legal to sell in America yet. That particular diesel engine.

Participant #6 - I had a Volkswagen diesel during 1980 I think it was, and I had it for... I bought it brand new and I had it for 110,000 miles, but in the winter, if it was really cold you had to plug it in... did they solve that kind of problem or...

Participant 1 - No, but you should understand that it's a battery, in themselves are way down in production in the cold by the tube. You asked our associate who has a Prius what gas mileage he gets in the winter time and it's not any better than a Toyota Corolla's. Yeah it's like 38 miles per gallon. That's what it gets in the winter time. And 38 maybe 40 is good because battery capacity goes down as a factor of temperature as well and then of course you have to heat up the fluids for the heater and keep the engine running almost all the

time anyway, and so hybrids get much less gas mileage in winter time than they do during summer time.

Participant #3 - See I don't think the average person would ever know that.

Participant 1 - Yeah.

Participant #3 - That's why they come to WPI and talk to people here. But like I would never know that except for you just said that, I would never have thought of that...

Participant 1 - But all of our gas mileage goes down during winter time too cause they reconfigure the fuel, and most people and regular cars get 5-10% less gas mileage too cause they put the ethanol and stuff in there. Which is, you know, reconfigures the fuel to the point where you don't get the same...

Participant #3 - And now what would you say to me that for my IQP that for me the environment and the effect on it definitely matters and that if they get to something that I'm thinking about, especially with children and their future, but it's not, and maybe it's selfish of me, not affordable yet because at the same time I have to feed and clothe and educate my children so I think that if technology is looking where to go and wants to appeal to people, it needs to be at a point where it's cost effective in that the average person who's gonna use it can afford it and that it's worth it and that I think it does make a difference that I do want to you know help the environment whenever I can you know as long as it makes some sense and I don't think it's quite there yet given all the other factors. Hopefully someday.

Participant 1 - Yeah. I mean with all things being equal, you would take a car that was more environmentally friendly, that's the economic decision for a lot of folks which is what it is, and you mentioned safety as well which is interesting as well because the 8 series Audi was the first car in America to sell with 5 star protection in all quadrants, but it was very, very unaffordable, and so I can tell myself about this car that it was very safe. That's why I bought it.

Participant #5 - I was discouraged, because I really wanted a hybrid but... the numbers wouldn't work, the upfront cost and the payback... and I really wanted it but it's just...

Participant 1 - And if you think carefully on it from the engineering details it's got to be more expensive, you know in fact the argument was that Toyota was losing money on Prius' for quite some time. And even though they were priced above and so if you look at the technology, there's a lot of technology in it to get what they got and it is expensive technology, and so if they were to sell it for the same prices then someone's a cost error here cause there's no reason why they should sell it for the same price. You have an entirely

nother system in there. And the engine itself is a much more expensive engine to build than a regular internal combustion engine. It's not even running on auto cycle it's running on a miller cycle. It's a different cycle and it requires different valve manipulation and lots of things so it's expensive and engine, let alone batteries, chargers and electronic controllers .

Mike - And the materials that go into them allow the hybrid to pull out more aluminum and copper and stuff which is way more expensive to get from raw material and to produce than you know steel and most other ice's and stuff...

Participant 1 - And odd thing is if you were to take a car, if you were to take a Prius shell , use a Prius low rolling resistance tires, use a Prius high efficiency electric power steering and all the other stuff, and you put in the ergonomics of a Prius, and then you put in an internal combusting engine which gives you the same performance as the people in hybrids are willing to take, it will exceed the gas mileage of the hybrid, but no one is willing to take a 12 second 0-60 time. No one is willing to have a car you can't pull a trailer with. No one's willing to do that unless they have this feel good thing about it being a hybrid. If you were to sell a car with a Prius performance to the American public and it wasn't a hybrid, you couldn't sell it. Why would I want something that couldn't get out of its own way? And the hybrids that do perform well like again the Toyota cruiser and these... the Lexus, the payback doesn't work out, because they need to have a big enough engine to provide the performance you want. And then you're hauling all the extra weight in batteries and all this other stuff so it doesn't make sense. The number 1 factor ever to predict the fuel economy of a vehicle is its weight. Not its driveline, not whether it's a 4,6 or 8 cylinder or even if it's a hybrid, you look at its weight that's the number 1 predictor for fuel economy. And when you start putting in 500 pound batteries, you gotta go with aluminum chassis, you gotta go with super light weight wheels, you gotta go with all these sorts of things.

Mike - And then it'll cost more to make and manufacture and get the raw materials...

Participant 1 - Aluminum is, we talked about the carbon footprint for making aluminum, aluminum is really expensive to make, luckily it's recyclable. Aluminum is really easy to recycle but man, aluminum plants is what eat up all the power. Of course, my car is totally aluminum.

Mike - It's almost three times as much as steel manufacturing ...

Participant 1 - But you can recycle it with very little cost, and that's the good thing about it...

Participant #6 - Are you gonna share your results with us?

Alyssa - I think so.

Mike - I think after we finish.

Participant #3 - What's your IQP, like you're just looking at the difference between why one group chose to buy one vs. the other?

Mike - Well it's more of, are they up to the hype.

Participant #3 - Oh.

Mike - So we're doing analyzing how they're made and the processes from start to finish. Getting rid of the NiCad batteries vs. other batteries and how much goes into manufacturing and then also the consumer side. What causes people to buy them. If they're just looking to get one for the hype or for this reason or that. So that was the purpose for this area of study.

Participant #6 - Just to reiterate what some people have said is, I try to buy cars that are coming off of a lease, I don't like buying a brand new car. And there definitely is a cost factor in terms of looking at these hybrids vs. you know, another car. I got a lot more money in terms of another car that I got vs. what I could have gotten in a hybrid. Like this gentleman was saying I think that the hybrid is kind of like, you know, what it's going to be 2 years from now, that technology is gonna be very different and I'm just not willing to pay an extra 5 to 7000 dollars for a hybrid.

Alyssa - Thank you guys very much for participating...

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