Environmental and Social Issues Concerned with Hybrid Cars

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Introduction

Since the dawn of the modern era, consumption and distribution of energy has quickly become mankind's highest priority. However, the continued apathetic attitude that was initially taken toward energy and its side effects can no longer be used. A new more environmentally friendly source of energy has to be utilized in order to fulfill our own needs otherwise we self-destruction while relying on non-renewable oil based methods. In the last few decades two new technologies have emerged; the development and implementation of Hybrid Electric Vehicles (HEVs) and more recently the Plug-in Hybrid Electric Vehicles (PHEVs). These emerging technologies may make it possible for the United States to adapt these technologies on a larger scale to reduce harmful emissions and cut our dependence on foreign oil dramatically. However, the future of the technologies will heavily depend on the everyday American consumer's willingness to forgo the 'tried and true' combustion engine for the infantile technologies of the HEV and PHEV.

With the introduction and continued popularity of HEVs and as well as the recent hype over the PHEVs, the future of transportation in the United States is on the brink of change. This project has objectives relevant to the aforementioned HEVs and PHEVs. First, verify if independence of foreign oil is truly a possibility and how to accomplish this feat. Second, identify the major motivators for the American consumers who purchase these vehicles and how that can be used to increase the sales of HEVs and PHEVs respectively. The third and last objective is to determine the future impact of the all electric vehicle (EV).

Earlier civilizations relied on a number of power sources such as water to turn wheels, to run mills, fire to heat water and create steam, or windmills to turn grinding stones. Since roughly

the 17th century various forms of oil have been used, such as kerosene, as fuel for lanterns. Even into the 18th, 19th, and early 20th centuries whales were hunted for their blubber which could be converted into oil among other things. In the more recent years with the invention of the combustion engine, which has not only increased the shear amount of oil consumed annually but also drastically augmented our dependence upon it in our daily lives. Our oil 'addiction' has lead us to the realization that our usage has its limits, not only does the environment suffer adverse effects because of its use but our society is so dependent upon that if it were suddenly removed, most of modern society would cease to function properly if it all. Without a reasonable alternative this fate is all too possible and this has caused huge concerns over how, on a large scale, we can change our consumption habits and create a cleaner energy for our use.

Hybrid cars have come a long way in the past 20 years, but most people are unaware they have been around since the mid 1800s. The early electric vehicles at the turn of the 20th century were expensive, problematic and not very powerful. Given certain weather conditions or too steep a hill the electric vehicle of yesteryear was simply unable to perform up to our expectations. With the introduction of the Ford Model T, a revolution in vehicles was made. The Model T was cheaper and more powerful and was made relatively simplistic, it also ran on a then abundant source of gasoline, and the United States could meet its own internal demand enough so that it actually exported its excess to European countries such as France and Britain. Ultimately, the Model T made the early EVs defunct and as such fell off the radar until events like the 1973 oil crisis and 1979 energy crisis where the electric technologies were eventually reconsidered.

The first electric car is claimed to have been built between 1832 and 1893 by Robert Anderson of Scotland. From then until the late 1800s, when they became efficient enough to use as taxi cabs in England, the cars were heavy, slow and impractical. Modern batteries development in the early 1900s pushed the development of more efficient, reliable, and practical electric cars in that period. The Hybrid came about in 1900 in Belgium, when a small gasoline engine was paired with an electric motor. During normal operation the electric motor charged onboard batteries, but during acceleration and uphill stints the electric motor provided a boost to the 3.5 horsepower motor. In 1905 H Piper patented the first hybrid in America. In 1910 a hybrid truck was manufactured in Pennsylvania, which used a 4 cylinder to power a generator and an electric motor. 1916 saw the production of hybrid cars claiming 35 mph and 48 mpg, however this also saw the end of the electric car era due to the advances in combustion engine technology. Until the mid to late 1960s, there is little commercial advance in hybrid or electric cars.

As early as the mid 1960s congress recognized the importance of reducing emissions to improve air quality, and that the use of electric cars was a possible way to achieve this. In the late 60s and early 70s the oil embargo sparked a renewed interest in hybrid and electric vehicles. A few hybrids were released by major manufacturers, but most were underpowered and small. More importantly, three scientists patented the first modern hybrid system in 1971, much of which closely resemble the hybrids of today. The next big push from congress come s with the 1976 Electric and Hybrid Vehicle Research, Development, and Demonstration Act which encouraged the commercial improvement of electric motors and other hybrid components.

The research lead toward new developments and new vehicle released in the United States, including all electrics from GM and Honda, even including an electric truck, the Chevrolet S-10. These vehicles reached a niche group, but still did not receive the sales numbers

to be feasible. This all changed with the release of the Toyota Prius in Japan in 1997. With 18000 sold in the first year it becomes the first economically feasible hybrid produced. With its import to the united stated in 2000 and the release of Hondas Insight to the US in 1999 the hybrid age had finally arrived.

However, PHEVs and HEVs are not without limitations, which are mainly caused by the current state of battery technology. With future research and development into creating improvements on battery technology many of the limitations will be greatly reduced if not expunged completely. We have come a long way since the nickel and lead batteries of the 1960s, more recently the Nickel Metal Hydride and Lithium Ion battery technologies have been developed and successfully implemented. Today's HEVs are a far cry from the small four horse power models of the 1800s, modern HEVs include the same power, acceleration, comfort, and price of their counterpart conventional cars (CVs), but can reach upwards of 50 miles per gallon depending on the model.

The importance of this project is not simply limited toward the contemporary state of the automotive industry. It is also a generalized overview of what to expect in the near future concerning the status of the global automotive market and the respective technologies of which it encompasses. Valuable insight given into possible implications of using the aforementioned technologies and how they may affect the US and its ability to reach its energy goals all while becoming both more energy independent and environmentally conscious. Projections for the future give an overall view of what is to come, including future vehicles available for purchase, their collective impact on the populace, and how that technology can be built upon and advanced. It is essentially a forecast of the automotive industry from both a national and global level. Based on the examination of information and projection from qualified data sources, it

gives as full as possible understanding to the reader of where, when, and how the automotive industry is now and in the foreseeable future.

Literature Review

The emissions caused by the use of motor vehicles in the United States have resulted in a significant amount of environmental and health related damage. In 2005 alone, these emissions caused an estimated $56 billion in just in health and other nonclimate-related damages, according to a study done by the National Research Council (2009), and worsen environmental problems such as higher levels of greenhouse gases and the overuse of fossil fuels. Plug-in hybrid vehicles (PHEV) present a cleaner alternative to traditional vehicles, as they use less oil and have lower emissions. PHEVs also use less oil than standard hybrid electric vehicles (HEV), and at first glance seem to have lower emissions than HEVs. However, according to a study by the Electric Power Research Institute (2007), the additional emissions from power plants caused by plugging in PHEVs can cause them to have higher emissions than HEVs in some cases.

In areas which have clean methods of energy production, such as wind and solar power, PHEVs can have lower emissions than HEVs. When the power for PHEVs is provided by more pollutant sources such as coal however, PHEVs will generate higher emissions than HEVs, even though they use less oil, according to the Electric Power Research Institute (2007). A study by Kalhammer, Kamath, Duvall, Alexander, & Jungers (2009) found similar results, stating that a PHEV with a range of 40 miles would have approximately half the emissions of a HEV if it were powered by a carbon-free energy source, but would have higher emissions if 50% of its electric power was generated by coal. As coal accounts for approximately half of the energy production in the United States, there is much room for improvement, as noted by the National Research Council (2009) and the Electric Power Research Institute (2007).

Consumer interest in PHEVs has been on the rise in the past several years. A survey conducted in 2007 found that only 25% of consumers were interested in purchasing a PHEV as their next vehicle (Harris, 2007), while a survey conducted in 2009 found that 48% of consumers were interested in purchasing a PHEV as their next vehicle (Pike Research, 2009). While some consumers have been concerned with issues such as battery life and increased load on the electrical grid, most of these issues have been found to be small. A study by Peterson, Apt, & Whitacrea (2009) found that it required over 5300 battery cycles of 95% discharge to decrease a PHEV's battery to 80% of its initial capacity. The concerns over the overloading of the electric grid have also been found to be unneeded as well. A study by Pike Research (2009) found that by 2015, the introduction of PHEVs would have only added a ½% increase to the grid load in the United States. A similar study in the UK by Ricardo plc. (2009) found that PHEVs would only add a 2% increase to the electric grid load.

A study by Curtin, Shrago and Mikkelsen (2009) found that for many consumers, helping lower foreign oil importation (54%) and emissions (15%) resulting from vehicle usage in the United States were the main advantages of owning a PHEV. The savings consumers would get from PHEVs was the greatest advantage to only 31% of those surveyed, which would suggest that consumers place higher importance on the environmental advantages of PHEVs. However, the relation between the premiums of PHEVs compared to the willingness of consumers to purchase them still show that most still place high importance on the difference in lifetime cost of a PHEV compared to a standard vehicle. While the average probability of a consumer purchasing a PHEV with a $2,500 premium was 46%, this number dropped to 30% when the premium was increased to $5,000, and dropped again to 14% when the premium was increased

to $10,000, according to the survey by Curtin, Shrago, & Mikkelsen (2009). To achieve a large market penetration, this premium must be kept as low as possible.

While studies on the effects of PHEVs have generally been favorable, there has been significant debate on whether PHEVs will be cost effective. A recent study by the National Research Council (2010) found it unlikely that PHEVs with a range of 40 miles would be cost effective until 2040. A similarly pessimistic report from the Boston Consulting Group (2010) found that consumers who purchased PHEVs with a range of approximately 40 miles were unlikely to break even on the additional cost of purchase. Another study from Carnegie Mellon University (2008) found the while PHEVs with a range of under 40 miles could be cost effective in certain situations, PHEVs with a range of 40 miles or more would not be cost effective due to the cost of the battery.

However, many other studies and sources stand in opposition to these claims. In particular, GM VP Jon Lauckner (2009) has claimed that the figures used for the cost of the batteries in these studies mentioned previously were far above the current price to produce the batteries. With the announcement that the Volt will sell in the low $30,000 range, significantly lower than the $18,000 premium assumed in the study by the Boston Consulting Group (2010), it may be that these reports are too conservative in their estimates of the price of PHEVs. Other lower estimates of battery cost have also come from the Argonne National Laboratory (2009) and from a study by Kalhammer, Kamath, Duvall, Alexander, and Jungers (EPRI, 2009). A study from the Electrification Coalition (2009) also found that PHEVs with a 40 mile range are already cost effective with the current subsidies. In the end, whether or not PHEVs are cost effective will depend on future innovations in battery technology, government regulations and subsidies, and upon the price of gasoline.

Various groups have attempted to make predictions about future market penetration of PHEVs, and have formed multiple scenarios based on consumer wants, gas prices, the cost of PHEVs, and the subsidies given by the government. As study by Sullivan, Salmeen, & Simon (2009) predicts that PHEVs will have a 2% market penetration in the United States by 2020, with an average of 4-5% of new vehicle sales if current subsidies are left in place. Without these subsidies, however, the market penetration in 2020 drops to an abysmal <1%. While this simulation cannot perfectly predict factors such as future gas prices, its findings correspond to the drastic drop in consumers' willingness to purchase PHEVs when the premium was significantly raised. The factor of gas prices is an important one, and as the price of gasoline rises, so does the willingness of consumers to purchase PHEVs. Some executives in the automobile industry, as well as others, have suggested an increased gasoline tax solely for the purpose of pressuring consumers into purchasing vehicles with better fuel economy (Reuters, 2009). However, most consumers have expressed resistance to such measures (Rasmussen, 2009), and politicians have been hesitant to enact such taxes. As the majority of these studies assumed the Chevy Volt would cost approximately $40,000 along with similar PHEVs, the recent announcement that the Chevy Volt will sell in the low $30,000 range makes it likely that the actual market penetration of PHEVs to be higher than these estimates.

Methodology

This Interactive Qualifying Project pursued and researched information pertaining to both Hybrid Vehicles (HEV) and Plug-In Hybrid Vehicles (PHEV). Data collection consisted of several methods including, questionnaires, articles, books, reports, and interviews. In the aforementioned methods only specific information will be drawn out to emphasize the main focuses of our research which include but are not limited to economic and global impacts, the power implications, and the future models of the PHEVs and HEVs.

The questionnaire is for distribution on a large scale of people. The group distributed it to a group of roughly 100 people and received back 60. They were given to college students in Worcester, MA at the college campuses of Worcester Polytechnic Institute and Assumption College. Questionnaires were also distributed at the town hall of Bourne, MA which were given out to the public and returned at their own convenience. However, it was designed with the ability to be used on much larger groups of people anywhere from hundreds or thousands of participants. The idea was to ask a small portion of direct questions with a short section on demographics for grouping analysis. The questionnaire was distributed to a wide variety of people varying in age, gender, occupation, and level of education. This was done in order to attempt a public opinion which could be further subdivided into smaller groups to characterize perceptions of HEVs and PHEVs based on these groupings. No personal information was asked such as level of income in order to keep the questionnaire anonymous and hopefully obtain more honest answers from the participants. Our results from the questionnaire that we distributed were then compared with larger national surveys conducted by larger organizations, such as Pike

Research and the Electric Power Research Institute (EPRI), in order to find some consensus between our data and others.

Interviews were conducted in with current hybrid owners who are in the Worcester Polytechnic Institute Police Department's database. A total of ten interviewees were contacted via email and volunteered to cooperate with us in our study. Interviews were conducted in two person teams with the interviewee. Each team member took independent notes which would be shared when extracting information for use in the report. The two person team was also least likely to miss any vital information the interviewee may have stated and if one team member missed that it would be highly unlikely the second team member would have. Interviews lasted approximately fifteen minutes at the time and place of the interviewees choosing. Questions were asked in a mutual non-pressure or suggestive manner in order to get more honest answers from the interviewees themselves.

To help predict consumer purchases of HEVs in the future several models were developed. Using the Texas Instruments TI-89 calculator model's regression functions over a select data set. The data set was the total sales of all HEVs from 2000 to 2008 and was collected from various sources and yearly announcements of sales from automotive manufacturers such as General Motors, Toyota, and Honda. Eventually, four models were developed from the data set each with a different behavior and mathematical function; the models followed an assumed behavior of exponential growth, cubic, quartic, or logistic. These were then plotted next to the actual values in sales. Each model also corresponds to a unique possible situation, for example in the quartic model shows if some key event allows for combustion vehicles or some other vehicle besides HEVs is introduced and quickly forces HEVs out of the market.

Articles were drawn from various sources both written and electronic via internet databases or other internet archives as well as blogs. These articles were examined for literary worth and then if selected were thoroughly inspected for usable information which could be included into one of the sections that we as a group wished to present. The article's author was also looked at to see if the article may have been written in any biased fashion. Included in this were the reports filed by EPRI on the current and future status of HEVs and PHEVs and just how effective they will be reducing polluting emissions and how taxing it will be on the current power grid nationwide. All articles used in the report were then placed in literary review.

Our ultimate goal will be to take our finalized data pool and organize it into our respective categories. Once that is completed the information will be put into a lengthy and detailed format and submitted for both private and public viewing.

Findings

Oil Independence

As a global economy which is largely dependent on oil, the price and origin of oil has a heavy bearing on many countries foreign policy. An interesting question arises from this, that is, what if we could be independent of all other countries oil? If not this then could we be independent of oil from the Middle East, and how would this affect our current policies? The first and most important question for us is: can this independence be accomplished through the use of hybrid and plug in hybrid cars? Let's look at some absolute best case scenarios to determine if it is even theoretically possible.

Table 1: US Oil Consumption

Total Barrels per day	19,498,000
Barrels per day Imported	11,114,000
Barrels Available Without OPEC	13,544,000
If None Imported	8,384,000
Amount Used for Other Products	5,654,420
Transportation non Gasoline	4,854,580

According to the Energy Information Administration (EIA) the United States imports just over 11.1 million barrels of oil per day, which amounts to 57% daily of our daily use. The other 43%, 8 million barrels per day, we make ourselves. At face value, energy independence seems perfectly plausible. The average gas mileage of the current fleet of vehicles on the road in the United States is only 17 miles per gallon (mpg), so increasing the current fleet average by the

prescribed 57% results in a necessary mileage of only 39.5 mpg. This mileage is available today. Most small cars like the Toyota Carrola, the Honda Fit and civic, the Ford Focus. Nearly every major car manufacturer has a model which performs to this standard. This makes President Obama's cash for clunkers program seems like a great idea; however the fleet's fuel economy is only part of the battle.

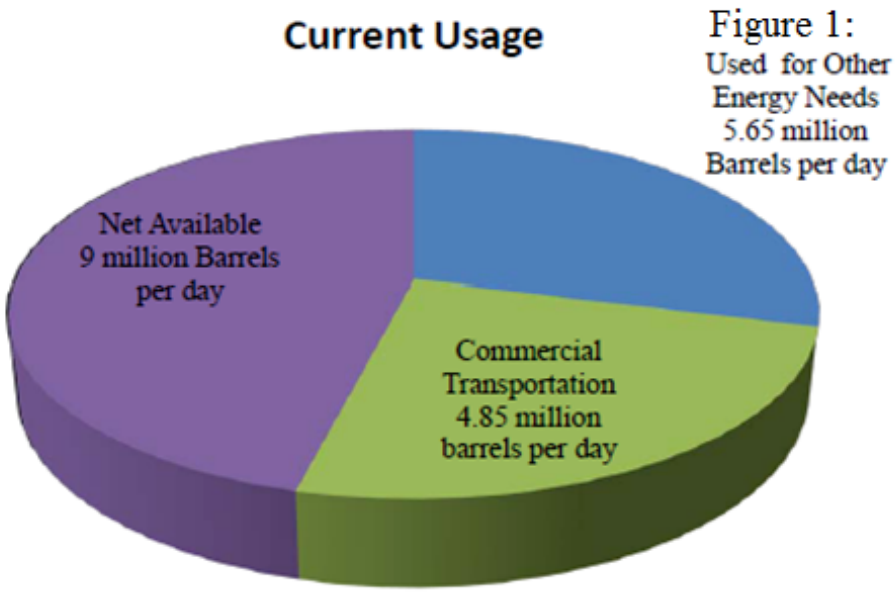


Figure 1:

First, only 71% of the oil used in the United States is used for transportation, therefore 29%, in the best case scenario, is unchanged by increased gas mileage. With this new information, 29% of the 43% which is independently produced goes to other products and other energy production. This leaves only 13% of the oil produced in this country for transportation vehicle usage, which unfortunately, means we need to drive just as far on this new 13% as we did on the previous 71%.

It is easier at this point to start talking about fuel usage in terms of barrels of oil per day. Right now we use 19,498,000 barrels per day (bbl/day). Of these, as mentioned above, 57% or 11,100,000 bbl/day are imported, which leaves us with only 43%, 8,348,000 bbl/day to use in

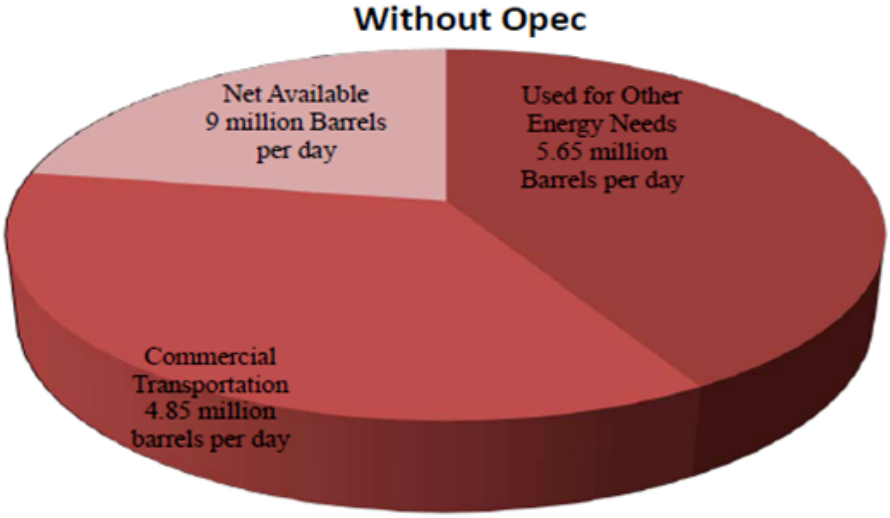
our vehicles. Of our total 19.5 million barrels 29%, or 5,654,420 bbl/day, are used in the making power and other petroleum based products like plastics. Some simple subtraction tells us that we now only have 2,729,000 bbl/day available for the transportation sector. This works out to a fleet average fuel economy of just over 92.8 mpg, and it gets worse.

Of the 71% which was used for transportation, only 65 % is are used in gasoline production. In barrels per day this means that of the 13.8 million bbl/day used in transportation industry, 4.85 million bbl/day are unchanged and used in large trucks, boats, trains and planes. Adding this to the 5.6 million bbl/day used for power production and we come up with just over 10.2 million bbl/day which will be unchanged by more fuel efficient cars. The bottom line here is that we produce about 8.3 million bbl/day and if only the consumed gasoline sector is changed, we need 10.5 million bbl/day to run the other sectors. Hybrid cars can only touch a small portion of crude oil imports, and even if they got infinite gas mileage it is still not enough to declare energy independence as a country.

Let us consider oil independence from the Organization of Petroleum Exporting Countries (OPEC). OPEC sends the US 5,954,000 bbl/day. Eliminating this cuts our daily supply by 30.5%. Combine this with the 30% which we need for power production and other products, and we are down to an available 39.5% of the original 71% available for vehicle use. Translated to barrels per day this means we still have 13.5 million barrels per day from non OPEC nations. Take out the 10.5 million bbl/day which will remain unchanged, and we still have 3 million barrels to run our cars on. This seems like a lot, and is certainly better than the -2 million we had in the previous section, but is it enough? Previously we used 8.98 million barrels at 17mpg, in order to survive on the new 3 million we need to increase that number to about 50.89 mpg. If everyone were to own a hybrid or a plug in hybrid, this number does not seem too far off. If in

the future we have cars which are capable of obtaining even higher fuel economies, say roughly 100 mpg, only approximately one half of the registered fleet would need to own them to obtain the same numbers.

Figure 2:



Now let us consider another possible scenario, a 50% reduction in our oil consumption. In order to do this let us only consider the transportation sector and leave our other uses for oil constant. The total amount of barrels per day we use is 19.5 million, so with our new scenario we only have 9.75 million barrels to use. Besides transportation the other uses for oil which we are holding constant are 5.655 million bbl/day. Meaning we need to use only 4.095 million barrels to sustain our transportation sector. Currently, we use 13.845 million barrels which is a reduction of 70% in oil used for transportation. Currently the average mpg is roughly 17, in order to facilitate the total 50% oil reduction that number must be increased substantially to 57.48 mpg. This is certainly a reasonable number that higher end fuel efficiency cars of today can match or exceed. However, this also means that large transportation trucks, trains, and airplanes must all contribute to this new fleet mpg which would require a ‘hybridized’ version of each respective

transportation vehicle both on land and through the air which would be to minimize their oil use as well. This is also reasonable since the new HEV and PHEV systems should also be easily adaptable to other configurations for use in trains, planes and other large commercial shipping vehicles. (EIA)

Environmental Effects

Global warming has numerous effects the planet. The polar ice caps are melting at an increasing rate causing the seas to rise. If this continues at the rate it is going millions of people around the world will be left homeless due to flooding. More deaths due to disease will be unavoidable due to higher toxin levels in the air; also there is a larger range of disease carrying insects such as mosquitoes. The change in climate will also drastically affect many plants and food crops needed for human survival. Some have also predicted that global warming will be the end of our planet due to war between countries for the remaining goods after the climate causes them to become scarce.

Automobiles also produce other harmful gases other than carbon dioxide. Some of these include Nitrogen Oxides, Volatile Organic Compounds, volatile matter and carbon monoxide. All of these can lead to ground level smog that damages the respiratory system and kills plant life. Some environmental effects from automobiles will remain a problem even if automobiles were all electric. First, the power plants would still be releasing large amounts of greenhouse gases into the atmosphere during electricity generation to charge the cars. Less obvious are other effects such as runoff of from oils, washer fluid, and salt; as well as brake dust. Also another overlooked effect on the environment is the large amount of energy expended in the actual manufacturing process of the vehicles.

Electric vehicles may not have any direct emissions, however they are not emissions free either. Some even believe that electric vehicles are no better than traditional fossil fueled vehicles for the environment. Although there are no gases emitted from a tail pipe of an electric vehicle, a significant amount of pollutants are emitted in the generation of electricity to charge the car's batteries. Almost fifty percent of the United States electricity is still produced by

burning coal. According to Energy Information Administration, one gallon of gasoline produces 19.564 pounds of carbon dioxide. If an average gasoline powered vehicle in the United States gets 17 miles per gallon, then it would emit 115 pounds of carbon dioxide per 100 miles driven. A plug in electric vehicle requires about 30 kilowatt hours of electricity to cover a 100 mile distance. One kilowatt hour of electricity produces 1.55 pounds of carbon dioxide to generate, meaning an electric vehicle will produce about 45.5 pounds of carbon dioxide per 100 miles driven. Looking at these numbers one can see that an electric vehicle has much less of a negative impact on the environment than a fossil fueled vehicle. Keep in mind that the values for gasoline vehicles do not include emissions from pumping the oil or transferring it to filling stations.

On the other hand there are some downfalls of plug in electric vehicles and hybrids. The first is the amount of energy that is required to manufacture the vehicles' battery packs. Some studies suggest that 1.5 times the energy is required to manufacture a hybrid/electric vehicle when compared to their gasoline counter parts due to the added energy needed to produce the battery packs. It has not been determined just how much energy is required to produce the batteries; however some researchers believe that the energy required is enough to offset the decreased emissions of the vehicles, putting them on the same level as traditional cars.

Another major concern with hybrid and electric vehicles is in the recycling of the vehicles battery packs. Most batteries in the automotive market are made from lead, nickel, or lithium. When batteries are disposed of improperly these metals can be detrimental to the environment. Lead and nickel sitting in a landfill can cause pollution to the groundwater causing acid rain and making it unsafe for drinking and also harmful to plant life. Both are also know to be carcinogens, causing disease and respiratory irritation in humans. According to a study done

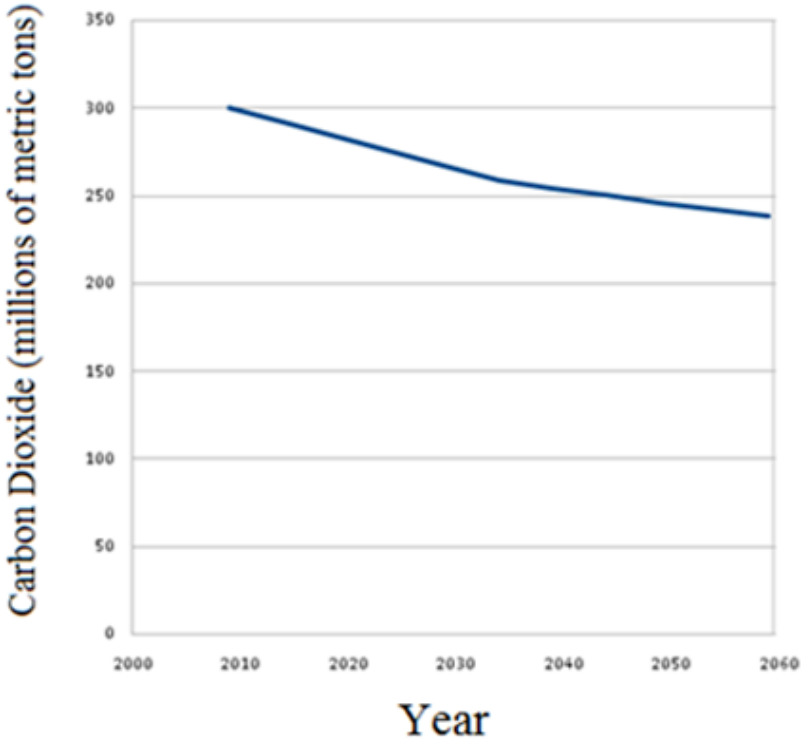
by Environmental Defense the more popular lithium ion batteries found in most hybrids and electric vehicles are not as toxic as their lead and nickel counterparts, but still have negative effects on the environment. Automakers such as General Motors and Toyota claim that their battery packs are 100% recyclable, however it is expensive to do so. Some companies are offering incentives in order to promote the recycling of the batteries. For example Toyota offers a $200 stipend and even provides a number to call printed on the battery itself. Even with these incentives there is no way to guarantee that owners will in fact recycle the batteries; leaving the window open for batteries to end up in the landfills causing further destruction of the environment.

Switching over to hybrid vehicles can make a difference in the impact on global warming. For every gallon of gasoline burned, 20 pounds of carbon dioxide is produced. This means that our cars and trucks alone are producing 300 million metric tons of carbon dioxide gas every year. Carbon dioxide is the greenhouse gas most responsible for global warming. When inhaled it restricts oxygen to the brain, cause respiratory problems, and has been known to cause cancer. The gas also reacts with the air causing acid rain and ozone.

By increasing the average gas mileage by five miles per gallon the United States would save 1.5 million barrels of oil per day decreasing carbon dioxide emissions by 960 million pounds every day. Over the course of a year that is billions of pounds of carbon dioxide that is no longer being expelled into the air. This would not be enough to stop it completely, or reverse its effects, but it would certainly slow down pollution effects by at most 3 or 4 % thus marginally increasing some regional air quality over the course of a decade. However, this would have a fraction of a percent change in global air quality due to increased oil usage in some of the rapidly industrializing third world countries of today and also in other countries who have not adopted

the policies of cutting down on green house gas emissions. While automobiles do contribute greatly to the Earth's environmental decay, they only play a fractional role. In order to bring global warming to a standstill, countries all over the globe we would be required to implement new eco friendly modes of transportation, drastically reduce energy consumption, and find cleaner methods of disposing of waste (EPA).

Figure 3
Carbon Reduction



The projected carbon dioxide reduction in million metric tons over the next 50 years based on normal hybrid emissions and the projected hybrid fleet.

Government Policies

Since the release of the first mass-produced hybrid vehicles the government has been doing everything possible to be involved and regulate the purchasing of HEVs and PHEVs. The first generation of hybrids such as the Prius and the Honda Insight, had extremely large tax rebates and credits that were given our nation to increase the popularity. The United States government has always viewed hybrids as environmentally friendly alternatives to vehicles that run purely on gasoline.

Today President Obama has created the New Energy For America plan to change the way the United States uses energy. The plan includes a section on hybrid vehicles and plug-in hybrids (Appendix A). Soon the tax credits will end for the regular hybrid electric vehicles. Rebates have been given for theses automobiles for years. Now, due to the rapid rate of HEV sales the government has withdrawn its tax rebates on the HEV models, giving exclusive tax cuts on PHEV and EV models based on the total electric charge the battery pack can hold. Four billion dollars in tax credits to American automakers has been budgeted to update plants for the production of plug-in hybrid cars. Credits will be given to people purchasing plug-in hybrid vehicles. The projected cost of the upcoming Chevy Volt will be in the low thirty thousands. With the planned $7,500 tax credit for consumers who buy the early plug-ins, the vehicles will be in an affordable range. Also, the plan claims that half of all the cars purchased by the federal government will be plug-in hybrids or all-electric by 2012. *The New Energy for America* plan will be one of many steps taken to change our energy problems.

Vehicle Cost Calculator

The Rocky Mountain Institute developed a vehicle cost calculator, which compares the relative costs of two vehicles over a set period of time at a specific cost of gas per gallon with typical drives within a certain mile range. When comparing vehicles we used an average price of $2.61 per gallon and 10 years as the life of the car and 12,000 miles driven per year with the typical drive lasting only 40 miles or less. We found that many different models of the HEV and PHEV cost a large amount only during the initial purchase of the vehicle. While the Honda Civic only cost $14,810, the cost of the Chevy Volt was $35,068 however the lifetime cost of fuel for the Civic was $9,213 while the Volt was only $3,068.

A huge difference in emissions was notice however from CVs to HEVs and PHEVs. Where the Civic produced 44 tons of carbon dioxide the Volt and Prius only produced 21 tons and 27 tons respectively. The amount of oil used was also dramatically reduced, as was expected with the Civic using 112 barrels over 10 years while the Volt and Prius used 6 barrels and 69 barrels respectively. There was little variation between the PHEV and the Tesla Model S the highly acclaimed sports car battery electric vehicle (BEV), with only $366 difference in fuel cost over 10 years. The emissions were also very close, 20 tons of carbon dioxide emitted by the Tesla while 21 tons were produced by the Volt. The Tesla Model S also costs roughly $25,400 more just to buy. The only ‘real’ difference was the Volt used 6 barrels of oil while the Tesla used zero over the estimated lifetime of 10 years.

Figure 4 Two vehicles at the forefront of the US automotive front the HEV Ford Fusion (left) and the PHEV Chevy Volt (right)

The Ford motor company has recently revealed plans for its own version of the HEV called the 'Ford Fusion.' It will first appear on the market in the 2010 automobile model line. It has a reasonable initial cost of $27,625 which is about $2,652 more than the current Toyota Prius but less when compared to Chevy Volt's $32,000 price tag. The lifetime cost of the Fusion including fuel over a ten year period is roughly $38,357 versus the $30,919 and $35,068 lifetime cost of the Prius and Volt respectively. In addition, the Fusion does lag behind the competition in some aspects. Where the Prius uses 69 barrels of oil in a ten year period the Fusion will use 83. Also, the Fusion will produce roughly 35 tonnes of carbon dioxide compared to the Prius emissions level of 27 tonnes. Although it is comparable in price to other HEVs currently on the market it is already lagging behind some of the competition especially in its environmental 'green' aspects.

The last interesting result found was that the Toyota Prius outfitted with an additional battery pack to convert it into a PHEV was virtually identical to the Chevy Volt in almost every category. Although there is a catch, the additional batteries and the conversion has a rather expensive cost of installation, it's in the neighborhood of $10,000. However, this additional cost of conversion increases the total Prius lifetime cost over and beyond the Volt's. Therefore from

an economic standpoint, if you already have a HEV Prius its better to stick with that rather than convert it to the PHEV format, it is simply not worth it over the lifetime of the vehicle.

Taking into the consideration the federal tax break also can change the total cost of many of these vehicles. The baseline break is $2,500 and an additional amount per kilowatt hours on the electric battery within the vehicle. The Volt and both Tesla models qualify for the maximum tax break of $7,500 which lowers there lifetime cost of the Volt to $27,568 with only an initial purchasing price of $24,500.The Tesla models still remain relatively expensive for the average consumer with lifetime costs of the Model S at $53,541 and the Roadster at $112,052 and initial purchasing costs of $49,900 and $101,500 (Appendix H).

Table 2:

Car1/Car2	Price[$]	Lifetime Cost[$]	Lifetime Cost of Fuel[$]	Oil Used [barrels]	CO2 Emissions [tonnes]
Honda Civic/Toyota Prius (HEV)	14810/25000	26200/30919	9213/5684	112/69	44/27
Honda Civic/Chevy Volt (PHEV)	14810/32000	26200/35068	9213/3068	112/6	44/21
Honda Civic/Honda Insight (HEV)	14810/22500	26200/29227	9213/6516	112/79	44/31
Honda Civic/Toyota Prius (PHEV)	14810/37000	26200/37919	9213/2979	112/5	44/21
Honda Civic/ Ford Fushion (HEV)	14810/27625	26200/38357	9213/6850	112/83	48/35
Tesla Model S (BEV)/Chevy Volt	57400/32000	61041/35068	2702/3068	0/6	20/21
Tesla Roadster(BEV)/Chevy Volt	109000/32000	119552/35068	2027/3068	0/6	15/21
Honda Insight/Toyota Prius (PHEV)	22500/37000	29227/37919	6516/2979	79/5	31/21
Honda Insight/Toyota Prius	22500/25000	29227/30919	6516/5684	79/69	31/27
Honda Insight/Ford Fushion	22500/27625	29227/38357	6516/6850	79/83	31/35
Honda Insight/Chevy Volt	22500/32000	29227/35068	6516/3068	79/6	31/21
Toyota Prius (PHEV)/Chevy Volt	37000/32000	37919/35068	2979/3068	5/6	21/21
Ford Fusion/Chevy Volt	27625/32000	38357/35068	6850/3068	83/6	35/21
Toyota Prius/Chevy Volt	25000/32000	30919/35068	5684/3068	69/6	27/21

One thing to keep in mind is that these figures do not include any kind of kind deduction or look at other aspects of the vehicle which may contribute to the numbers discussed here. The calculator does not take into account any kind of external deduction. For instance, the HEV model is losing its tax break credentials and instead all PHEV models and EV models are having

a tax break of roughly $7,500. If this is taken into consideration for the overall lifetime cost of the vehicle it drops the figure dramatically. This would push the Volt's lifetime costs under both the Fusion and the Prius both of which are HEVs. It would even reduce the overall price below that of the Honda Civic which is an extremely common CV known for its relatively low price.

Another thing to consider is the size of the vehicles. The Volt was designed as a kind of electric sports car something that was environmentally friendly but did not look or perform like one would expect. As such it is light and small, perfect for high efficiency in both areas of fuel and emissions. The Prius was designed as a compact car aimed for the small family as such it is light and small, much like the Volt, and for the same reasons it is also highly efficient with both fuel and emissions. However, the Ford Fusion was designed as a mid-sized sedan and is expected to do for the mid size line what the Prius did for the compact line. (For a small list of vehicles and their respective attributes please see Appendix L)

International

In 2007, a total of 71.9 million new automobiles were sold worldwide: 22.9 million in Europe, 21.4 million in Asia-Pacific, 19.4 million in USA and Canada, 4.4 million in Latin America, 2.4 million in the Middle East and 1.4 million in Africa ("2008 Global Market Data Book", *Automotive News*, p.5). Not only is the United States moving forward with vehicle technology, but all over the world different countries are working to develop new technologies every day. These new advancements cause the automotive industry to constantly change from year to year.

Automobiles Sold (in 2007)		
Region	**Sold (in million)**	**Percent of Total**
Europe	**22.9**	**31.8%**
Asia-Pacific	**21.4**	**29.8%**
USA & Canada	**19.4**	**27%**
Latin America	**4.4**	**6.1%**
Middle East	**2.4**	**3.3%**
Africa	**1.4**	**1.9%**

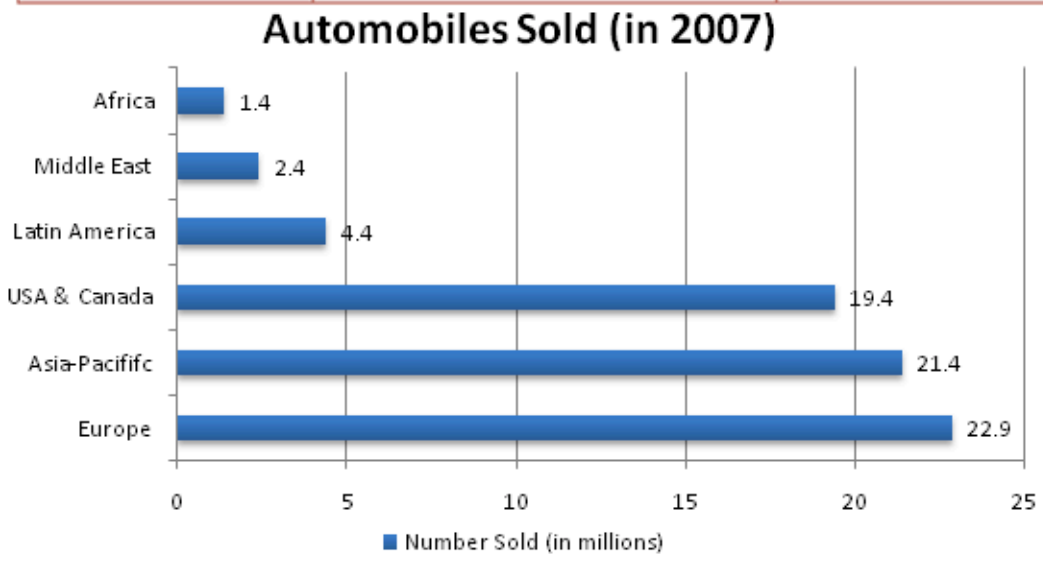


Figure 5: 2007 Automobile sales by region

Since Europe is at the top of the market for automobile sales, several countries stand out in technological advancements. A few leading automotive countries in Europe include:

Germany, Italy, and Denmark. Germany being is the powerhouse of Europe's automotive industry has dedicated a great deal effort to developing new technologies. Germany's current major manufacturers include Audi, BMW, Mercedes-Benz, Opel, Porsche, Smart, and Volkswagen. BMW has put funding into a number of the newer technologies including hydrogen-powered vehicles. However, not enough research has been conducted to make an impact on the automotive industry. Since Germany is known to be the powerhouse of Europe they should be a part of the top hybrid markets. It is extremely surprising that the Netherlands is ahead of Germany in the hybrid market. Italy is at the same level as Germany with new technology development. Both countries concentrate more on industry and production, and have very little focus on alternative research. Italy's major manufacturers are Fiat, Alfa Romeo, Ferrari, Maserati, and Lamborghini.

Figure 6: Top 5 global hybrid markets

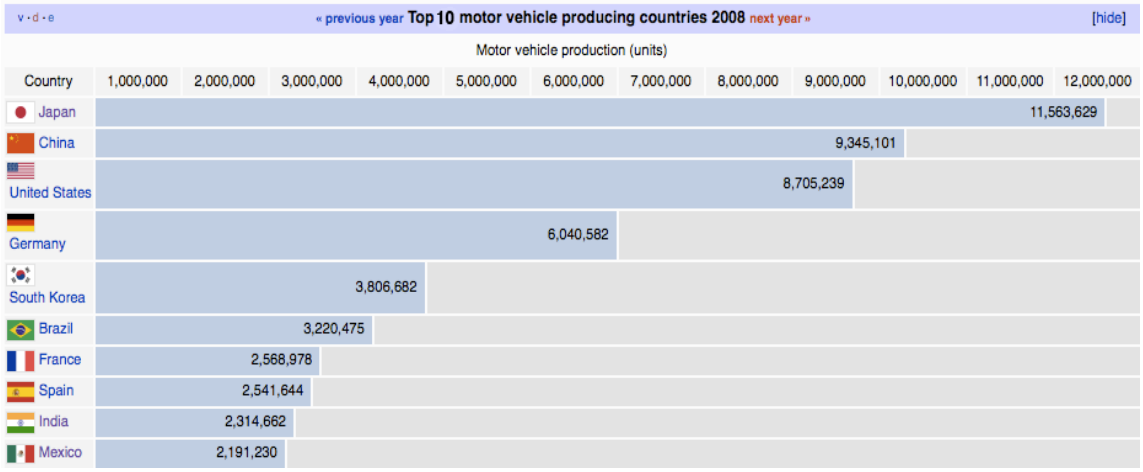
Denmark is a country that is not big on automotive sales, but the country has put considerable amount of money into funding the development of automobile technology. They are currently one of the world's leading countries in electric vehicle progress. An electric car-charging network is said to be in place by 2011. This network will have battery-swapping capabilities in addition to the charging stations. Automaker Renault-Nissan has agreed to work in

sync with Denmark to make the charging network operational. Also, to increase popularity with the electric system, the government will be offering a $40,000 tax break on each new electric car purchased. If the new electric vehicles are going to be as expensive as they are predicted to be, in the range of $60,000-$70,000, then with the tax break the vehicles would only cost between $20,000 and $30,000. This would appeal to many because in Denmark the cost for new automobiles is already extremely high.

In the Asian-pacific region there are many notable countries with automotive leaders working to develop vehicle technology. Countries such as Japan, China, India, and South Korea are working hard developing and testing new equipment. Japan being the world's leading country in the automotive industry has the money to spend on advancements. Major companies include Toyota, Honda, Nissan, Suzuki, Mazda, Mitsubishi, Subaru, Isuzu, Kawasaki, and Yamaha. Many would even argue that Toyota is currently at the head of the world's automotive industry. Toyota and Honda both have top selling hybrid-electric vehicles that improve each year. They are currently working to release their plug-in hybrid-electric vehicles. Nissan has developed technology to build all-electric vehicles that can be released to the consumers within the next few years.

China being the most populated country in the world builds and sells more vehicles than the United States every year. In the table comparing the top 10 populated countries in the world China has 19.64% of the world's population. However, China is second in automobile production behind Japan (shown in the table below). This is due to China not having many native automotive companies. Their biggest automotive companies are joint-venture manufacturers, which include: Toyota, Honda, Nissan, Suzuki, Mazda, Daihatsu, Fiat, Ford, General Motors, and Volkswagen. China has always encouraged the development of clean and fuel-efficient

vehicles to optimize their countries energy consumption. Their aim over the next few years is to increase the sales of the alternative fuel vehicles to account for 5% of China's vehicle sales. Working in tandem with the joint-manufacturers China expects to make an impact on battery-electric cars and plug-in hybrid vehicles over the next few years.



Rank	Country / Territory	Population	Date Last Updated	% of World Population
1	China[5]	1,335,910,000	February 18, 2010	19.64%
2	India	1,177,213,000	February 18, 2010	17.3%
3	United States	308,705,000	February 18, 2010	4.54%
4	Indonesia	231,369,500	July 2009	3.4%
5	Brazil	192,497,000	February 18, 2010	2.83%
6	Pakistan	168,764,000	February 18, 2010	2.48%
7	Bangladesh	162,221,000	2009	2.38%
8	Nigeria	154,729,000		2.27%
9	Russia	141,927,297	January 1, 2010	2.09%
10	Japan	127,470,000	January 1, 2010	1.87%

Figure 7: Top 10 vehicle producing countries (top) and 10 most populated countries (below)

India also being an extremely populated country has to develop new technologies in order to keep increasing their automotive industry. The country has more problems with transportation each year due to their high population. India just recently introduced their country-specific vehicle called the Nano. The Nano is made by the company Tata and is made to be an affordable vehicle for all people and families. The car only costs $2,000 and is said to get 61mpg. The car is

build similar to a motorcycle, with a small engine and very few features. The vehicle compares to HEV because of the small engine that comes equipped with the vehicle. The company also claims that the emissions will meet the low emission standards as well. The automobile is an excellent development that helps to lead to solving the countries transportation problem.

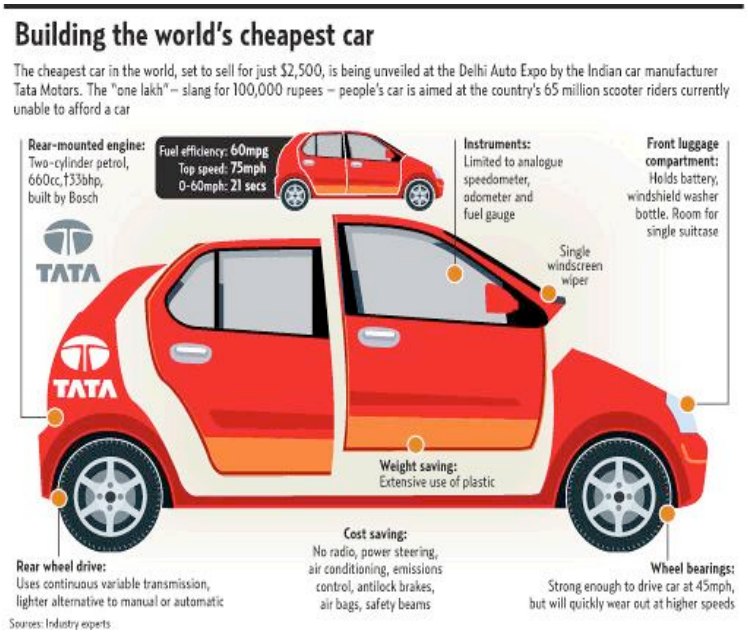


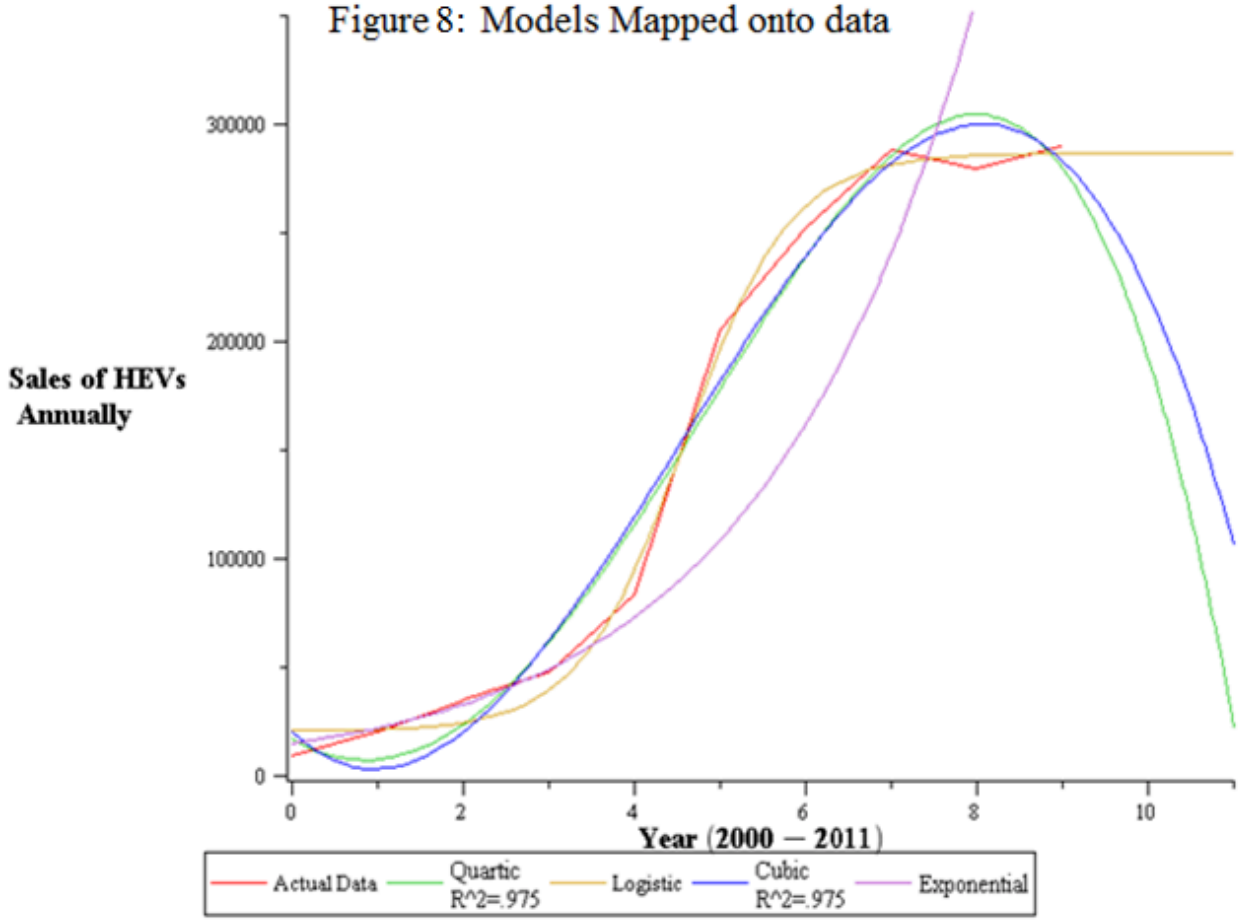
Figure 8: India's low emissions vehicle the Nano

Many countries other countries should begin to turn towards the development of new technologies in the next 5-10 years. Already there are many countries working with the United States to solve energy problems. There are currently countries with automotive technology that could even be placed ahead of our country.

Visual Representation

The graphs were developed from data of sales between 2000 and 2009 to predict the annual sales of HEVs (Appendix C). Due to the nature of the applied mathematical equation, each respective model has its own unique applicable situation. The exponential model was chosen to simulate the ideal growth scenario which has its apparent limitations in a real world situation, such as the 'limitless' growth that it projects over time. The quartic model, which is one of three that has a more accurate reading of the annual sales, predicts an abrupt drop in sales starting in roughly 1 or 2 years

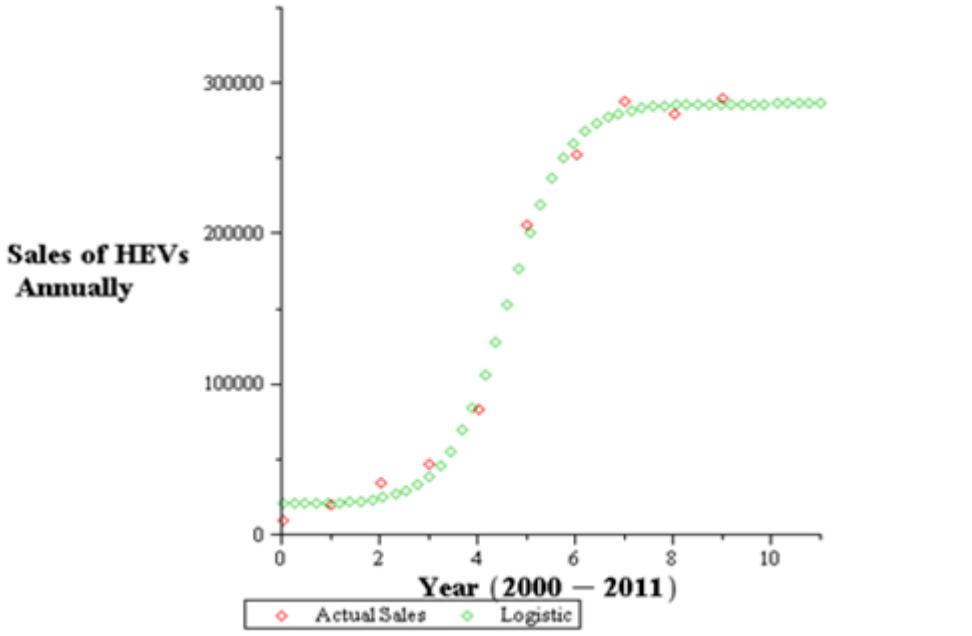
Figure 8: Models Mapped onto data



The last two models are the two we believe are the most likely to be correct in their predictions of the future sales are the cubic and logistic models. The cubic model has a high alignment factor however, due to the nature of the function, shows an increasingly steep decline of sales from 2008 onward which is also true of the quartic model. Seeing as how both the scenario presented in the quartic and cubic models is highly unlikely we believe to be the most accurate and consistent of the models used is the logistic model.

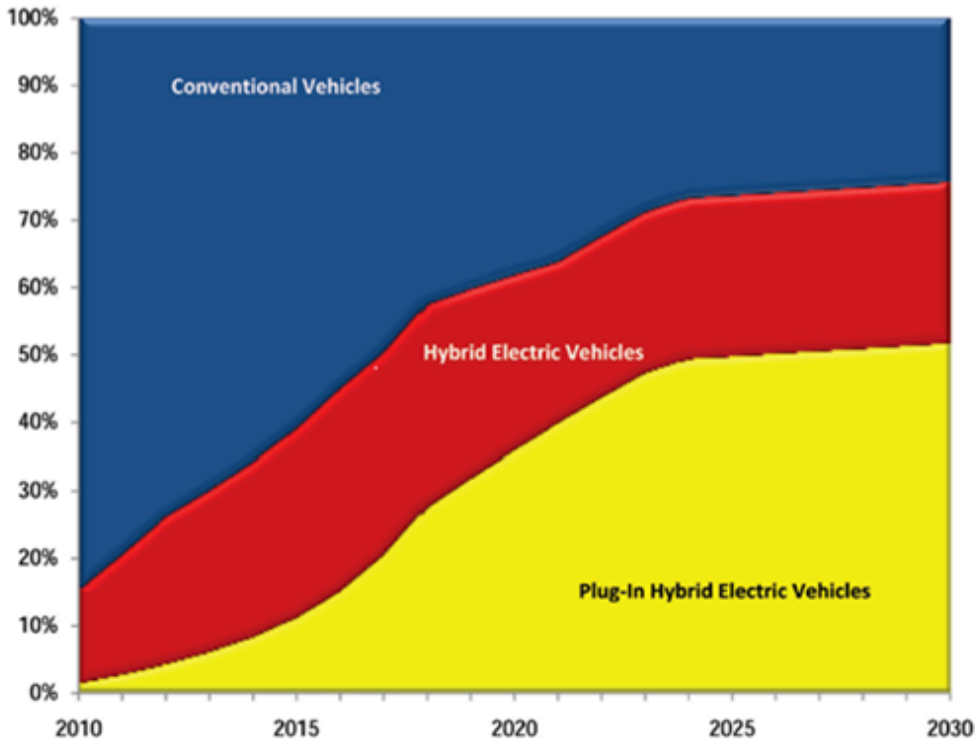
The logistic model represents the typical 'S-curve' for the well known population models. They predict an initial period of exponential growth and a linear period followed by an asymptote leveling off to some constant value. Because car sales are essentially a population among all vehicles it is fairly intuitive that the logistic model should be the most accurate and precise for modeling HEV sales. Our intuition is also supported by the fact that. Not only does it stay in alignment and coalesce with the actual sales data with but the function tops off at a steady value as it climbs to its asymptote at around 2010.

Figure 9: Logistc Model with Actual Data



The logistic model also completely agrees with the Electric Power Research Institute's (EPRI) market penetration graph which spans from 2010 to 2030. From 2010 it predicts an approximately linear growth in the population of HEVs and PHEVs. The logistic model shows a steady sales rate of HEVs through and past 2010 which, if the function were integrated, would show a roughly linear line with positive slope proceeding from 2009 onward. We found the logistic model is accurate up through about 2024 give or take a few years.

Figure 10 : EPRI HEV/PHEV Predicted sales



EPRI's estimate of future sales of HEV/PHEV/CV
from Environmental Assessment of Plug-in Hybrid Electric Vehicles

Based on the current HEV sales from both our model and the EPRI estimates we have collectively agreed that the PHEV sales will follow the same trend as the HEV sales. Initially each will have some form of exponential growth which will level out in roughly 8 to 10 years to some constant rate of sales. This trend will continue for roughly another decade at which point it

will level off to a final overall percent of the vehicle population. This trend also can be characterized through the use of a logistic model and will likely prove the most accurate and consistent for the PHEV sales similar to the HEV logistic model.

EV sales will also likely mirror that of both the PHEV and the HEV. With an early exponential growth period followed by linearity in about a decade then reaching some asymptote another decade later. Once again, this is very characteristic of the logistic model which will likely be used to model the EV sales behavior and overall market penetration.

Interview Summary

Every person that we interviewed that owned a hybrid vehicle provided us with positive feedback about his or her vehicle. Not one of the owners had any specific problems with their brand-new or first generation hybrid. The type of car varied from interview to interview but the most popular car owned by the interviewees was by far the Toyota Prius. The main reason for the majority of the owners switching from their regular gasoline powered cars was to reduce the cost of refueling their vehicle. Although most of the drivers also knew they were helping the environment as well, that was typically a secondary concern. The vast majority of those interviewed were so pleased with their HEV that they said they do not plan to return to conventional vehicles in the foreseeable future. In fact, they plan to continue to purchase HEVs for their own personal vehicles and have become their vehicle of choice. From these interviews we were able to further support our conclusion that people who purchase HEVs have a highly positive experience. Other than the routine maintenance there were no minor or serious problems that any owner had experienced.

Professor Arthur Gerstenfeld Interview

- Drives 2004 Toyota Prius
- Reduced cost of gas, reduced emissions and reduced dependency on foreign oil were all considered of equal importance in his choice to purchase a hybrid
- Improvements he'd like to see: better fuel economy
- Has had no problems with his Prius so far
- Does not believe that the current prices of PHEV are worth it; wants over 100 mpg before he would consider purchasing one
- Believed that the government should subsidize both the research of plug-ins and the cost to consumers

Professor Gerstenfeld was very interested in plug-in hybrid technology and thought it could be useful for helping lower greenhouse emissions and oil usage. However, at the current costs of plug-in hybrids compared, he did not believe it was worth it compared to regular hybrid vehicles until there had been a significant increase in gas mileage for plug-in hybrids. Prof. Gerstenfeld also mentioned that he was concerned with the disposal of the large batteries from both plug-in hybrids and conventional hybrids.

Catherine Fradette Interview

- Drives 2006 Toyota Highlander
- Most important reason for purchasing a hybrid was the savings on fuel
- Of secondary importance was that it had reduced emissions and oil usage
- Mentioned that reduced dependence on foreign oil did not factor into her decision
- Improvements she'd like to see: an increase in average mpg, for highway mpg to be raised to similar levels as city mpg
- Has had no problems with her Highlander so far
- She believed that the additional cost of plug-in hybrids was worth it; it was the improved fuel economy made the additional cost worth it
- Believed that the government should subsidize both the research of plug-ins and the cost to consumers

While she had heard of plug-in hybrids, Catherine Fradette was unfamiliar with how they differed from conventional hybrids. However, she seemed enthusiastic with idea; she welcomed the idea of a vehicle which had higher gas mileage than her current hybrid vehicle.

Dexter Bailey Interview

- Drives 2006 Lexus 400h
- Most important reason for purchasing a hybrid was the savings on fuel
- Of secondary importance was that it had reduced emissions and oil usage
- Improvements he'd like to see: better fuel economy, higher performance when the vehicle was only running on the electric motor
- Has had no problems with his Lexus so far
- He believed that the additional cost of plug-in hybrids was worth it; it was the improved fuel economy made the additional cost worth it
- Believed that the government should subsidize both the research of plug-ins and the cost to consumers

Dexter Bailey was somewhat familiar with plug-in hybrids, and also seemed enthusiastic about vehicles which would have a better fuel economy than his current hybrid. He also was concerned with possible emissions from electromagnetic fields from the batteries from plug-in hybrids and standard hybrids.

Professor Susan Vernon-Gerstenfeld Interview

- Drives 2008 Toyota Camry
- Most important reason for purchasing a hybrid was reduced emissions
- Of secondary importance was the reduced consumption of oil
- While reduced cost of fuel was also mentioned, she said it was less important than the other reasons
- Improvements she'd like to see: she stated that the battery took up too much cargo space, and wanted it to either become smaller if possible
- Has had no problems with her Camry so far
- She was unsure if the additional cost of plug-in hybrids was worth it; she said she would need to see a breakdown of the differences in emissions and oil usage compared to standard hybrids
- She stated that the issue of government subsidies was too complicated for her to have an informed opinion on the matter

Professor Vernon-Gerstenfeld was spoke very strongly on the issue of emissions from vehicles, and said that the reduced emissions of hybrid cars was the chief factor in her decision to purchase one over a stand vehicle. While she seemed open to plug-in hybrid technology, she seemed to want to gather more facts about them before she was willing to consider purchasing one.

Bruce Fiene

- 2004 Ford F-350 Powerstroke desiel, 1989 Mercades turbo diesel
- 18 miles to work every day 17-20 mpg
- Converted the truck himself, car was converted by a friend who does that for a living in western mass.
- Gets his own oil from WPI, filters it and uses it straight.
- Gets the same gas mileage, has a 90 gallon oil tank.
- Would never buy anything other than diesel.

Bruce expressed that he was not interested in purchasing a hybrid vehicle at this time. He did however mention that if an affordable, practical electric vehicle came out he would consider it. His reasoning was simply that he is able to attain good gas mileage at a low cost using his two converted diesel vehicles. He attains used frying oil at no cost from the school which he filters and uses to run his 99 Ford F-350 and his 96 Mercedes. The vehicles are required to run on diesel fuel only while starting, and get the same mileage whether running diesel or oil. Bruce prefers his converted diesels based on their resale value, as he sold a converted 84 Mercedes for $5000.

Chistine Drew

- 2007 Toyota Prius
- Drives 15 min to work 48-51mpg
- Bought it for the fuel mileage, says she likes to drive places on the weekends.
- Bought it new, has preformed no maintenance other than scheduled.
- Would not like to own a pure electric or a plug in electric based on the cost.
- Wishes it was faster.

Christine bought a Prius after having several friends that were satisfied with theirs. She mentioned that she wishes it were sportier, and accelerated faster. As of now she is not interested in plug in hybrids due to anticipated cost, but did mention that more research should be funded for the study of electric and alternative fuel vehicles.

Ingrid Shockey

- 2007 clean burning VW Jetta Diesel
- 75 miles to work every day from western mass 46-50mpg
- Loves the car
- Did not choose a Prius because they are not good in the snow, and was afraid the battery would not last many years due to her long commute
- Has performed no maintenance other than scheduled yet
- Was burning biodiesel, stopped because her mechanic told her it could void her warranty.

Ingrid Shockey was seriously considered the Toyota Prius and was generally impressed by it. However, being in Worcester snow is a big factor and the Prius does handle to well in the snow and due to her long commute was worried about the vehicle's battery life. She has performed no other maintenance other than routine such as oil changes etc. She was using biodiesel in her 2007 clean burning Volkswagen Jetta diesel. She topped when her mechanic warned that it could void the warranty on the car.

Toyota Prius Mechanic: Sam Bolles

- Drives 1994 Toyota Tacoma
- Has been working on hybrid Prius since they were released
- Improvements he'd like to see: plug-in option in Prius
- More emphasis on fuel efficiency
- Less emphasis on performance of the vehicle
- Their diagnostic scanner currently shows a plug-in option for Prius
- Not familiar with Chevy Volt, has hear of it though
- Likes the governments current approach to promote hybrids
- Would love to own a Prius if he had the money
- No specific problems with the hybrids he has worked on
- Prius is not the only hybrid he sees, popularity of other hybrids is going up
- Believes that Honda hybrids are only considered 'mild' hybrids
- Usual work consists of oil change, filter change etc.
- Revealed that 7 Toyota dealerships are licensed to change Prius battery

The interview with the hybrid mechanic confirmed our theories that there are no specific problems with Toyota's hybrid line of automobiles. Sam has been working on the Prius since it was released and all of the other hybrid vehicles that his company has to offer. He has not had any specific problems with any part of the Prius or other hybrid vehicles in the time he has been employed at Toyota. He did reveal to us that the only bad news he knew of was a battery recall in some of the first generation Prius'. Sam enjoys working on the Prius hybrids and believes that they are actually very simple machines. The one improvement he wants to see is more emphasis on fuel economy rather than vehicle performance. An interesting fact that he revealed to us was that only seven Toyota dealerships in the country are licensed to upgrade the Prius to be outfitted as a PHEV. This upgrade allows for a lithium ion battery that gives the car 100mpg. The upgrade is costly and ranges between 8,000 and 10,000 dollars. One of the seven dealerships is located in Westborough as well. All in all, Sam Bolles is pro-hybrid and enjoys working with the vehicles daily.

Professor William Martin Interview

- Drives 2010 Toyota Prius
- Previous car was Toyota Camry
- Has not owned any other hybrid vehicles prior to new Prius
- Number one reason for buying vehicle: for fuel efficiency
- Second most important reason: to help the environment
- Improvements he'd like to see: more mpg, plug-in Prius
- Familiar with Chevy Volt, but doesn't trust Chevy because of past conflicts
- Believes in plug-in technology
- Wants to see 100mpg automobiles
- Government should not have to tell people what to do
- Government should implement tax penalty/reward system for hybrids
- No specific budget for next vehicle, wants best option possible
- No problems with Prius so far
- Global warming could be a factor in the long run
- No easy solution for fossil fuel dependency
- Future solution is mass transport

Overall we found a general positive attitude from Professor Martin toward hybrid technology and plug-in vehicle technology. He would like to see more funding and developments in hybrid vehicles. The interview showed us that he is an extremely strong supporter of the plug-in technology that is currently being researched. Unfortunately he is not too interested in the Chevy Volt. More interest was expressed in the release of a plug-in version Toyota's Prius. He believes that the technology is already there to manufacture 100mpg vehicles and have them on the market. The main reason for buying his Prius was for its outstanding fuel efficiency, but the environment was also a factor. After mentioning the government's approach, he explained that the government should implement a tax penalty/reward system for automobiles. He believes that the government should be doing more than they are currently to support hybrid vehicles. Professor Martin believes that mass transport is the future direction the world.

Professor Brad Miller Interview

- Drives 2005 Toyota Prius
- Prius has approximately 60,000 miles on it
- Has extended warranty; 6 years 100,000 miles
- Previous car was Volkswagen Jetta
- Has not owned any other hybrid vehicles prior to Prius
- Number one reason for buying vehicle: for fuel efficiency
- Improvements he'd like to see: more mpg
- Extremely interested in a plug-in Prius
- Familiar with Chevy Volt, likes the incentives, must have correct price point
- Government should step in and make people feel good about smaller cars
- No specific budget for next vehicle
- No problems with Prius so far
- Would never switch back to a 'regular' vehicle
- Wants to reduce dependency on foreign oil
- Believes that companies should be pushing electric cars in the future
- For future believes all vehicles are going to be solely electric

Professor Miller was unquestionably an example of a pro-hybrid user. He owns a 2005 Prius and wasn't sure about how it was going to run when it was first purchased. After a few months and a couple thousand miles the vehicle did not disappoint. After owning a Volkswagen Jetta and having everything go wrong on him, he now has complete confidence in Toyota. The main reason for purchasing the vehicle was to combat the high gasoline prices with its excellent fuel efficiency. The only improvement he would like to see is even more miles per gallon. Professor Miller expressed a high interest in a plug-in Prius. When the Chevy Volt was mentioned, a smaller amount of interest was expressed. He explained to us that the vehicle must have the correct price point for him to consider it when looking for his next vehicle. For the future, Mr. Miller sees electric cars taking over the industry and the road.

Data Collection

The group as a whole designed and implemented a specialized questionnaire for the general public. The group found that overall the general public held a very favorable position toward the creation and further research into PHEV and HEV technology. For instance, 88.3% of all surveyed participants said that they believed that hybrid technologies were worth the costs of investment. However, only 40% said they would buy a HEV at this time which says that the general public has little faith in the current state of the HEV (Appendix E).

Of those surveyed, 55% identified the cost as the least attractive aspect of the HEV and an additional 20% said that they didn't have enough horsepower. However, the most attractive aspect of the HEV behind fuel efficiency was reducing dependence on foreign oil with 56.66%, while 26% said saved emissions and 15% said the government tax credits. Participants were asked their budget for their next car and 30% stated up to $10,000 and the next leading figures were $10-15,000 with 23.3% and $15-20,000 with 21.67%. Also, 62% said that they planned on purchasing a new vehicle within the next five years, while only 10% planned in the next 6-10 years and 28% said in more than 10 years (Appendix F).

Table 3: Total Results from Questionnaires

N=60 (Total)	Q#	Yes[%]	No[%]				
	1	88.3333333	11.66666667				
	2	40	60				
	3	65	35				
	4	68.3333333	31.66666667				
	5	68.3333333	31.66666667				
		A[%]	B[%]	C[%]	D[%]	E[%]	F[%]
	6	55	11.66666667	20	13.33333		
	7	26.6666667	15	56.66667	1.666667		
	8	30	23.33333333	21.66667	10	6.666667	8.333333
	9	28.3333333	58.33333333	13.33333			
Educational Level	No H.S. degree	H.S. degree	Some College	Bachelors	Masters	PhD	
	0	3	51	5	1		
Ages	<30	31-49	50+				
	45	8	7				

The questionnaire was then compared to over large scale surveys from other reputable organizations. We found near complete consensus between our data collection and the larger scale projects, Pike Research found 79% found consumers willing to invest in technology for the PHEV. Only 65% said they would be willing to pay a premium price for the PHEV above the price for CVs. They also found that 45% of consumers wanted to wait until the technology had increased in quality in the coming years (Appendix G).

Vehicle Comparison

As consumers search for more fuel efficient vehicles, they are presented now with many choices. Hybrid electric vehicles (HEV) have been available to consumers for many years now, but with plug-in hybrids (PHEV) soon to be available commercially, and electric vehicles (EV) gaining popularity once more, consumers have more options now than they have ever had to pick a vehicle with higher fuel economy.

Hybrid electric vehicles tend to be slightly higher priced than their standard counterparts, but provide a significant boost in fuel economy. One of the benefits of HEVs compared to PHEVs and EVs is that there is a wide range of choices for consumers to choose from. Ranging from compacts cars to SUVs to trucks to luxury sedans, HEVs provide most consumers with a more fuel efficient model of whatever type of vehicle they wish to purchase.

By far the most common HEV is the Toyota Prius, which currently costs $22,400, but gets 51/48 mpg on city streets and highway. Similar in size and cost is the Honda Insight, which costs $19, 800, and has a fuel economy of 40/43 mpg. Both models appeal to consumers who want a very fuel efficient vehicle, and who do not require a large amount of cargo space or room.

For those who do not wish to sacrifice comfort or space for better fuel economy, there are also many mid-sized car HEVs to choose from. While it is still new, the Ford Fusion Hybrid has received much attention, and even won the North American Car of the Year award at the North American International Auto Show in Detroit in 2010. (1) Its price tag is $27,300, and has a fuel economy of 41/36 mpg. For those desiring a more luxurious HEV, the Lexus HS250h costs $34,200, while getting 35/34 mpg.

For consumers who need even more space, HEVs also come in a variety of SUVs. The Ford Escape, which won the North American Truck of the Year award in 2005 (2), costs $29,300

and has a fuel economy of 34/31 mpg. Again, for those wanting a more luxurious model, there is the Lexus RX400h, which costs $42,000 and has a fuel economy of 27/24 mpg.

While plug-in hybrids have had great media attention for several years now, the first commercially available model still will not be available until late 2010 at the earliest. There has been much debate on how fuel efficient they will actually be, whether the increased fuel economy will justify the increased cost, and even over which battery size is the best. Despite this, there are many consumers who cannot wait to try them out.

The Chevrolet Volt will be the first PHEV available, and will reach consumers sometime in late 2010. With a 16kWh battery, the Volt promises to a range of 40 miles using only battery power. For consumers who travel less than 40 miles in between charges, the Volt will not consume any gasoline. It is because of this that there has been some controversy over how exactly to measure the fuel economy of the Volt, but we can safely assume that after this it will probably get similar gas mileage to other mid-size hybrids once its battery has depleted. While the exact price of the Volt is not yet known, we do know that the government will be providing a $7,500 tax credit to those who purchase the Volt. (3) The price of the Volt before the tax credit will be somewhere around $30,000, according to GM executive Ed Whitacre. (4)

While there have been kits on the market to convert Priuses into PHEVs for several years now, the first plug-in Prius from Toyota will not be available until sometime in 2011. The plug-in Prius will have a much smaller battery than the Volt, only 5.2 kWh. Consequently, Toyota has only given it a range of 14.5 miles. While this gives the plug-in Prius a much shorter range than the Volt, it gives it a lower price tag as well. While the exact price has not yet been released, Toyota has said it will be somewhere in the high $20,000 range. Consumers who purchase the

plug-in Prius will also be receiving a tax credit; however it will not be as much as those who purchase the Volt.

For consumers who want a plug-in SUV, Ford plans to release a PHEV version of the Escape sometime in 2012. Though several details are still unknown, such as the price, the plug-in Escape will have a 10kWh battery, and Ford says it will have a range of approximately 30 miles using only the battery. As the HEV version of the Escape gets 34/31 mpg, we can safely the plug-in version will probably have a similar fuel economy once the battery is depleted.

While PHEVs will cost more than their standard HEV counterparts, they have the ability to be far more fuel efficient. However, with the tax credit provided by the government, the price different will be fairly small. How small this difference is will remain to be seen until the exact prices are announced.

Though much of the media attention has been focused on PHEVs, vehicles which only use electricity are starting to come back into popularity. However, there are few models currently available, and many of those are priced far beyond what most consumers can afford. The soon to be released Nissan Leaf has received the most attention of the EVs which will be within the means of most consumers.

The Nissan Leaf will be available sometime in late 2010, and will have a 24kWh battery, capable of a range of up to 100 miles according to Nissan. Unlike the HEV and PHEV, the Leaf will use no gasoline at all, and is reliant totally upon its battery for power. While this makes some consumers hesitant to purchase it, its range of 100 miles is farther than most consumers' daily drive. Once again, the official price of the Leaf has not yet been announced, but Nissan has said it will be approximately $30,000. Like the Volt, consumers who purchase Leaf will qualify for a $7,500 tax credit, so it will help lower the price down to what most consumers can afford.

Another option consumers will soon have to choose from is the Ford Focus EV. While little information has been release on the Focus EV, it will have a 23 kWh battery, and will have an estimated range of around 100 miles. While the cost has not yet been announced, the Focus EV will be available sometime in 2011. While EVs have the attractive quality of consuming no gasoline, it comes at the high cost of returning to somewhere the vehicle can be charged. However, as EVs and PHEVs become more popular, charging stations will become more common, and eventually may no longer even be an issue. The lack of available EV models also presents a possible problem for the success of EVs, as consumers are less likely to find an EV which suits their needs and taste. Despite these drawbacks, EVs still remain a viable contender in the market of more environmentally vehicles.

The Electric Vehicle

Based on our findings we are able to infer many things for the future of HEVs, PHEVs, and even extend our knowledge into the all electric vehicle (EV). With the PHEV and the HEV being heavily invested upon now, it seems only logical that eventually the technology will arise before 2030 to produce either prototypes of an EV. These EVs will not only have comparable power, acceleration, torque et cetera but can in fact exceed its predecessors in almost every desirable way possible. Chemical reactions have some significant losses for example energy loss due to heat transfer and friction, however electricity is much easier to harness and is highly efficient once contained within a power source, such as a battery which is utilized in the EV.

The EV could potentially also lead to a type of 'wireless' electricity which will be produced on the electromagnetic spectrum and emitted by power stations. To input this power into your vehicle you will simply dial into the local emitting frequency using something similar to an antenna. The electromagnetic waves will enter the antenna and be instantly transferred to your battery providing an on demand charge whenever required regardless of location. Electrolysis is another option where the battery is charged by capturing the energy released when hydrogen and oxygen combine to form water. The power station would supply the power to separate the two once and then the vehicle would pump the two around in a circuit to continually produce electric energy which can be converted into mechanical energy.

Figure 11: A high performance BEV Tesla Roadster

The new technologies developed for the HEV/PHEV will be applied to future models of the EV. The EV could bring about complete foreign independence due to its independence of oil based products using other coolants besides the tradition motor oil. Changing the face of American energy consumption habits where you recharge your house battery instead of refilling your oil tank.

It is also reasonable to believe that after the EV's introduction into the market, it will eventually become the largest component of the American fleet composing anywhere from 50% to 75% perhaps even 90% or higher given ample time. The sale rate will be approximately the same as the HEV and PHEV during their first years. However, once the technology has been perfected after some additional research it will be the vehicle of choice for millions of people not only in the US but worldwide.

The wide spread usage of the EV would require their respective refueling locations which in this case, is a charging station. Plans for the 'Coulomb Charging Station' have already been designed and developed; these are basically electric gas stations for use by any vehicle with an electric car. This includes both PHEV and the EV models; of course the PHEV may require some minute modification for use in the charging stations but it is completely within reach and

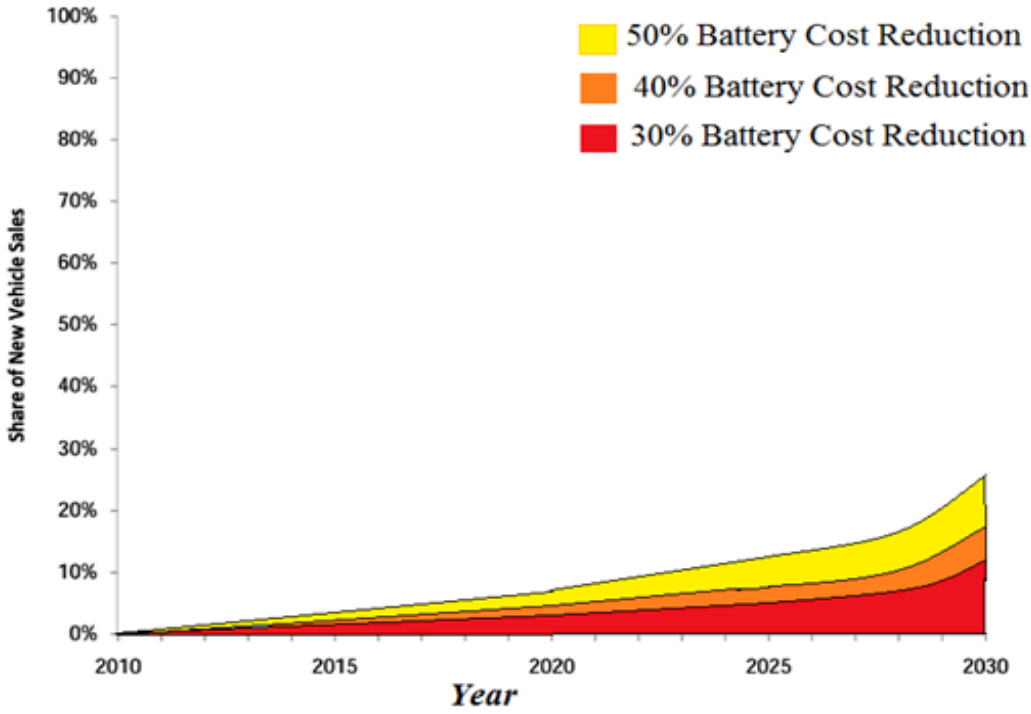
reasonable to assume that the PHEV will be completely compatible. These stations have also already had projected costs assigned to each installation including location, availability of power, conduit size, and labor. We believe collectively that at first these stations will likely be installed at already popular refueling gasoline stations. Over time, as the need for gasoline in our every day transportation vehicles diminishes, the charging station would become the sole function.

Figure 12: Charging Station run on solar power in Rio de Janeiro, Brazil

Many communities are already embracing the future idea of the PHEV and EV technology. For instance, Houston, Texas has already anticipated the wide spread use of PHEV and EV throughout the city. As such, they have budgeted for a future project to install various charging stations around the city at various locations. They used an assortment of projection figures and have decided to set aside $10,000 for the first station and an additional $1,000 for every station afterward. This could potentially create a whole new job market for employment helping lower the already staggeringly high rate of unemployment that is currently sweeping the country from coast to coast (Appendix D) .

However, there are some drawbacks associated with the EV and its components. The EV is bound to a small roaming area due to a few factors. The battery can only take you so far before the driver must stop and recharge the battery packs for a given length of time. This severely limits its long distance use, which is ironically where it would also help the most especially the commercial shipping industry. The recharge time on some battery packs can take a few hours which means while you are recharging your vehicle you are sitting there just waiting unless you can find something to do. Another problem is the current lack of recharging stations; although plans are underway the charging stations are few and far between. This makes even a simple trip say from Boston to New York a very complicated maneuver. So if you plan on taking a nice long drive, keep a global positioning system handy that can track the nearest charging station or public electrical outlets.

Figure 13: Predicted Sales of EVs



Estimation of market penetration of the EV based on battery cost reduction of certain % in 10 years

We were able to conclude that in the long run hybrid vehicles and plug-in hybrid vehicles will be able to help the United States reach the goal of becoming independent of foreign oil. Based on the research we conducted and other findings the popularity of hybrids will continue to grow and people will buy these state-of-art vehicles. We can increase these sales by lower the purchasing cost, and increasing the overall performance of the vehicle. If the majority of the fleet is PHEV/HEV by 2030 then it is conceivable that the US will be nearly if not completely foreign oil independent by then or soon thereafter. Especially when considering the current investments by both government and the auto industry into batteries and other electric technologies. The impact of the EV will be extremely significant; it will eventually replace the entire American fleet and with clean energy and therefore no harm to the environment due to transportation byproducts, all while giving us independence from our current rapid oil consumption rate.

Figure 14: Nissan Leaf the brand's first fully electric vehicle available in late 2010

Safety Concerns

While conventional combustion vehicles have existed for quite some time the new configurations for the HEVs, PHEVs, and EVs are relatively new. This means that the average person has basic knowledge and understanding of the CV however has very little understanding of the HEV, PHEV, and EV. When dealing with any of the electric hybrid models they do use a fairly high voltage amount, say in the area of 650 Volts. This is certainly enough to do some serious damage or potentially kill a human.

The electrocution problem is by far the largest complaint from critics of the technology. However, according to Consumer Reports as well as various representatives from automotive companies, if a person is in an accident in a hybrid vehicle and they read the safety section of their owner's manual they are in no more danger than using a conventional vehicle. Just like in a CV, the first thing you want to do is to stop the engine from running, that means taking the keys out of the ignition to stop the vehicle from pumping the highly volatile gasoline and turning your wreck into a time bomb. Hybrid vehicles work along the same lines, if you want to avoid letting 650 volts of electricity pass through you then simply remove your key and turn your engine off. This essentially makes the vehicle 'dead' and stops the power circuits from functioning. As long as this is done the hybrid and combustion engines are much safer to work around. No reports of any rescuer have ever been filed claiming that they were injured due to a battery electrically discharging into them or near them (Consumer Reports 2010).

Many automakers have even gone through the trouble of color coding their hybrid internal wiring to indicate what carries high voltage power and what does not. High voltage lines

on typical hybrid vehicles are coded with a very intense orange or other bright color to get your attention.

Figure 15: High Voltage wires indicated by orange caps

These lines are insulated but under no circumstances, if the vehicles power circuits are on, should anyone be anywhere near these lines. It is outlined in the owner's manual a step by step procedure if you want to do maintenance on the vehicle, which is actually remarkably simple. In addition these battery packs come with their own disconnect or 'kill switches' which stop the electrical flow in the power circuits to and from the battery. These are also highlighted and given a section in the owner's manual for a detailed explanation to the owner or technician. Much like the rescuers no reports have been filed saying that anyone has been injured working on or near the hybrid vehicle due to battery discharge.

Many modern hybrids have an automatic protocol should the vehicle be in an accident. If the airbags are deployed then the vehicles computer executes a series of actions which will isolate the high voltage battery. In the Toyota Prius, the battery and wiring circuitry are separate from other electrical components in the vehicle. They also do not use the body or the chassis of

the vehicle as a ground. The Prius contains its own ground fault interrupter the same kind that is built into many household electrical outlets. This GFI will disconnect the battery and turn on a warning light if the sensors detect a voltage leak to the body of the vehicle (AA1car).

Another common misconception is that the hybrid vehicles are a highly dangerous thing that can cause explosions or leak highly acidic substances. The batteries included in Ford, Toyota, and Honda models are non-flammable and non-explosive units according to the Emergency Response Guide for Hybrid Vehicles. They are encased in a thick protective metal shell. This is done to insulate the battery from the vehicle and as a safety precaution for the contents of the batteries themselves. They are also located in a specific spot to avoid damage in collisions, the rear of the vehicle specifically the rear axle. They must also meet the additional government standards of vehicle safety which every vehicle on the road in the US must meet (Consumer Reports 2010 & AA1car).

With the recent recall of the Toyota Prius concern of hybrid vehicles has resurfaced. However, it was not only the Toyota Prius but rather an entire fleet of Toyota vehicles that were recalled due to an electronic accelerator malfunction. The problem is not a hybrid problem but rather a Toyota problem the hybrid technology itself was not to blame for the recall. Thus, the accelerator recall should not dissuade potential buyers from continuing to look at the hybrid vehicles as their next vehicle purchase.

Due to these current problems that Toyota was experiencing many companies utilizing similar technology is taking a long hard look at their control systems. One of the more vocal changes was the software update made by the Ford Motor Company. This was done to correct

some small errors as well as routine software maintenance on its more computerized and automated components of the new models being put out for 2010 and 2011.

Battery Technology

Throughout the 19th and 20th centuries, mankind's technological advancements have grown exponentially. We have conquered the air with the commercial aviation industry. We have mastered the indomitable, reaching to the farthest parts of our galaxy and beyond with our state-of-the-art satellites. We have planted a man where he was not meant to walk, the moon, and even sliced the infinitesimal atom collecting its energies for our own interests. And so our advancements continues to grow as does our understanding of the world around us, we are now able to convert and revert energy in its various forms from potential, kinetic, mechanical, strain to and from electrical, chemical, and nuclear possibly even some we have not even discovered yet.

Harnessing energy is useless unless it is stored properly, which is the purpose of the battery. The battery contains the ability to take one type of energy and then convert it, by a number of ways, into electrical energy to be stored in the unit for later use. These electrical energy storage devices are the 'X-factor' in the new HEVs, PHEVs and will continue to be into the EV generation of vehicles. Meaning the battery is the ultimate determining factor in the output of the vehicle, including mileage per unit energy and power that can be delivered to the mechanical system, such as a transmission or gears, which physically drives the vehicle.

The early 1900s ended the era of the back yard tinkerer inventing new types of batteries. From here on out is large corporations with large budgets, producing a battery for a specific application which drives advancements. Modern electric and hybrid cars generally use one of three types of batteries, nickel cadmium (NiCd), nickel-metal hydride (NiMH), and Lithium-ion (Li-ion).

The nickel cadmium (NiCd) battery has been used in early electric models such as the Peugeot 106, which started production in 1995. These batteries are capable of an energy density of 50Wh/kg and power density of 200W/kg, a recharge cycle of around 2000, and Nissan has reported the ability to recharge in as little as 15 min. It consists of a Ni positive electrode and a Cd negative electrode with a highly porous separator to absorb the free electrolyte. The down sides here are many. One, they are relatively expensive. Two, and most importantly, they are highly toxic, requiring an expensive and complex recycling process (Westbrook, 2001, p. 77).

Nickel metal hydride batteries correct the problem of toxic and expensive recycling. GM is the major producer of these batteries, using them in their EV1 models through late 1990s. The positive electrode is still Nickel hydride based, however the negative electrode is a complex metal hydride in a potassium hydroxide electrolyte. When charged, the hydrogen is stored in the alloy and the nickel hydroxide is converted to nickel oxyhydroxide. All of this translates to a higher energy density, 70 Wh/Kg, with a similar power density and a recharge time around 35 minutes. A second important advancement is that these batteries are far less susceptible to overcharging and over discharging, which means that power regulation need not be as precise and thus can be cheaper. In 1996 GMs EV1 went 245 miles using these batteries in the Tour de Sol (Westbrook, 2001, pp. 78-79).

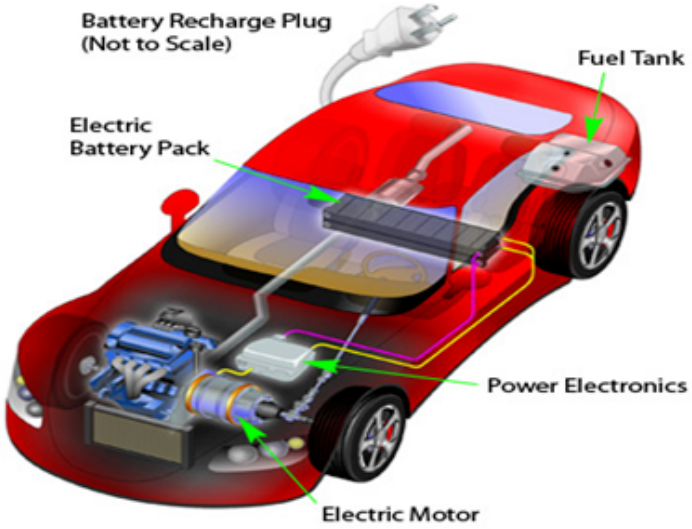


Figure 16: General layout for PHEV model

Based on our information gather, we believe lithium ion batteries are the future of battery technology. The 2009 Prius is currently using this technology. The battery consists of thin flexible plates in a sandwich formed from aluminum coated with vandiumoxide, a solid electrolyte polymer, and finally in what's known as a negative insertion host. The most important third plate has lithium contained in the atomic structure. When discharged the lithium ion travels from the negative host cell to the positive host, reversing the process when being charged. These are sometimes called swing batteries because the charge is produced when the lithium ion swings between the two hosts. This process results in an energy density nearly doubled to 120Wh/kg, and an increased power density of 300W/kg. Another important advancement is the flexibility of the pressed plates. They can be cut into many different sizes, as well as formed to any contour. This is essential when space and weight are at a premium.

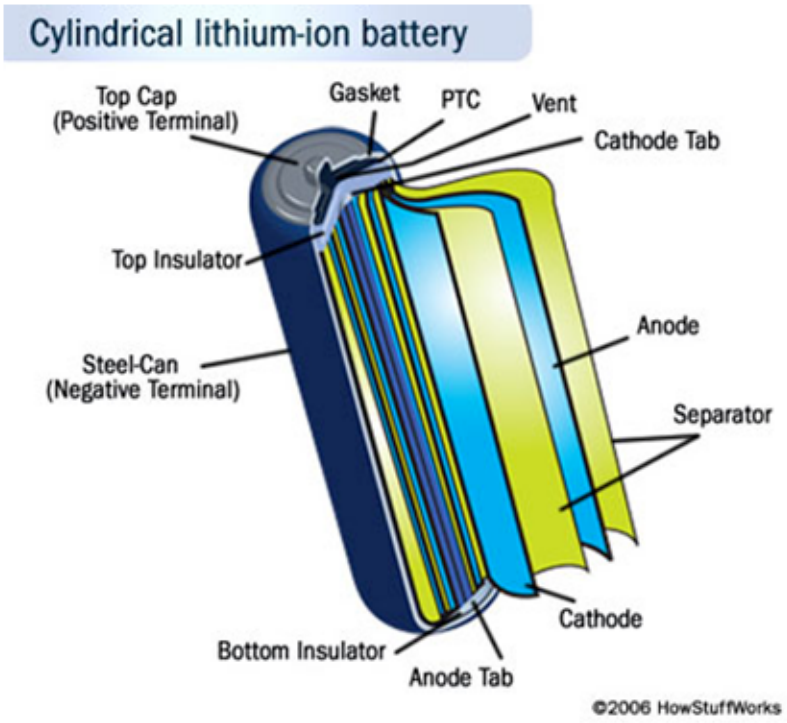


Figure 17: Cylindrical Lithium Ion battery

The future of battery technology is debatable. Many experts contend that we have reached near the end of our ability to produce new advancements in this field. Electronics will continue to get smaller and faster, as they always have, due to advanced circuitry and smaller batteries like the lithium ion battery. Moors Law has been seen in many technologies of today, however battery technology is not one of these. The physical size can only be reduced so much based on the materials it is produced from. The mastery of nanotechnology has some hopeful prospects; however we are nowhere near having this as available technology. The direction most experts foresee, and which nearly all major manufacturers are taking, is that of fuel cell vehicles ((Buchmann, 2005).

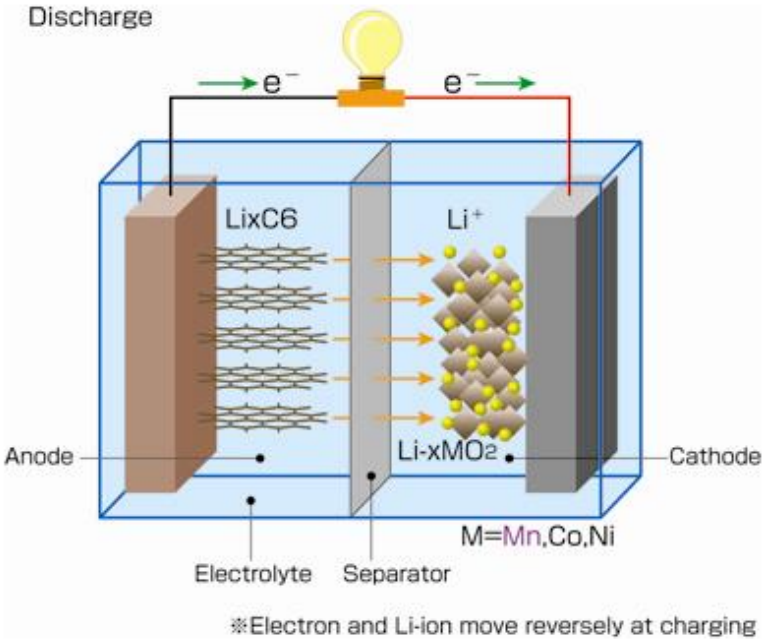


Figure 18: How a lithium ion battery works

A fuel cell is a way of "burning" hydrogen to produce electricity. You can literally burn hydrogen in a traditional combustion engine, but with a fuel cell 40-60% efficiency can be obtained compared to 20-25% with combustion. Either way the byproduct of power production is only water, making them very environmentally responsible (Westbrook, 2001, pp. 90-91). The current fuel cells use what's known as a Proton exchange membrane containing a catalyst, usually platinum, to strip the electron off the incoming hydrogen. The electrons are then routed through the electrical load, the motor. The hydrogen ions are transmitted across the proton exchange membrane and united with oxygen from the air on the other side. A catalyst, again platinum usually, is used on the other side to recombine the hydrogen ion with its electron and oxygen atom to produce H2O, water, as the byproduct. The result is that the hydrogen is now at a lower energy state in the water form on the other side and the excess energy is used in the electric motor. In the past this reaction needed 600-1000 ^{o}C to work. Advances in technology

have brought this temp down to 60-100 ^{o}C, making it feasible to put into a car (Westbrook, 2001, pp. 91-92).

Currently, the main problem with this method is obtaining and storing the hydrogen. Storing the hydrogen onboard requires either a heavy tank, able to take 400 atm of compressed hydrogen, or a different equally heavy tank able to insulate hydrogen in order to keep it a liquid at -253 ^{o}C. The solution to these problems is to produce the hydrogen on board using a process called reformation. The most efficient form of this process is a steam reaction involving liquid hydrocarbon, gasoline or an alcohol, which produces hydrogen in an endothermic reaction. This means the cell must be "started" with some conventional form of adding heat and continually heated to retain the hydrogen in a useful form (Westbrook, 2001, p. 167).

The current technology has not advanced to producing hydrogen onboard. The modern configuration is represented by the Honda FCX Clarity.

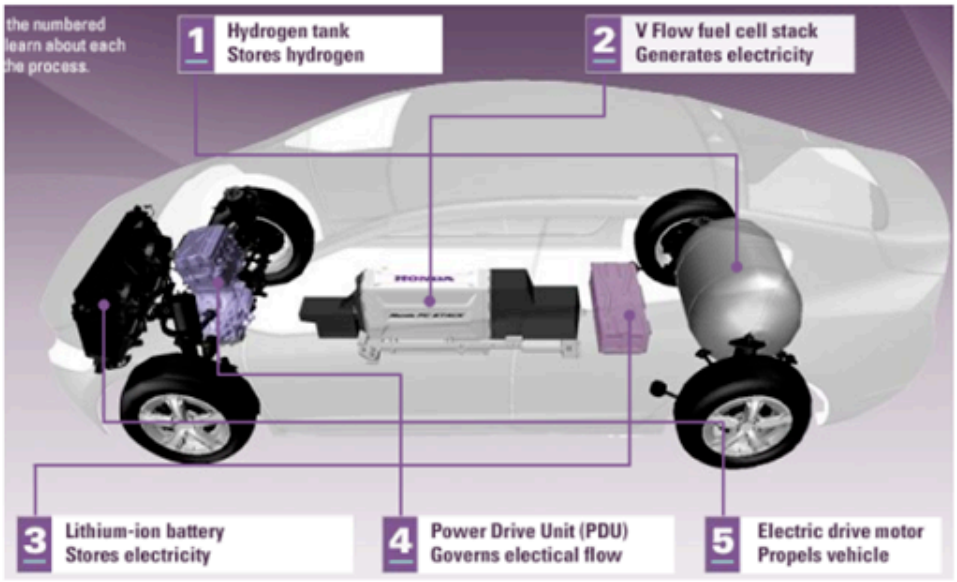


Figure 19: Hydrogen fuel cell used with battery pack in Honda FCX Clarity

The storage tank contains hydrogen which is pumped through the fuel cell, sending energy to the lithium ion battery and drives an electric power train ((FCX Claruty Power train, 2009). If the infrastructure could be efficiently implemented, we could see these cars on the road in the very near future. There are already a few on the road today in California. As this is new technology, it is also extremely expensive; however this could be overcome with processing techniques and mass production.

One concern that some critics have is the life of the battery pack. Some believe that the technology is still in its infancy and as such contains many flaws. Although this is partially true that the technology is fairly new, it does not contain as many flaws as some critics would suggest. A recent study on a small fleet of all electric Toyota Rav4s using Nickel Metal Hydride batteries revealed that the battery packs had been used in excess 100,000 miles while still maintaining roughly 76% of their nominal battery capacity. The EVs was also able to retain 86% of its initial range on a single battery charge. It was concluded that the EVs could run to a potential 130,000-150,000 putting the lifetime of the vehicle on par with the conventional internal combustion engine vehicles. The vehicles were also found to highly dependable and reliable needing little routine maintenance and being able to accomplish a wide variety of mission requirements. This is a testament to the durability and hardiness of the current battery packs which can only improve given funding for research and development (Appendix J).

Recently, a relatively unknown company called AFS Trinity has claimed to have developed a highly advanced ‘Extreme Hybrid’ drive train system capable of sustaining extremely high efficiencies in the neighborhood of 150 mpg designed for use in the PHEV configuration. This is seen as the answer to the question of how the battery technology can sustain the demand for power in both the PHEV and EV, which is typically the main concern

with these vehicles. By using a combination of ultra capacitors and lithium ion batteries the electric system can deliver high amounts of power needed for acceleration without taxing the battery grid or producing resistive heating.

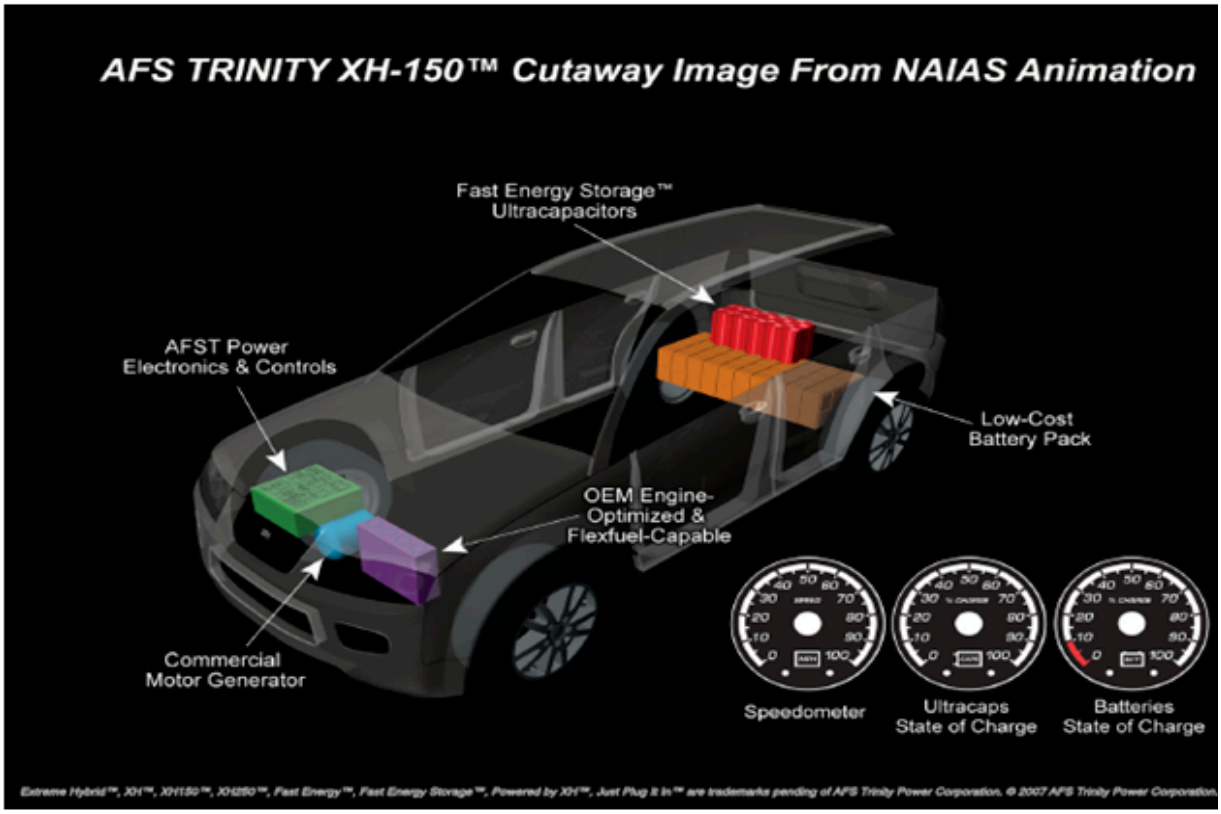


Figure 20: AFS Trinity XH-150 uses an ultracapacity in conjunction with battery

Ultra capacitors are electrochemical in nature and are basically the same as normal capacitors in principle but are much more functional and have their own unique practical purposes. They contain an extremely high energy to density ratio as high as 30 Wh/kg, which is thousands of times more than the electrolytic capacitors and is even almost as high as the lithium ion battery energy density of 50 Wh/kg. Take a D-sized cell (D-battery is a D-sized cell) an electrolytic capacitor of this size would be able to store a charge of tens of millifarads while an ultra capacitor could store several farads, obviously a huge improvement. Ultra capacitors can

also both apply loads quickly and be recharged to full strength in a matter of seconds; they cannot be overcharged, have low internal resistance thus high efficiency of around 95%, and long life usually lasting hundreds of thousands of cycles. However there are some drawbacks, although they can supply high amount of power they cannot supply a high amount of voltage, high dielectric absorption meaning that not all of the stored charge is able to be discharged completely. The additional large capacitors also take up some more room, however the design was implemented with an Sports Utility Vehicle in mind so although there is not much room for large objects in the storage area in the back there is certainly enough to hold most common things one may transport such as small tables or duffle bags a few golf bags. It also holds four to five passengers comfortably, which is certainly a nice perk for the average family (Appendix I).

When comparing pros and cons for use in a PHEV vehicle they prove more than capable of adding additional power on demand while actually improving overall performance of PHEV motor configuration. The battery performance is not sacrificed during a period where a large power is attempting to be drawn from the battery quickly which, due to inherent losses and limitations, causes the battery to discharge faster than normal. The overall result without the ultra capacitor is a battery which carries a lower charge for a shorter amount of time. This result also applies equally to both the PHEV and EV as both rely heavily on battery technology. Although AFS Trinity designed the system with the PHEV specifically in mind it is easily extendable to the EV configuration. Due to the heavy use and reliance on battery technology in PHEV and EV then the ultra capacitor and its respective setup should be equally important in the EV in improving overall performance. Also due to their similar design of the vehicles themselves converting the ultra capacitors from one to the other should be relatively simple, the only

difference really between the two is the presence of a small gasoline tank and a corresponding small combustion engine (Appendix K).

A simplified model is as follows, when high acceleration is required meaning high power delivered in a short time, the ultra capacitors can supply that energy. For simple driving such as constant speed the lithium ion batteries will be used and the capacitors will be recharged from the electric circuit flow from the batteries in seconds. Then once fully recharged the capacitors are ready to supply power for a second acceleration burst. The net result is a longer battery charge life and improved acceleration both major areas of interest and concern in both the PHEV and EV markets and major factors in their future.

Future Directions & Summary

We were able to conclude that in the long run hybrid vehicles and plug-in hybrid vehicles will be able to help the United States reach the goal of becoming more independent of foreign oil. Based on the research we conducted and other findings the popularity of hybrids will continue to grow and people will buy these state-of-art vehicles. We can increase these sales by lowering the purchasing cost and increasing the overall performance of the vehicle. If the majority of the fleet is PHEV/HEV by 2030 then it is conceivable that the US will be nearly if not completely independent of foreign oil by then or soon thereafter, especially when considering the current investments by both government and the auto industry into batteries and other electric technologies. The impact of the EV will be extremely significant and it will eventually replace the entire American fleet and with clean energy no harm to the environment due to transportation emissions all while giving us independence from our current oil addiction.

One possible way to help increase the market penetration of HEVs, PHEVs and EVs is to add additional taxes to gasoline. Consumers' willingness to purchase more expensive, but more fuel efficient vehicles greatly increases when the price of gasoline rises. This has mainly been seen in America when the price of oil increases, these conditions can also be created through the use of additional taxes on gasoline. While this increase in gasoline prices would hurt most consumers financially, if the additional taxes were used to provide higher subsidies on fuel efficient vehicles such HEVs, PHEVs, and EVs, it would help consumers keep their expenditures on gasoline to remain the same, while at the same time consuming less gasoline. The additional taxes could also be used to help fund the building of charging stations for PHEVs and EVs, further reducing the use of gasoline. While most consumers are against the concept of extra taxes

on gasoline, it is it likely that the government will continue to increase taxes on gasoline, and such measures could help push consumers to more fuel efficient vehicles.

The future of battery technology is quite straightforward. To improve the battery is quite simple just by creating new electrically conducting materials that were better than the last, which improves power delivery and reduces losses of the battery itself. The ultra capacitor working with the battery pack also solves the problem of a quick discharge when needed; in the future we believe the ultra capacitor will be a standard addition to the battery pack for the PHEV and the EV models. A particular configuration that is interesting and quite possible is one using hydrogen as a fuel source to supply chemical energy then converted into electrical energy to be stored into the battery packs and the ultra capacitors which will then be converted to mechanical energy to move the car via the transmission and other gear oriented shafts and axels.

Of course chemical energy may not be the only form of energy to be used in the future of vehicles. Mankind will not simply utilize a single type of energy but rather all the energy possible. That means integrating solar panels into the body of the car to catch solar energy, absorbing heat from the engine or from the surrounding environment, regenerative breaking where the mechanical energy is retrieved, and chemical energy released during reactions including the burning of hydrogen. All of the aforementioned energies can be collected, converted to electric energy, and then stored into the battery packs. This creates a nearly perfect fuel independent car simply running on the energy from the environment around it, the ultimate green vehicle.

Once the HEV/PHEV/EV technology has been well researched and developed to work out any possible complications or kinks it will begin to be integrated and altered for other uses in

other facets of the transportation industry. For use in trains, these electric motors could be easily integrated into a separate car unit on board the train for use in power generation; these will most likely be used in conjunction with the magnetic lift railways such as the ones currently in use in Japan. Other uses in trains are the simple change from conventional engines to electric ones on normal railways. Large commercial trucks will require a more powerful version of the PHEV/EV engine designs. They will be needed to supply a lot of power to carry heavy loads on multiple types of terrains. We believe the ultra capacitors will play a huge role in interacting with the battery pack to supply large bursts of power for hills or other obstacles that require that extra energy burst. Airplanes which utilize high percentage octane fuel will also most likely be converted to a PHEV or EV format. Unlike a train or a large truck the airplane engines can be quite different and will present somewhat more of challenge to integrate EV technology into compared to the train or truck. Although it can be done, it would just be a matter or reconfiguring the engine layout to accommodate the EV technology such as battery packs or the ultra capacitors. Jet engines utilizing hydrogen or other non oil based fuels will not need an EV integration, however the battery pack from the EV and PHEV could help supply the power to run the complex array of electronic equipment on a jet plane.

The EV has a promising future. The next logical evolution of the HEV is the PHEV and then the EV. We can see no reason why ultimately the EV would not replace the PHEV/HEV as the vehicle of tomorrow. It remains to be seen how powerful the EV can be, however it can match or exceed the power and efficiency necessary for the shipping industry, it is foreseeable that given an ample amount of time, the American fleet can be completely composed of HEVs, PHEVs, and EVs, perhaps even exclusively EV. Adapting these newer electric technologies may also change our household uses and may ultimately lead to a completely oil independent

America, where you charge your house battery instead of refilling your oil tank. Other advances include ‘wireless electricity’ where the EV no longer has to be plugged in, but simply dialed to a power stations emitting frequency to receive power via light waves.

Moving forward toward the future there are a few things that we believe are essential for entering the forefront of the hybrid automotive race. Right now the US automotive companies need to play catch up in certain areas, however they do not have time to invest in research and development for their own particular models of batteries or other small advances. They need to learn and adapt technology that’s already been developed especially regarding batteries from overseas such as the Japanese or Korean models. The next step is to build upon these existing models with our own research and development or even joint research programs among companies. Investment is the next key step, not only in the hybrid technology but also investing in the future sales of the HEV and PHEV by building factories or converting factories to increase output of the hybrid models. Then marketing, currently Toyota maintains a ludicrously large portion of hybrid sales stateside, for the US hybrid models to survive this needs to end US companies have to rival Toyota’s marketing campaign and counter with their own. Consistency, putting out multiple models can lead to hurting your overall vehicle sales, that’s why US automotive manufacturers must stick to a few key car ideas and models to continually make better to build up the brand name. The last and probably most important step is persistence, sales may not catch on quickly but rest assured that in time PHEV and HEV sales will continue to climb as more and more people embrace this technology and as the vehicles of tomorrow.

With Worcester Polytechnic Institute’s reputable engineering departments, it is our recommendation that WPI create its own hybrid division. This division would focus exclusively on hybrid technology researching improvements in a variety of aspects including efficiency,

batteries, and overall performance. It would consist of an interdisciplinary team of engineers from a variety of departments including but not limited to mechanical, electrical, and chemical engineering. In conjunction, we also recommend writing a thorough proposal to the Environmental Protection Agency and the United States department of transportation for funding for this research group. This technology is almost market ready and by having WPI's unique approach and point of view can only improve the quality of the vehicles being produced.

It would be a monumental mistake if the American automotive industry did not seize the opportunity to immediately initiate not only researching and developing new technologies, but also begin advancing current technology for use in the HEVs, PHEVs and EVs. Many other companies around the globe have already conducted years of research with their dedicated teams and have much to show for it. Toyota produced the Prius which is the highest selling HEV on the market since its introduction and continues to be the global standard in HEV technology. Honda has released the Insight to compete with the Prius, and only now has Ford produced a Fusion HEV which remains to be seen how well it will sell. Chevy has its eyes set on its PHEV, the Volt, which is also highly anticipated but it will not be on the market until sometime in 2010. Countless other companies have begun to invest millions into the PHEV and EV. We know what the car of the future is, and whoever creates the best model available for the correct price will have enormous profits. If this future technology can be pioneered here in America, it would revolutionize and revitalize Detroit and other centers of US automotive might. Thus, breathing new life into our economy, returning America to its hay days of massive exports and millions if not billions in positive revenue.

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Appendix A

BARACK OBAMA AND JOE BIDEN: NEW ENERGY FOR AMERICA

America has always risen to great challenges, and our dependence on oil is one of the greatest we ha ever faced. It's a threat to our national security, our planet and our economy. For decades, Washing has failed to solve this problem because of partisanship, the undue influence of special interests, an politicians who would rather propose gimmicks to get them through an election instead of long-ter solutions that will get America closer to energy independence.

Our country cannot afford politics as usual – not at a moment when the energy challenge we face is great and the consequences of inaction are so dangerous. We must act quickly and we must act bol transform our entire economy – from our cars and our fuels to our factories and our buildings.

Achieving this goal will not be easy. Energy independence will require far more than the same Washington gimmicks and continued dependence on costly and finite resources. It will require a sustained and shared effort by our government, our businesses, and the American people. But Ame has overcome great challenges before. With clarity of direction and leadership, there is no question we possess the insight, resources, courage and the determination to build a new economy that is powered by clean and secure energy.

Barack Obama and Joe Biden have a comprehensive energy plan that provides immediate relief to struggling families. It also summons the nation to face one of the great challenges of our time: confronting our dependence on foreign oil, addressing the moral, economic and environmental chal of global climate change, and building a clean energy future that benefits all Americans.

The Obama-Biden comprehensive New Energy for America plan will:

- Provide short-term relief to American families facing pain at the pump
- Help create five million new jobs by strategically investing $150 billion over the next ten ye to catalyze private efforts to build a clean energy future.
- Within 10 years save more oil than we currently import from the Middle East and Venezuel combined
- Put 1 million Plug-In Hybrid cars – cars that can get up to 150 miles per gallon – on the roa 2015, cars that we will work to make sure are built here in America
- Ensure 10 percent of our electricity comes from renewable sources by 2012, and 25 percen 2025
- Implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions percent by 2050

Make our Cars, Trucks and SUV's Fuel Efficient

Last year, oil provided more than 96 percent of the energy in our vehicles. It is an economic, national security and environmental imperative that this near-total dependence comes to an end. To achieve t goal, Barack Obama and Joe Biden will implement a strategy that will – within 10 years - allow us to reduce our consumption of oil by more than we currently import from the Middle East and Hugo Cha Venezuela combined. In order to do that, he will:

- ***Increase Fuel Economy Standards***. Barack Obama and Joe Biden will increase fuel economy standards 4 percent per each year while protecting the financial future of domestic automake The plan, which will save nearly a half trillion gallons of gasoline and 6 billion metric tons of greenhouse gases, will establish concrete targets for annual fuel efficiency increases while giv industry the flexibility to meet those targets.

- ***Invest in Developing Advanced Vehicles and Put 1 Million Plug-in Electric Vehicles on the I by 2015.*** As a U.S. senator, Barack Obama has led efforts to jumpstart federal investment in advanced vehicles, including combined plug-in hybrid/flexible fuel vehicles, which can get ove 150 miles per gallon of gas As president, Obama will continue this leadership by investing in advanced vehicle technology with a specific focus on R&D in advanced battery technology. Th increased federal funding will leverage private sector funds and support our domestic automa to bring plug-in hybrids and other advanced vehicles to American consumers. Barack Obama Joe Biden will also provide a $7,000 tax credit for the purchase of advanced technology vehicl well as conversion tax credits. And to help create a market and show government leadership i purchasing highly efficient cars, Barack Obama and Joe Biden will commit to:
  - Within one year of becoming President, the entire White House fleet will be converted plug-ins as security permits; and
  - Half of all cars purchased by the federal government will be plug-in hybrids or all-elect by 2012

- ***Partner with Domestic Automakers.*** Barack Obama and Joe Biden will also provide $4 billion retooling tax credits and loan guarantees for domestic auto plants and parts manufacturers, s that the new fuel-efficient cars can be built in the U.S. by American workers rather than overs

This measure will strengthen the U.S. manufacturing sector and help ensure that American workers will build the high-demand cars of the future.

- ***Mandate All New Vehicles are Flexible Fuel Vehicles.*** Sustainably-produced biofuels can c jobs, protect the environment and help end oil addiction – but only if Americans drive cars will take such fuels. Barack Obama and Joe Biden will work with Congress and auto compar ensure that all new vehicles have FFV capability – the capability by the end of his first term office.

- ***Develop the Next Generation of Sustainable Biofuels and Infrastructure***. Advances in bic including cellulosic ethanol, biobutenol and other new technologies that produce synthetic petroleum from sustainable feedstocks offer tremendous potential to break our addiction t Barack Obama and Joe Biden will work to ensure that these clean alternative fuels are deve and incorporated into our national supply as soon as possible. They will require at least 60 gallons of advanced biofuels by 2030. They will invest federal resources, including tax ince and government contracts into developing the most promising technologies and building th infrastructure to support them.

- ***Establish a National Low Carbon Fuel Standard.*** Barack Obama and Joe Biden will establ National Low Carbon Fuel Standard (LCFS) to speed the introduction of low-carbon non-petroleum fuels. The standard requires fuels suppliers in 2010 to begin to reduce the carbo their fuel by 5 percent within 5 years and 10 percent within 10 years. The Obama-Biden pla incentivize increased private sector investment in advanced low-carbon fuels and has a sustainability provision to ensure that increased biofuels production does not come at the e of environmental conservation. The LCFS is an important mechanism in ensuring that our to reduce our oil dependence also reduce carbon emissions.

Promote the Supply of Domestic Energy

With 3 percent of the world's oil reserves, the U.S. cannot drill its way to energy security. But U.S. gas production plays an important role in our domestic economy and remains critical to prevent g energy prices from climbing even higher. There are several key opportunities to support increased production of oil and gas that do not require opening up currently protected areas.

- ***A "Use it or Lose It" Approach to Existing Leases.*** Oil companies have access to 68 million of land, over 40 million offshore, which they are not drilling on. Drilling in open areas could significantly increase domestic oil and gas production. Barack Obama and Joe Biden will re oil companies to diligently develop these leases or turn them over so that another company develop them.

- ***Promote the Responsible Domestic Production of Oil and Natural Gas.*** Barack Obama ar Biden will set up a process for early identification of any infrastructure obstacles/shortage possible federal permitting process delays to drilling in:

    - Bakken Shale in Montana and North Dakota which could have as much as 4 billion recoverable barrels of oil according to the U.S. Geological Survey.

    - Unconventional natural gas supplies in the Barnett Shale formation in Texas and the Fayetteville Shale in Arkansas.

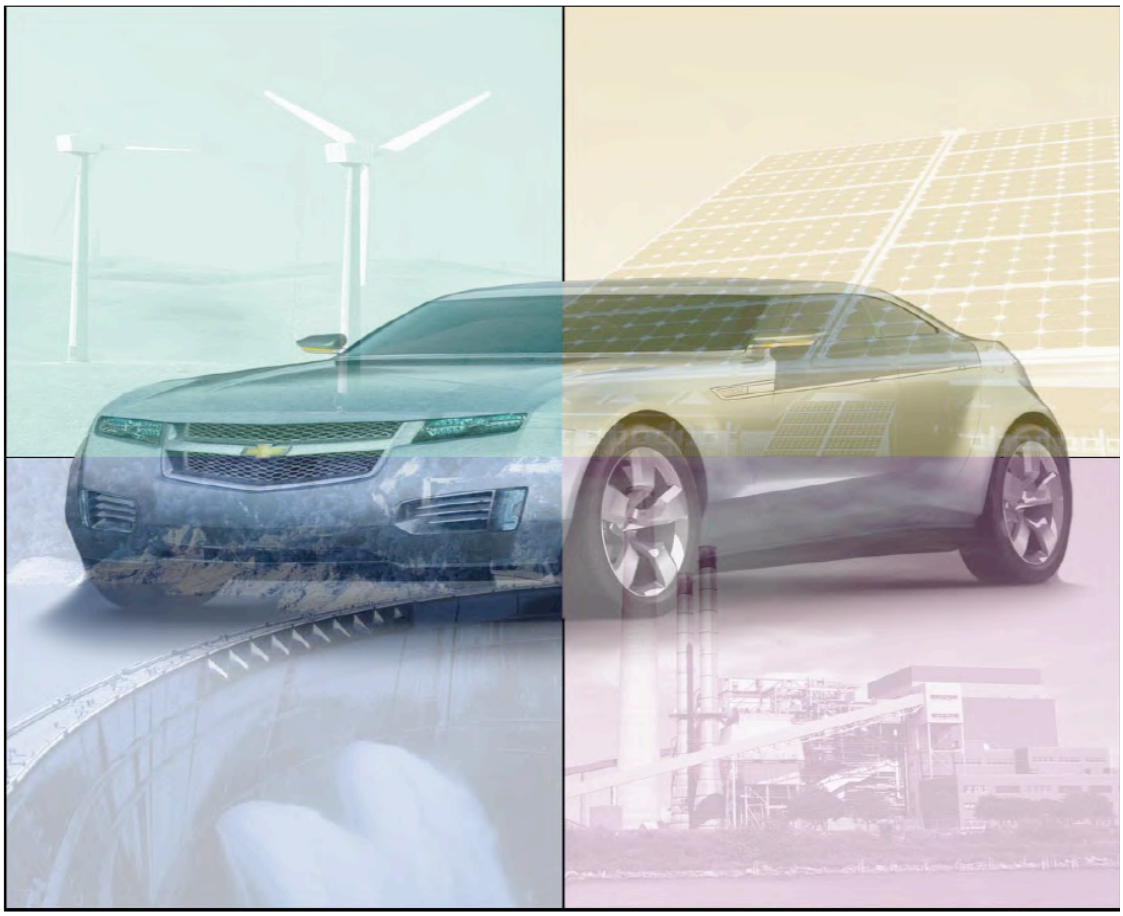
Appendix B

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

NRDC
THE EARTH'S BEST DEFENSE

Environmental Assessment of Plug-In Hybrid Electric Vehicles

Volume 2: United States Air Quality Analysis
Based on AEO-2006 Assumptions for 2030



Environmental Assessment of Plug-In Hybrid Electric Vehicles

Volume 2: United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030

1015326

Final Report, July 2007

Each of the ... scenarios showed significant Greenhouse Gas reductions due to PHEV fleet penetration ...

... PHEVs adoption results in significant reduction in the consumption of petroleum fuels.

EPRI Project Managers

E. Knipping

M. Duvall

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Appendix C

December 2009 Hybrid Market Dashboard

read more online at http://www.hybridcars.com/market-dashboard.html

hybridCARS in partnership with POLK

December 2009: A Hybrid Recovery?

The final tally of hybrid sales for 2009 comes in at 290,272 units—not bad for a year in which auto sales imploded. Hybrid sales were off by 8 percent compared to 2008, while the overall market fell by 21 percent. The total market share of hybrid gas-electric vehicles was 2.8 percent.

How did hybrids manage to maintain a decent sales performance in 2009, when they are more expensive than comparable conventional models, and gas prices were modest? The answer is new product introductions, including the Ford Fusion Hybrid, Honda Insight, and Lexus HS250h. Sales of all the existing popular hybrid models took a tumble, but the new models softened the blow to the segment.

The expected growth of hybrids in 2010 will benefit from even more new models, as well as an improved market, and higher production output on popular models like the Toyota Prius. We expect the share of market to easily surpass 3 percent next year, as it climbs approximately one point a year throughout the decade. There will be casualties along the way—particularly hybrid models from General Motors, such as the Chevy Malibu Hybrid, and the Saturn Vue and Saturn Aura hybrids. These models are either dead or will soon be killed off. These cancellations will have limited impact on the market, because they never made more than a blip on the sales radar in the first place.

The arrival of plug-in hybrids and electrics makes it difficult to forecast hybrid sales for 2010. What impact will these electric-drive cars have on conventional hybrids? Will buyers waiting for a more robust electric drive hold off on a hybrid purchase in 2010, until plug-in technology arrives? Will the new models simply displace sales of conventional models? Or will plug-in cars fuel growth in all greener advanced technology vehicles? With the right economic conditions and government incentives—and compelling new models coming to market—sales of hybrid and electric cars could exceed the rosiest predictions

2009 global hybrid registrations

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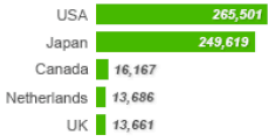
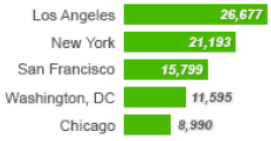
Top 5 global hybrid markets



Top 5 US hybrid markets



SOURCE: R. L. POLK & CO.

US Sales

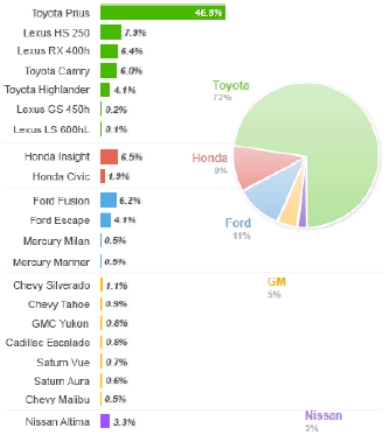
Our information is based on hybrid sales as reported by the manufacturers. For each model, this month's sales are shown compared to sales in the previous month and at the same time last year. We also examine hybrid market share by model and manufacturer.

Hybrids sold in the U.S. (December 2009): 25,160

US Hybrid Sales for December 2009

Model	Units	vs. 11/09	vs. 12/08
Prius	11,775	22.4%	49.8%
HS250h	1,980	40.7%	n/a
Insight	1,639	16.8%	n/a
RX400h	1,598	32.1%	9.2%
Fusion	1,556	19.3%	n/a
Camry	1,513	3.3%	-19.9%
Escape	1,036	18.5%	-0.7%
Highlander	1,029	42.5%	15.6%
Altima	842	67.4%	18.6%
Civic	471	93.8%	-54.5%
Silverado (est)	279	78.6%	n/a
Yukon (est)	237	78.6%	-46.3%
Escalade (est)	205	78.6%	-33.0%
Tahoe	203	-15.9%	-79.3%
Vue	186	38.7%	-45.0%
Aura	159	448.3%	367.6%
Malibu	132	-37.7%	-70.9%
Milan	130	34.0%	n/a
Mariner	121	40.7%	14.2%
GS450h	54	45.9%	5.9%
LS600hL	15	0.0%	-70.0%
All hybrids	25,160	25.8%	42.2%
All vehicles	1,029,936	37.9%	15.1%

U.S. Hybrid Sales for December 2009 by Manufacturer and Model



Regional Data

Curious where hybrid buyers live? We present the data in two ways. First, w list the 15 cities and states that boas the largest numbers of new hybrids their roads within the past year. For example, residents in the New York area put over 8,000 new hybrids on road in 2007. Second, we adjust for population and look at hybrids per person (in states) or per household (metro areas). This lets us include citi like Portland, OR: a city that has few overall vehicles (and thus fewer hybr but has more hybrids per capita thar anywhere else.

States with the Most Hybrid Sales

Rank	State	New Hybrids*
1	California	55,553
2	New York	15,348
3	Florida	14,949
4	Texas	14,632
5	New Jersey	11,367

Most Popular States for Hybrids

Rank	State	New Hybrids 1000 resident
1	District of Columbia	3.790
2	California	1.540
3	Washington	1.530
4	Vermont	1.420
5	Massachusetts	1.320
	U.S. State Average	0.87

Cities with the Most Hybrid Sales

Rank	Metropolitan Area	New Hybrids*
1	Los Angeles	26,677
2	New York	21,193
3	San Francisco	15,799
4	Washington DC	11,595
5	Chicago	8,990

Most Popular Cities for Hybrid

Rank	Metropolitan Area	New Hyb per 1000 residents
1	Portland, OR	8.800
2	Helena	6.700
3	San Francisco	6.700
4	Washington, DC	5.100
5	Los Angeles	4.800
	U.S. Metro Area Average	1.800

*Registrations CYTD November 2009

http://www.hybridcars.com/hybrid-sales-dashboard/december-2009-dashboard.html

December 2008 Hybrid Market Dashboard

read more online at http://www.hybridcars.com/market-dashboard.html

hybridCARS in partnership with

Overview

Overall 2008 auto sales ended down 18 percent compared with 2007, with hybrid sales down by 10 percent. Most of the pain came in the fourth quarter, when sales of all vehicles (hybrids included) plummeted by more than a third to levels not seen since the early 1990s.

While dismal sales are predicted to continue well into 2009, automakers are betting that the way out of this mess lies in green, high-tech offerings. Nearly every major automaker showcased new electric-drive vehicles at the Detroit show, including hybrids (Toyota Prius, Honda Insight, and Ford Fusion), plug-in hybrids (Daimler E-Cell Plus, Cadillac Converj, and Chrysler Town & Country EV) and electric vehicles (Toyota FT-EV, Dodge Circuit EV, and Ford Focus EV). Finally, the auto industry seems to be getting the message that there is a market for more than just horsepower, towing capacity, and cup holders: electrification is widely accepted as the next big thing.

But the area to watch in 2009 is not vehicle launches or high-tech concepts: it's production volumes. Introducing new hybrid and electric vehicle models is fine, but those vehicles will only have a real impact on oil consumption and emissions if they are produced and sold in large volumes.

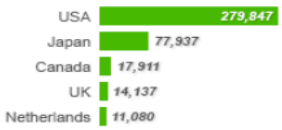
Consider the relative hybrid "take rates" for three hybrid makers. Honda sold 1.4 million vehicles this year in the US, and roughly 31,500 hybrids—equal to 2.2 percent of the total. Almost 11 percent of the Toyota's US sales were hybrids.

General Motors, offer an impressive number of hybrid models, but produce them in such small quantities that hybrids amount to an insignificant fraction of the companies' overall vehicle offerings. If automakers like GM are truly betting their future on hybrids and other electric-drive technologies, they have put surprisingly few chips on the table to-date. Whether this changes in 2009 remains to be seen.

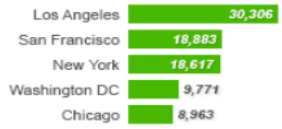
The way to tell will be to look beyond this week's flashy product announcements and the slick advertising copy that follows. Instead, scrutinize next year's production numbers, and you'll be able to tell who is serious about electrification, and who is simply trying to steal momentum from the latest automotive trend.

2008 global hybrid registrations

Top 5 global hybrid markets



Top 5 US hybrid markets



SOURCE: R. L. POLK & CO.

US Sales

Our information is based on hybrid sales as reported by the manufacturers. For each model, this month's sales are shown compared to sales in the previous month and at the same time last year. We also examine hybrid market share by model and manufacturer.

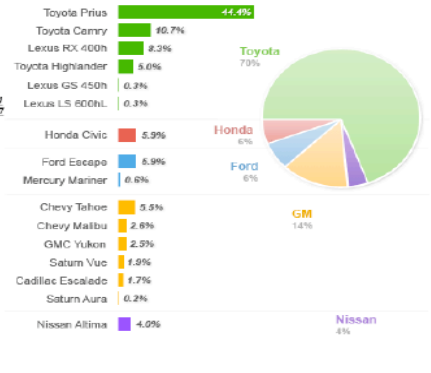
Hybrids sold in the U.S. (December 2008): 17,697

US Hybrid Sales for December 2008

Model	Units	vs. 11/08	vs. 12/07
Prius	7,859	-9.2%	-44.7%
Camry	1,888	-13.2%	-62.0%
Highlander	890	-1.9%	-68.1%
RX400h	1,463	134.5%	-28.0%
LS600hL	50	35.1%	-61.2%
GS450h	51	21.4%	-62.5%
Civic	1,036	-0.7%	-67.9%
Escape	1,043	-12.0%	-47.6%
Mariner	106	-39.8%	-61.6%
Yukon	442	132.6%	n/a
Malibu	454	132.8%	n/a
Vue	338	3.0%	1,509.5%
Tahoe	981	142.8%	n/a
Aura	34	-24.4%	3.0%
Altima	710	101.1%	-26.3%
Escalade	306	56.9%	n/a
Aspen*	46	n/a	n/a
All hybrids	17,697	7.0%	-42.8%
All vehicles	894,967	19.7%	-35.6%

*Aspen Hybrid sales number includes sales for both Chrysler two-mode SUV models

U.S. Hybrid Sales for October 2008 by Manufacturer and Model



Regional Data

Curious where hybrid buyers live? present the data in two ways. First list the 15 cities and states that bo the largest numbers of new hybric their roads within the past year. Fo example, residents in the New Yor area put over 8,000 new hybrids o road in 2007. Second, we adjust fo population and look at hybrids pe person (in states) or per household metro areas). This lets us include like Portland, OR: a city that has fe overall vehicles (and thus fewer hy but has more hybrids per capita th anywhere else.

States with the Most Hybrid Sale

Rank	State	New Hybric
1	California	67,92
2	New York	15,43
3	Texas	14,43
4	Florida	14,38
5	Illinois	11,25

Most Popular States for Hybrids

Rank	State	New Hybr 1000 resid
1	California	1.88
2	District of Columbia	1.79
3	Oregon	1.49
4	Washington	1.46
5	Vermont	1.40
	U.S. State Average	0.88

Cities with the Most Hybrid Sale

Rank	Metropolitan Area	New Hybric
1	Los Angeles	30,30
2	San Francisco	18,88
3	New York	18,61
4	Washington DC	9,771
5	Chicago	8,963

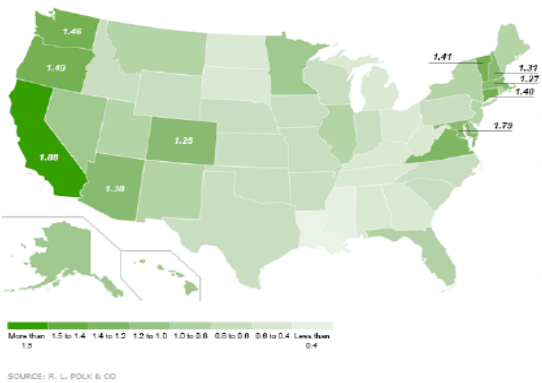
Most Popular Cities for Hybrid

Rank	Metropolitan Area	New per 1 resid
1	Portland, OR	11.1
2	San Francisco	8.01
3	Monterrey, CA	6.62
4	Santa Barbara, CA	6.29
5	San Diego	5.94
	U.S. Metro Area Average	1.96

*Registrations CYTD October 2008

Hybrid Sales Intensity for US States

New Hybrids per 1000 Residents - 2008 (Through October)



SOURCE: R. L. POLK & CO

http://www.hybridcars.com/hybrid-sales-dashboard/december-2008-dashboard-focus-production-numbers-25416.html

December 2007 Hybrid Market Dashboard

hybridCARS in partnership with POLK

read more online at http://www.hybridcars.com/market-dashboard.html

Overview

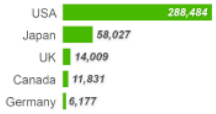
The final 2007 hybrid sales numbers have been tallied, and the headline news is the 100,000-unit increase in gas-electric cars purchased in the Unites States. In a year when total light-duty vehicle sales declined by 2.5 percent, hybrid sales grew by 38 percent to 350,000 units compared with 250,00 in 2006.

97 percent of the increase came from two vehicles and one carmaker. The Toyota Prius increased sales year-over-year by 74,250 units, while the Toyota Camry added more than 23,000 units. All other hybrids remained almost completely flat or slightly declined. So while automakers like General Motors talked a lot about hybrids in 2007, only Toyota put large volumes of hybrid vehicles on US roads, and only Toyota saw substantial sales growth for its hybrid models.

The other story for the year is the impressive "take rate" of hybrid versions of some cars that offer both gasoline and gas-electric variants—and the failure of others. Nearly one in five Highlanders leaving showroom floors were hybrids. Approximately one in eight Camrys were hybrids; and ratios for Escapes and Civics were approximately 1:9 and 1:10 respectively.

2007 global hybrid registrations

Top 5 global hybrid markets



Top 5 US hybrid markets

SOURCE: R. L. POLK & CO.

"Top 5 global hybrid markets" based on vehicle registrations January – October 2007.

and "Top 5 US hybrid markets" based on vehicle registrations January – October 2007.

Despite all the hand-wringing about the importance of cars like the Prius that are offered only as hybrids, carmakers can successfully introduce hybrid options in conventional vehicles and slowly increase sales of those hybrid versions. The key is finding the right hybridization formula. Which vehicle gets the hybrid option? What kind of hybrid system, mild or full? Which gas engine is mated to a hybrid drivetrain? What are the overall benefits of the hybrid version?

Toyota succeeded by offering the hybrid option on the four-cylinder Camry—and the Civic Hybrid, also a four-banger, sold relatively well. But full-hybrid systems added to more expensive Lexus luxury sports sedans did poorly, and the Saturn BAS mild hybrid combination barely made a blip. Saturn may have more luck in late 2008 when it introduces the full two-mode hybrid version of the Saturn Vue, which provides a more a significant boost in fuel economy compared with the conventional Vue. The fact that Lexus is having modest success with the hybrid RX400h SUV, despite only a small improvement in mpg, proves that concocting the right hybrid formula is more art than science.

Looking Ahead

There are three major trends to consider for "alternative autos" in 2008. The first is gas prices. In 2007, interest and sales of hybrids rose and fell in rough correlation with gas prices. May brought the biggest jump at the pumps, and hybrid sales bounced right along. High gas prices, combined with energetic hybrid marketing efforts from Toyota, produced a whopping 47,096 sales for May. That pattern of high gas prices and high hybrid sales repeated itself more modestly in November. Could hybrid waiting lines return if gas makes its way to $4 per gallon in 2008?

The next factor is General Motors. GM's plans to introduce a new hybrid every quarter are underway. GM finally has hybrid vehicles to offer, and in a range of sizes from medium to extra large. Will GM provide more sales and marketing support for their available hybrids, or will they focus marketing dollars and television commercials on the Chevy Volt, which is still at least three years away? If the company pushes the available hybrids, then those marketing dollars should be focused on California, the West Coast, and major metropolitan areas, where hybrids still represent the lion's share of sales.

And the final trend is diesel. A handful of "clean diesel" vehicles from Mercedes, Jeep and Volkswagen will pass stringent California emissions standards so they can be sold in all 50 states. It will be up these companies to convince fuel- and eco-conscious buyers that diesels offer the best combination of performance, efficiency, and overall value. Clean diesel probably won't displace hybrids as the leading green car option. However, the new diesel offerings will provide another solution for consumers seeking high-mpg vehicles.

US Sales

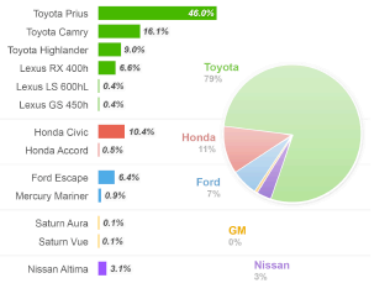
Our information is based on hybrid sales as reported by the manufacturers. For each model, this month's sales are shown compared to sales in the previous month and at the same time last year. We also examine hybrid market share by model and manufacturer. The historical sales graph for top-selling hybrid models shows final 2007 volumes.

Hybrids sold in the U.S. (December 2007): 30,925

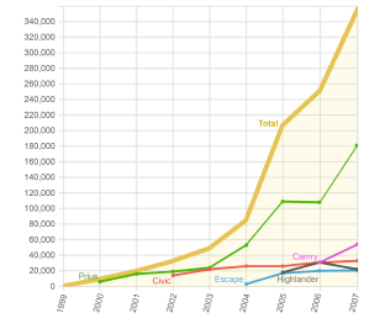
US Hybrid Sales for December 2007

Model	Units	vs. 11/07	vs. 12/06
Altima	964	-19.1%	n/a
Prius	14,212	-15.1%	53.0%
Civic	3,223	-0.5%	33.8%
Accord	150	-26.5%	-58.7%
Camry	4,969	-2.9%	24.1%
Highlander	2,791	8.3%	18.6%
RX400h	2,032	21.4%	2.6%
GS450h	136	36.0%	-46.0%
LS600hL	129	-24.1%	n/a
Escape	1,989	7.7%	13.8%
Mariner	276	-27.0%	25.5%
Vue	21	0.0%	-96.9%
Aura	33	-45.9%	n/a
All hybrids	30,925	-7.2%	32.7%
All vehicles	1,390,092	17.8%	-2.9%

U.S. Hybrid Sales for December 2007 by Manufacturer and Model



U.S. Hybrid Market Sales (1999 – 2007)



Regional Data

We present the data in two ways. First, we list the cities and states that boast the largest numbers of new hybrids on their roads within the past year. Second, we adjust for population and look at hybrids per person (in states) or per household (in metro areas). This lets us include cities like Portland, OR: a city that has fewer overall vehicles (and thus fewer hybrids) but has more hybrids per capita than anywhere else.

States with the Most Hybrid Sales

Rank	State	New Hybrids*
1	California	74,737
2	Florida	15,265
3	New York	14,580
4	Texas	13,909
5	Illinois	10,865

Most Popular States for Hybrids

Rank	State	New Hybrids per 1000 residents*
1	California	2.068
2	Oregon	1.922
3	Vermont	1.725
4	Washington	1.715
5	Washington DC	1.646
	U.S. State Average	0.892

Cities with the Most Hybrid Sales

Rank	Metropolitan Area	New Hybrids*
1	Los Angeles	33,450
2	San Francisco	21,964
3	New York	17,105
4	Washington DC	10,697
5	Seattle	9,110

Most Popular Cities for Hybrids

Rank	Metropolitan Area	New Hybrids per 1000 residents*
1	Portland, OR	14.229
2	San Francisco	9.324
3	Monterey, CA	7.681
4	Santa Barbara	6.420
5	Los Angeles	6.042
	U.S. Metro Area Average	1.952

*Registrations CYTD October 2007

http://www.hybridcars.com/market-dashboard/dec06-overview.html

December 2006 Dashboard

Published January 8, 2007

"Expected 2006 global hybrid sales" based on vehicle registration trends through October 2006.

"Top 5 global hybrid markets" and "Top 5 US hybrid markets" based on vehicle registrations CYTD October 2006.

Mark Twain once quipped that the reports of his death had been greatly exaggerated. So too have the reports about waning hybrid demand. A few weeks ago, the *Chicago Tribune* published a widely-syndicated article suggesting that hybrid sales were slumping, just as automakers like Nissan and GM are readying new models for the marketplace. While the story raises some interesting issues, the suggestion that hybrids are dead is just plain wrong.

It's true that hybrid sales have lagged somewhat this fall, a topic that has been noted on this dashboard. But sales of hybrids were back up in December, buoyed partly by rising sales across the automobile market. 22,625 hybrids were sold in December, 24% more than last month, and substantially more hybrids than were sold last December. So after a few slower months, hybrid sales seem to have rebounded.

Of course, current sales don't really tell us much about what will happen in the future. According to the *Tribune* article, things may not look good. The article presents ominous data from CNW Market Research claiming that the number of car shoppers considering hybrids has fallen by more than half in the past year. To be sure, fewer people saying they are interested in hybrids can't be great news. But just how much of an effect this has on hybrid sales remains to be seen. In the first eight months of 2006, CNW claimed that interest in hybrids was falling steadily, yet sales jumped 68% from January to August. Some of this increase is certainly due to seasonal variation in auto sales, but the number of people who say they are considering a hybrid doesn't always match well with the number of people who actually buy one.

The real news about hybrids is the 2006 sales numbers. This year, hybrid sales grew almost 23% in an overall vehicle market that declined slightly. Much of this growth was due to the introduction of the Camry hybrid in April 2005, but even if we exclude new models, hybrid sales grew at a respectable 6.6%. Some critics may point out that sales of the most popular hybrid model, the Prius, were flat in 2006. In our view, the fact that a vehicle with a three-year-old design, inflexible pricing, and constrained availability continued to attract more than 100,000 buyers this year is a signal that the hybrid market is alive and well. In fact, looking across the field of hybrid models, just one (the Honda Accord Hybrid) saw a significant sales drop in 2006. No one can be sure what 2007 will bring, but we believe hybrid sales will be far healthier than many analysts predict.

US Sales

Our information is based on hybrid sales as reported by the manufacturers. For each model, this month's sales are shown compared to sales in the previous month and at the same time last year. We also examine hybrid market share by model and manufacturer. The historical sales graph for top-selling hybrid models shows estimated 2006 volumes based on sales-to-date.

Hybrids sold in the U.S. (January - December 2006): **252,636**

U.S. hybrid sales for December 2006

Model	Units	vs. 11/06	vs. 12/05
Insight	3	50.0%	92.9%
Prius	9,291	16.0%	2.9%
Civic	2,408	9.1%	4.7%
Accord	363	16.7%	49.6%
Camry	4,005	29.2%	n/a
Highlander	2,354	41.2%	7.1%

Model	Units	vs. 11/06	vs. 12/05
RX400h	1,981	49.3%	8.8%
GS450h	252	43.2%	n/a
Escape	1,748	32.1%	24.6%
Mariner	220	36.6%	46.7%
All hybrids	22,625	23.7%	24.0%

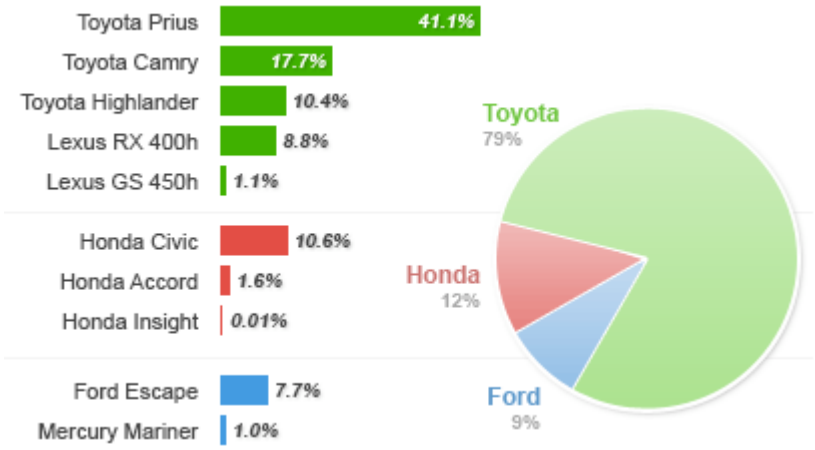
U.S. hybrid 2006 monthly sales by make

	Jan	Feb	Mar	Apr	May	Jun
Insight	59	72	79	110	92	77
Prius	7,654	6,547	7,922	8,234	8,103	9,696
Civic	3,165	1,780	2,232	3,087	2,890	2,601
Accord	351	783	581	614	520	396
Camry	n/a	n/a	n/a	86	3,032	4,268
Highlander	2,263	2,631	2,987	3,768	3,755	2,705
RX400h	1,477	1,803	2,470	2,247	2,006	1,190
GS450h	n/a	n/a	n/a	141	294	231
Escape	801	1,233	1,441	3,039	2,434	1,569
Mariner	97	108	149	381	428	315
Total	15,867	14,957	17,861	21,707	23,554	23,048

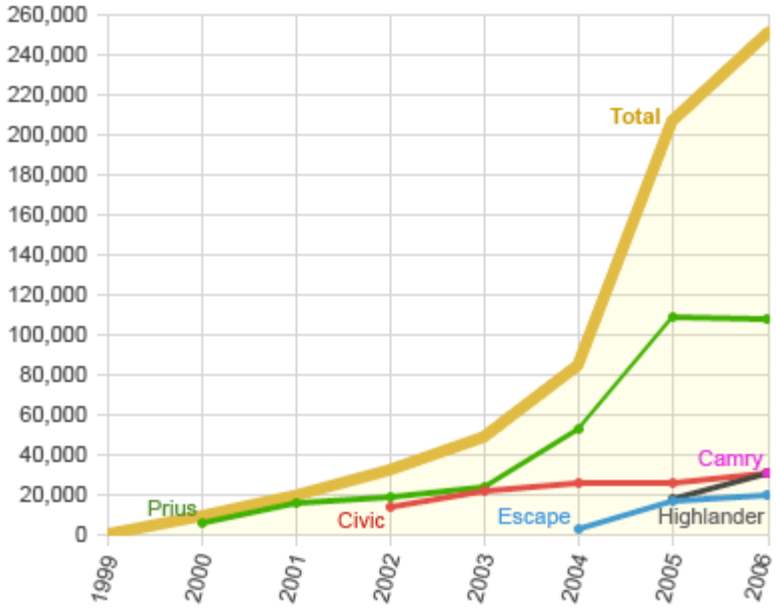
	Jul	Aug	Sep	Oct	Nov	Dec	2006 Totals
Insight	91	109	19	9	2	3	722
Prius	11,114	11,177	10,492	8,733	8,008	9,291	106,971

	Jul	Aug	Sep	Oct	Nov	Dec	2006 Totals
Civic	2,673	3,411	2,508	2,288	2,208	2,408	31,251
Accord	504	499	389	287	311	363	5,598
Camry	5,023	4,977	4,044	2,806	3,100	4,005	31,341
Highlander	2,784	2,581	2,347	1,643	1,667	2,354	31,485
RX400h	1,220	1,514	1,687	1,239	1,327	1,981	20,161
GS450h	157	192	164	177	176	252	1,784
Escape	2,060	1,789	1,369	1,343	1,323	1,748	20,149
Mariner	423	351	282	259	161	220	3,174
Total	26,049	26,600	23,301	18,784	18,283	22,625	252,636

U.S. hybrid sales for December 2006 by manufacturer and model



U.S. hybrid market yearly sales (1999 - 2006)



Regional Data

Source: R. L. Polk & Co.

Curious where hybrid buyers live? We present the data in two ways. First, we list the 15 cities and states that boast the largest numbers of hybrids on their roads. For example, residents in the New York City area put over 9,000 new hybrids on the road this year. Second, we adjust for population and look at hybrids per person (in states) or per household (in metro areas). This lets us include cities like Portland, OR: a city that has fewer overall vehicles (and thus fewer hybrids) but has more hybrids per capita than anywhere else.

Monthly Update: So we've told you the states where hybrids are most popular. But how about the state where hybrid SUVs are most popular? Or the state where hybrids from the Big 3 get the best reception? Or what about the state where people like luxury hybrids best? In fact, the answer to all three of these questions is the nation's capital: Washington, DC. In the first 10 months of 2006, buyers in the District of Columbia put 746 hybrids on the road. While that may not sound like a lot, it is when you consider that there are just over a half a million people living within the District (we left out the suburbs in this analysis). That puts DC just behind #1 California for the most hybrids per capita. And it seems that DC's hybrid drivers like SUVs, perhaps since they offer more seating for bodyguards, aides, or groups of Congressional interns. DC buyers also

show strong brand preferences: Ford and GM models sell well here, as do luxury hybrids from Lexus. One may signal patriotism and the other status—two messages that are always fashionable in the nation's capital.

States with the Highest Hybrid Sales

Rank	State	Registered Hybrids*
1	California	56,466
2	Florida	10,751
3	Texas	10,656
4	New York	9,904
5	Virginia	9,112
6	Illinois	7,884
7	Pennsylvania	7,120
8	Washington	7,089
9	Massachusetts	6,218
10	New Jersey	5,954
11	Maryland	5,755
12	North Carolina	5,668
13	Ohio	4,976
14	Oregon	4,931
15	Arizona	4,627

*2006 Registrations (October 2006 YTD)

States where hybrids are most popular

Rank	State	Hybrids per 1000 residents*
1	California	1.56
2	District of Columbia	1.36
3	Oregon	1.35
4	Vermont	1.21
5	Virginia	1.20
6	Washington	1.13
7	New Hampshire	1.10
8	Hawaii	1.10
9	Maryland	1.03
10	Colorado	0.98
11	Massachusetts	0.97
12	Connecticut	0.84
13	Delaware	0.81
14	New Mexico	0.78
15	Arizona	0.78

*2006 Registrations (October 2006 YTD)

Metropolitan areas with the highest hybrid sales

Rank	Metropolitan Area	Hybrids*
1	Los Angeles	26,031
2	San Francisco	17,151

Rank	Metropolitan Area	Hybrids*
3	New York	11,953
4	Washington, DC	9,796
5	Boston	6,564
6	Chicago	6,341
7	Seattle	5,891
8	Philadelphia	5,762
9	San Diego	4,286
10	Sacramento, CA	3,996
11	Denver	3,977
12	Portland, OR	3,747
13	Phoenix	3,519
14	Dallas/Ft. Worth	3,086
15	Houston	3,057

*2006 Registrations (October 2006 YTD)

Metropolitan areas where hybrids are most popular

Rank	Metropolitan Area	Hybrids per 1000 Households*
1	Portland, OR	9.21
2	San Francisco, CA	7.28
3	Monterey, CA	5.83
4	Santa Barbara, CA	5.15
5	Los Angeles	4.70

Rank	Metropolitan Area	Hybrids per 1000 Households*
6	Bend, OR	4.42
7	Washington, DC	4.35
8	Charlottesville, VA	4.23
9	San Diego	4.18
10	Eugene	3.76
11	Seattle	3.46
12	Honolulu	3.37
13	Eureka	3.15
14	Sacramento, CA	2.97
15	Madison, WI	2.91

*2006 Registrations (October 2006 YTD)

Looking Ahead

Americans purchased more than one-quarter of a million hybrid cars and trucks in 2006. So what will hybrid sales look like in 2007? Analysts' forecasts vary widely, projecting sales growth as low as 19% and as high as 86%. We're not sure which of those forecasts is the right one, but we're optimistic about next year's hybrid sales for two reasons:

Toyota is optimistic. At the moment at least, Toyota drives the hybrid market. Their models accounted for more than three-quarters of all hybrid sales in 2006. In an interview last month with *Automotive News*, Toyota President Katsuaki Watanabe estimated 2007 North American sales at 300,000 units, roughly a 50% increase from 2006. Market analysts (including us) can predict whatever sales number they want for next year, but when Toyota's President provides sales guidance, it's the real deal.

The number of hybrid offerings will expand dramatically. In the next 12 months, the number of vehicles offering hybrid powertrains will double (planned launches are shown in the table below.) The result will be more choice for consumers interested in buying hybrids. While some of the new vehicles (like the Mazda Tribute) are essentially just rebadged versions of existing hybrid models, other new models expand the hybrid footprint into new vehicle classes. Pay close attention to sales of the hybridized Chevy Tahoe, GMC Yukon, Cadillac Escalade, and Dodge Durango. Unlike previous mild-hybrid truck offerings, these four are true full-hybrids,

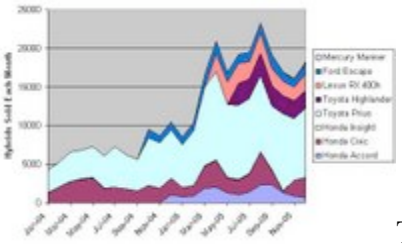
employing the dual-mode hybrid system developed by the GM/DaimlerChrysler/BMW alliance. We have our doubts about how enthusiastic full-sized SUV buyers will be about hybrid technology. But a half a million Americans bought full-sized SUVs last year. Even if a modest fraction of them opted for a hybrid version, it could boost overall hybrid sales considerably.

Nissan Altima	Early 2007
Chevrolet Malibu	Mid 2007
Lexus 600h	Mid 2007
Mazda Tribute Hybrid	Mid 2007
Saturn Aura Green Line	Mid 2007
GMC Yukon	Late 2007
Chevrolet Tahoe	Late 2007
Cadillac Escalade	Late 2007
Dodge Durango	Late 2007
Audi Q7	Late 2007

Source: http://www.hybridcars.com/market-dashboard/dec06-overview.html

Thursday, January 05, 2006

Record number of hybrids sold in the US in 2005



The number of hybrid vehicles sold in the US increased from 83,924 to 205,748 units from 2004 to 2005. That's an increase of 245%.

Toyota/Lexus captured 71.2% of the hybrid market in 2005 increasing it's share in 2004 by 7.2%. Driven mainly by the Accord and Civic sales, Honda took 21.1%, a decrease from the 32.5% share it had in 2004. Relative newcomer Ford, minimally aided by the recent production of the Mercury Mariner took 7.7% of all sales in the US of all hybrid vehicles.

The Toyota Prius is still selling the majority of hybrids, capturing 52.4% of they hybrid market. While it's share is down from 64%, it's overall units sold have doubled from last year (53,721 units in 2004 to 107,897 units in 2005). In a distant second place comes the Honda Accord with 25,864 units (12.6% of the total hybrid market) sold in 2005.

Altogether, Toyota sold 146,512 units between the Prius (107,897), Highlander (17,954), and Lexus Rx400h (20,661). Honda sold 43,356 hybrid Accord (16,826), Civic (25,864) and Insight (666) units over the 2005 period. Ford sold 15,880 units with it's Ford Escape (15,571) and the recently introduced Mercury Mariner (309).

Month-Year	Honda Accord	Honda Civic	Honda Insight	Toyota Prius	Toyota Highlander	Lexus RX 400h	Ford Escape	Mercury Mariner
Jan-04		1282	45	2925				
Feb-04		1975	59	3215				
Mar-04		2725	83	3778				
Apr-04		3041	107	3684				

May-04		3183	130	3962				
Jun-04		1802	61	4219				
Jul-04		1963	34	5230				
Aug-04		1816	23	4393				
Sep-04		1535	12	4039				
Oct-04		2266	11	6123			1130	
Nov-04		1867	35	5866			864	
Dec-04	1061	2116	8	6287			969	
Jan-05	805	1169	7	5566			908	
Feb-05	855	1353	22	7078			1092	
Mar-05	1862	2896	56	10236			1569	
Apr-05	2023	3466	90	11345		2345	1705	
May-05	1314	1895	52	9461		2931	1234	
Jun-05	1080	1852	69	9622	2869	2605	1126	
Jul-05	1376	2329	68	9691	2564	2262	1138	
Aug-05	2336	4146	80	9850	2925	2607	1363	
Sep-05	2352	1916	83	8193	2715	2113	1808	
Oct-05	1266	231	37	9939	2330	1904	1227	
Nov-05	837	2083	60	7889	2353	1722	998	161
Dec-05	720	2528	42	9027	2198	2172	1403	148

4 comments:

Mark said...

Hey Mike,
Where did you get these numbers?

11:59 AM

Mike said...

All numbers were taken from press releases made by the various companies.

2:22 PM

Anonymous said...

Could you specify where you got these numbers from? Especially the numbers on your diagram comparing different hybrids from various companies?
thanks a lot.

5:22 AM

Mike said...

Again, I got most of the numbers from the press releases the companies put out.

11:21 AM

Source: http://hybridreview.blogspot.com/2006/01/record-number-of-hybrids-sold-in-us-in.html

Published on Monday, April 25, 2005 by the Associated Press

Hybrid Car Sales Soar in U.S. in 2004

by Dee-Ann Durbin

DETROIT -- The lure of the Toyota Prius and other hybrid cars helped drive healthy sales of electric and alternative-powered vehicles last year, according to new data that shows the hybrid market has grown by 960 percent since 2000.

New hybrid vehicle registrations totaled 83,153 in 2004, an 81 percent increase over the year before, according to data released Monday by R.L. Polk & Co., a Southfield-based firm that collects and interprets automotive data.

Even though hybrids still represent less than 1 percent of the 17 million new vehicles sold in 2004, major automakers are planning to introduce about a dozen new hybrids during the next three years.

Lonnie Miller, director of analytical solutions for Polk, said federal and state tax credits for fuel-efficient vehicles have helped spur hybrid sales. More people also are buying into the idea that driving a hybrid is socially responsible.

"What's different about this than other types of vehicles is that hybrids are about what people want to give back and what they want to feel they're doing with their vehicles," Miller said.

Despite the arrival of Ford Motor Co.'s Ford Escape hybrid in showrooms last year, Japanese automakers continued to control the vast majority of the U.S. market, Polk said. Japanese brands accounted for more than 96 percent of the hybrid vehicles registered.

Toyota Motor Corp., which was the first automaker to commercially mass-produce and sell hybrid cars, continues to dominate the market. The Toyota Prius, which went on sale in the United States in 2000, occupied 64 percent of the U.S. hybrid market last year, with 53,761 new Prius cars registered, Polk said.

Toyota is on track to double Prius sales again this year. The company sold 22,880 Prius cars in the first three months of the year, more than double the number it sold in the first three months of 2004, according to Autodata Corp. Toyota has said it plans to produce 100,000 Prius cars for the North American market this year.

The Honda Civic hybrid was second with 31 percent market share. Honda Motor Co. also sold several hundred Accord and Insight hybrids, which each commanded 1 percent of the market.

Ford sold 2,566 Escape hybrid sport utility vehicles, or about 3 percent of the market, Polk said.

Automakers are introducing hybrid versions of several models this year, including the Lexus RX400h, Mercury Mariner and Toyota Highlander SUVs. General Motors Corp. and DaimlerChrysler AG already sell hybrid pickups, but the system they use is less fuel efficient.

Hybrid vehicles are powered by internal combustion engines but also are equipped with batteries that are recharged while driving and an electric motor to assist with power. They typically cost $3,000 to $4,000 more than traditional models.

Miller said hybrids could make up 30 to 35 percent of the U.S. market by 2015 as long as automakers remain committed to producing them and market to people who are passionate about driving them. While some analysts believe there's a limit to the number of consumers who will pay more for a hybrid, Miller said the cost of hybrids eventually will come down.

"Some people are thinking there's absolutely no reason that all vehicles shouldn't be hybrid. The technology is there," Miller said.

Polk said California was once again the top state for growth in hybrid vehicle registrations. More than 25,000 new hybrids were registered in California, a 102 percent increase over 2003. Virginia, Washington, Florida and Maryland rounded out the top five states for hybrid registrations, the same as in 2003.

Source: http://www.commondreams.org/headlines05/0425-03.htm

January 24th, 2005

85,699 hybrid cars sold in the US in 2004

Posted by ZDNet Research @ 10:31 am

Seven gas-electric vehicles accounted for 85,699 sales in 2004, up 97.3% from the 43,435 sold in 2003. The numbers were reported by automakers. Most of the growth, and most of the sales of high-mileage hybrids, came from Toyota's Prius sedan. At 53,991 units, it accounted for 63% of the hybrid market.

Source: http://blogs.zdnet.com/ITFacts/?p=6951

USA Sales:

9,350 in 2000
20,287 in 2001
35,000 in 2002
47,525 in 2003
88,000 in 2004
205,749 in 2005
168,686 in 2006 (thru August)

Regional Breakdown
The best indicator of adoption rates by geography are new hybrid vehicle registrations. In 2005, California strongly outpaced all other states with 52,619 new hybrid vehicle registrations, about 5 times that of second place Florida with 10,470. Texas came in third with 9,632; New York came in fourth with 9,372; and Virginia rounds out the top five with 8,650 new hybrid vehicle registrations in 2005."

According to these stats an amazing 25% of hybrids are in California.

Source(s):

http://www.hybridcars.com/sales-numbers.…

http://hybridcaradvisor.info

- 3 years ago

  From the stats and that fact that California represents 10% of the USA's population, this would mean 1 in 570 Californians bought a hybrid last year while only 1 in 1760 Americans bought a hybrid, or 3 times more likely to buy a hybrid.

How many hybrids were sold?

Created November 29, 2004, at 5:00 pm by Anonymous

How many total hybrids were sold in the United States each year, from 1999 to 2004?

Anonymous

5 years ago

Hybrid sales have risen consistently in the U.S.:

9,350 cars in 2000
20,287 in 2001
35,000 in 2002
47,525 in 2003

I've seen projections for 2004 at around 100,000.

If anybody has a good source for detailed sales numbers, by model and month, please post to this thread.

John Acheson

1 year ago

You can get some great information at

http://johnacheson.blogspot.com/

In my 174 page thesis that I'm blogging on, it looks like we're well past one million hybrids worldwide and the US is leading the race!!!

If you would like any data or graphs,
email me at johnmba@sbcglobal.net

Source: http://www.hybridcars.com/forums/how-many-hybrids-were-sold.html

Appendix D

Home / Other / Resources / Charging Station Installation Costs

Houston has recently built out infrastructure to install 15 **Coulomb charging stations**. As should be expected, the costs are variable depending on location, availability of power, conduit size, and labor. Below is a chart with their approximate build out costs. These costs do not include the cost of the charging stations.

Location Type	Number of Stations	Total Installation Price	Unit Price
Street Side	1	$2300	$2300
Underground Garage	2	$4100	$2050
Street Side	2	$2800	$1400
Parking Garage	5	$4300	$860
Parking Lot	3	$3200	$1066
Parking Lot	1	$7400	$7400
	15	**$24100**	

Houston budgeted for the project by assuming $10,000 for the first station and then $1,000 for each additional station.

Please email **Tripp Hyde** to submit additional charging station installation cost data.

Source: http://projectgetready.com/resources/charging-station-installation-costs

Appendix E

Copy of Questionnaire that was distributed:

We are doing a project on hybrid technology, please answer the following:

1) Do you believe hybrid technology is worth the cost of investment? YES__ NO__

2) Would you buy a hybrid vehicle currently? YES__ NO__

3) If a hybrid vehicle were the same price as a non-hybrid vehicle would that change your decision? YES__ NO__

4) Do you believe that hybrid vehicles will actually make an impact on global warming? YES__ NO__

5) Do you agree with the government's current approach to hybrid technology (that every car company must have a hybrid vehicle on the market by 2011)? YES__ NO__

6) What is the least attractive aspect of a hybrid vehicle to you?

A. cost B. size C. horsepower D. other_____

7) What is the most attractive aspect part of a hybrid vehicle other than fuel efficiency?

A. emissions B. tax credit C. reduce dependence on foreign oil

D. other_____

8) What would you prefer to spend on your next vehicle?

A. under 10,000 B. $10-15,000 C. $15-20,000 D. $20-25,000 E. $25-30,000 F. $30,000+

9) Which of the three most popular hybrids interests you?

A. Chevy Volt B. Toyota Prius C. Honda Insight

10) What is the make model and year of your current vehicle?

_____

11) Approximately when would you consider buying your next vehicle?

_____

Appendix F

Assumption College	Q#	Yes	No				
	1	12	3				
	2	8	7				
	3	11	4				
	4	13	2				
	5	10	5				
		A	B	C	D	E	F
	6	9	1	3	2		
	7	3	2	10			
	8	6	3	4	0	1	1
	9	6	8	1		Vehicle Age	
		Car	SUV	Truck	0->5 yrs	6->10	10+
	10	11	2		5	1	7
		0->5 yrs	6->10	10+			No Car
	11	8	1	6			2
WPI Campus Center	Q#	Yes	No				
	1	5	2				
	2	2	5				
	3	4	3				
	4	3	4				
	5	4	3				
		A	B	C	D	E	F
	6	2	0	2	3		
	7	1	2	4			
	8	3	1	0	1	1	1
	9	3	3	1		Vehicle Age	
		Car	SUV	Truck	0->5 yrs	6->10	10+
	10	7			3		4
		0->5 yrs	6->10	10+			
	11	4	1	2			
OIE3400	Q#	Yes	No				
	1	19	1				
	2	8	12				
	3	14	6				
	4	10	10				
	5	15	5				
		A	B	C	D	E	F
	6	11	2	5	2		
	7	9	4	7	0		
	8	6	4	6	2	0	2
	9	4	13	3		Vehicle Age	
		Car	SUV	Truck	0->5 yrs	6->10	10+
	10	11	1	2			
		0->5 yrs	6->10	10+			No Car
	11	15	2	3			6
N=42	Q#	Yes[%]	No[%]				
	1	85.7142857	14.28571429				
	2	42.8571429	57.14285714				
	3	69.047619	30.95238095				
	4	61.9047619	38.0952381				
	5	69.047619	30.95238095				
		A[%]	B[%]	C[%]	D[%]	E[%]	F[%]
	6	52.3809524	7.142857143	23.80952	16.66667		
	7	30.952381	19.04761905	50			
	8	35.7142857	19.04761905	23.80952	7.142857	4.761905	9.52381
	9	30.952381	57.14285714	11.90476			
Educational Level	No H.S. degree	H.S. degree	Some College	Bachelors	Masters	PhD	
	0	0	42	0	0	0	
Ages	<30	31-49	50+				
	42	0	0				

Bourne, MA	Q#	Yes	No				
	1	17	1				
	2	6	12				
	3	10	8				
	4	15	3				
	5	12	6				
		A	B	C	D	E	F
	6	11	4	2	1		
	7	3	1	13	1		
	8	3	6	3	3	2	1
	9	4	11	3		Vehicle Age	
		Car	SUV	Truck	0->5 yrs	6->10	10+
	10	5	10	3	10	4	4
		0->5 yrs	6->10	10+			
	11	10	2	6			
N=18	Q#	Yes[%]	No[%]				
	1	94.4444444	5.555555556				
	2	33.3333333	66.66666667				
	3	55.5555556	44.44444444				
	4	83.3333333	16.66666667				
	5	66.6666667	33.33333333				
		A[%]	B[%]	C[%]	D[%]	E[%]	F[%]
	6	61.1111111	22.22222222	11.11111	5.555556		
	7	16.6666667	5.555555556	72.22222	5.555556		
	8	16.6666667	33.33333333	16.66667	16.66667	11.11111	5.555556
	9	22.2222222	61.11111111	16.66667			
Educational Level	No H.S. degree	H.S. degree	Some College	Bachelors	Masters	PhD	
	0	3	9	5	1	0	
Ages	<30	31-49	50+				
	3	8	7				
N=60 (Total)	Q#	Yes[%]	No[%]				
	1	88.3333333	11.66666667				
	2	40	60				
	3	65	35				
	4	68.3333333	31.66666667				
	5	68.3333333	31.66666667				
		A[%]	B[%]	C[%]	D[%]	E[%]	F[%]
	6	55	11.66666667	20	13.33333		
	7	26.6666667	15	56.66667	1.666667		
	8	30	23.33333333	21.66667	10	6.666667	8.333333
	9	28.3333333	58.33333333	13.33333			
Educational Level	No H.S. degree	H.S. degree	Some College	Bachelors	Masters	PhD	
	0	3	51	5	1		
Ages	<30	31-49	50+				
	45	8	7				

Appendix G

US: Pike survey highlights PHEV interest

Wednesday, September 09, 2009, AutomotiveWorld.com

A recent survey by Pike Research shows that consumer interest in plug-in hybrid electric vehicles (PHEVs) in the US remains strong. The report, 'Electric Vehicle Consumer Survey', analyses results from a web-based survey of 1,041 US consumers. Survey results show that 48% of respondents claimed to be 'extremely' or 'very' interested in purchasing a PHEV with a 40-mile range on a single charge.

Other key findings are as follows:

- 85% of consumers stated that improved fuel efficiency would be an important factor when choosing their next vehicle;
- 65% of survey respondents interested in PHEVs expressed a willingness to pay a premium price, over and above the price of a standard gasoline vehicle, with an average premium of 12%;
- 79% of consumers would be interested in investing in a fast-charging outlet for their home; however, willingness to pay is out of line with industry expectations.

The survey also investigated reasons why certain consumers were not interested in a PHEV. The most common reason (45%) was that consumers wanted to wait until the technology became more proven over the coming year; 33% said the 40-mile range was insufficient; 29% said they didn't like the idea of plugging in and that it seemed like it would be too expensive; 28% questioned PHEV reliability; and 25% questioned the quality of an electric vehicle.

Published on Wednesday, September 09, 2009

Source: http://www.automotiveworld.com/news/environment/78421-us-pike-survey-highlights-phev-interest

Appendix H

Exclusive: GM CEO Says Chevy Volt Will Sell in Low 30's and For a Profit

January 18th, 2010 | Posted in: Financial

The Chevrolet Volt will be an expensive car to produce. Cutting edge technology and large proprietary lithium-ion battery packs make up the lion's share of cost. Another speculated element of cost is factoring in the possibility of some degree of warranty-required battery replacements.

Long one of the most talked about Volt topics is what its price will be when it arrives later this year.

In the very early days of 2007, GM vice-chairman Bob Lutz had mentioned a goal of under $30,000. Eventually that target appeared to be moved higher, though never official confirmed by GM.

Along the way, the federal government passed legislation that will give initial Volt buyers a $7500 tax credit, and more recent media speculation has put the price closer to $40,000.

However, there have been new reports that GM may surpise the world with a lower number.

Also, though GM has plans to take the cost out in coming generations, it is often reported that the automaker will have to take a loss on each car of the first generation.

Now in an exclusive interview with GM-Volt.com, CEO Ed Whitacre speaks frankly on how much the Volt will be priced at, and for the first time ever says GM will actually be able to make money selling them.

He was asked whether it was true that GM will lose money on every Volt they sell.

“We’re not in business to lose money,” he said. “We did enough of that already.”

The Volt “is going to sell in the low 30s,” said Whitacre. “We’ll get a margin on that.”

Source: http://gm-volt.com/2010/01/18/exclusive-gm-ceo-says-chevy-volt-will-sell-in-low-30s-and-for-a-profit/

Appendix I

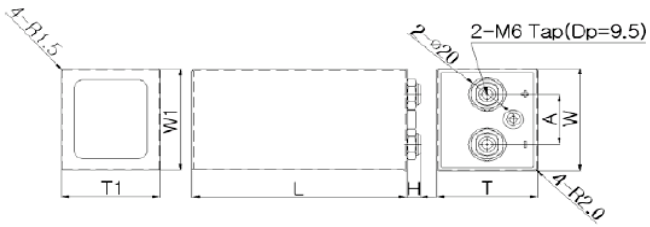
NESSCAP® Ultracapacitor Products

Features

EDLC(Electric Double Layer Capacitor)
Two screw terminals and prismatic design
Compliant with RoHS requirement (Ex : Cd, Pb)

Dimension

Dimension in mm (not to scale)



Capacitance	Dimension (mm)						
	L (±2.0)	W (±2.0)	W1 (±1.0)	T (±2.0)	T1 (±1.0)	H (±0.5)	A (±0.1)
600F	90	60	60	28	28	8	30
1700F	165	60	60	28	28	8	30
3500F	165	60	60	52	52	8	30
5000F	165	60	60	72	72	8	30

Product & Spec.

Rated Capacitance	Internal Resistance (mΩ)		Max. Current (A)	Leakage Current (mA)	Stored Energy (Wh)	Specific Energy (Wh/kg)	Weight (g)	Part Number
Discharge with constant current at 25℃	AC(100Hz)	DC	1 sec discharge rate to 1/2V_R	72hours, 25℃	at V_R	Gravimetric		
600F	< 0.64	< 0.83	541	1.7	0.608	2.90	210	ESHSP-0600C0-002R7
1700F	< 0.50	< 0.65	1,090	2.4	1.721	4.47	385	ESHSP-1700C0-002R7
3500F	< 0.28	< 0.36	2,091	5.5	3.544	5.17	685	ESHSP-3500C0-002R7
5000F	< 0.25	< 0.33	2,547	8.1	5.063	5.44	930	ESHSP-5000C0-002R7

Rated Voltage,V_R	2.7 V	
Surge Voltage	2.85 V	
Capacitance Tolerance	0% / +20%	
Operating Temperature Range	-40 ~ 65 °C	| ΔC | <5% and ΔESR < 0.5 times of initially measured value at 25°C, respectively
Storage Temperature Range	-40 ~ 70 °C	
Life Time at RT(1)	10 years	(1) | ΔC | < 30% and ΔESR < 1 times of initially specified value , respectively and LC < specified value (2) Cycle : between rated voltage and half rated voltage under constant current at 25°C
Cycle Life (25°C)(1)(2)	500,000 cycles	

※ Life time is provisional value

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www.nesscap.com

ISO 9001, ISO 14001, TS 16949

Appendix J

100,000-Mile Evaluation of the Toyota RAV4 EV

Author: Thomas J. Knipe
Co- Authors: Loïc Gaillac and Juan Argueta

Southern California Edison, Electric Vehicle Technical Center
Pomona, CA, 91767, USA
Tel. (909) 469-0390
Fax (909) 469-0276
E-mail: Thomas.Knipe@sce.com

4. Findings

On November 8, 2002, CON 1 reached the goal of logging 100,000 miles with an original battery pack. Test data show that one battery module stopped the latest C/3 capacity test at 72.1 Ah, or 76% of nominal battery capacity, while driving range was still 81 miles or 86% of nominal miles.

CON 2 and CON 3 reached the 100,000 mile mark on February 4 and April 1, 2003 respectively. CON 2 has had three modules replaced. Tests show that range had decreased to 51 miles, while battery capacity was 85% of the nominal value. CON 3 has experienced an increase in battery capacity but achieved lower range.

The two inductive vehicles are expected to achieve the 100,000 mile goal by the end of 2003.

One lesson learned to-date has to do with thermal management of the batteries: To assure proper operation of the cooling system, periodic cleaning of air vent screens was recommended by SCE and approved by Toyota.

Data collected with the test vehicles and the RAV4 EV fleet, are confirming that EVs with Nickel Metal Hydride batteries, and a mature drive train design, are compatible with a variety of mission requirements. Not only are the EVs meeting the employees' driving needs, they are also very reliable, with little routine maintenance required.

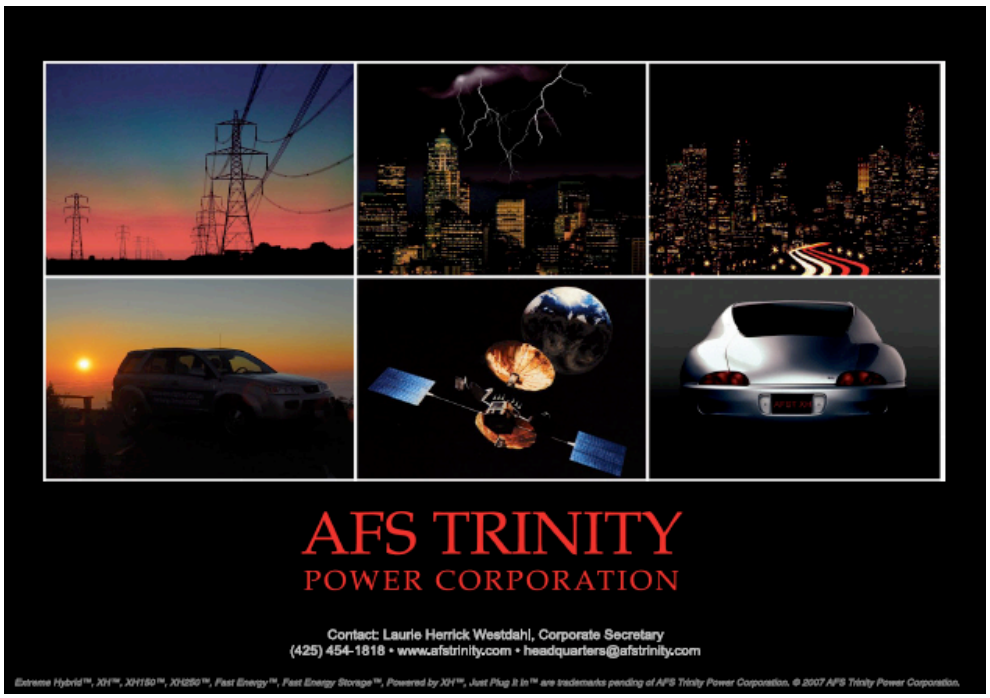
5. Conclusions

The five-vehicle test is demonstrating the long-term durability of Nickel Metal Hydride batteries and electric drive trains. Only slight performance degradation has been observed to-date on four out of five vehicles. CON 2 EV, as discussed earlier, still has a capacity of 85% of nominal value but the range is 53 miles. A similar loss in range was experienced by CON3 EV but was successfully recovered. EVTC test data provide strong evidence that all five vehicles will exceed the 100,000-

mile mark. SCE's positive experience points to the very strong likelihood of a 130,000 to 150,000-mile Nickel Metal Hydride battery and drive-train operational life. EVs can therefore match or exceed the lifecycle miles of comparable internal combustion engine vehicles.

In June 2003 the 320 RAV4 EVs of the SCE fleet were used primarily by meter readers, service managers, field representatives, service planners and mail handlers, and for security patrols and carpools. In 5 years of operation, the RAV4 EV fleet had logged more than 6.9 million miles, eliminating about 830 tons of air pollutants, and preventing more than 3,700 tons of tailpipe carbon dioxide emissions.
Given the successful operation of its EVs to-date, SCE plans to continue using them well after they all log 100,000-miles.

Appendix K



AFS Trinity XH-150™ Performance Comparison

	AFS Trinity XH-150™	2008 Lexus RX400h AWD	2007 Saturn Vue Greenline FWD	2008 Chevrolet Tahoe Hybrid 4WD
Combined City /Hwy MPG	150 MPG	25	26	20
0-60 Time (seconds) for three modes	6.9 as Full Hybrid 11.6 All-electric 12.5 as Mild Hybrid	7.5	10.2	8.1
Top Speed (MPH)	87	116	106	112
Weekly Gas Cost	$7.93	$47.60	$45.77	$59.50
Weekly Elec. Cost	$7.56	$0.00	$0.00	$0.00
Total Weekly Fuel Cost	$15.49	$47.60	$45.77	$59.50

1. Fuel economy figures for Chevrolet Tahoe, Toyota RX400h, Saturn Vue Greenline reflect published data citing latest 2008 EPA calculation method.
2. Weekly fuel cost based on gasoline at $3.50/gallon and 40 miles/day of driving Monday through Saturday and 100 miles of driving on Sunday for a total of 340 miles.
3. Tahoe top speed estimated based on 2007 conventional Tahoe.
4. Electricity cost based on PG&E off-peak EV charging rate of 6 cents/kWh.
5. Top speed based on transmission limit. Higher speeds possible with other components.
6. Although the XH™ system can be optimized for fuel economy, top speed or acceleration, fuel economy is AFS Trinity's priority, so maximizing all-electric range, in which no gasoline is burned, is our main goal.

XH-150™ Life Cycle Cost Comparisons - SUV

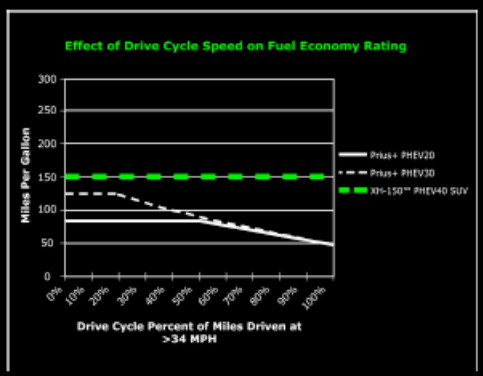
Vehicle Model (1)	Price Premium for Hybrid Drive Train	5 Yr. Cumulative Operating Cost (2)	10 Yr. Cumulative Operating Cost (2)
Lexus RX330 (conventional drive train)	Baseline	$18,625	$39,364
Lexus RX400h (hybrid)	$7,045 (Calculated based on today's component costs)	$14,440 Savings of $4,145 vs RX330	$30,933 Savings of $8,431 vs RX330
AFST XH-150™ (plug-in hybrid SUV)	$8,666 (Calculated based on projected 2015 reductions in component costs - tax credits would reduce this further	$6,181 Savings of $12,444 vs RX330	$16,408 Savings of $22,956 vs RX330

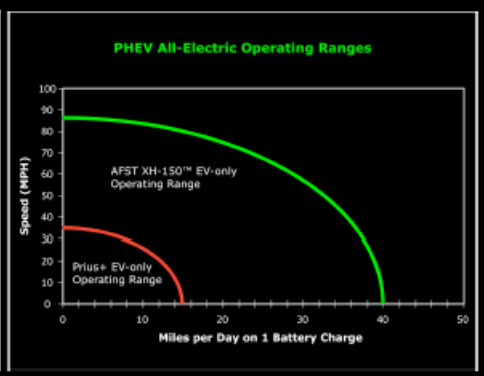
1. Comparisons are based on luxury mid-sized SUV.
2. Operating costs include energy cost, maintenance and repairs. Fuel costs and electric costs were held constant at $2.85/gal & 6 cents/kWh, respectively. Operation based on 340 miles per week ($17,680 miles per year), mixed urban/highway drive cycle.

How the AFS Trinity XH-150™ Compares to Other Plug-in Hybrids

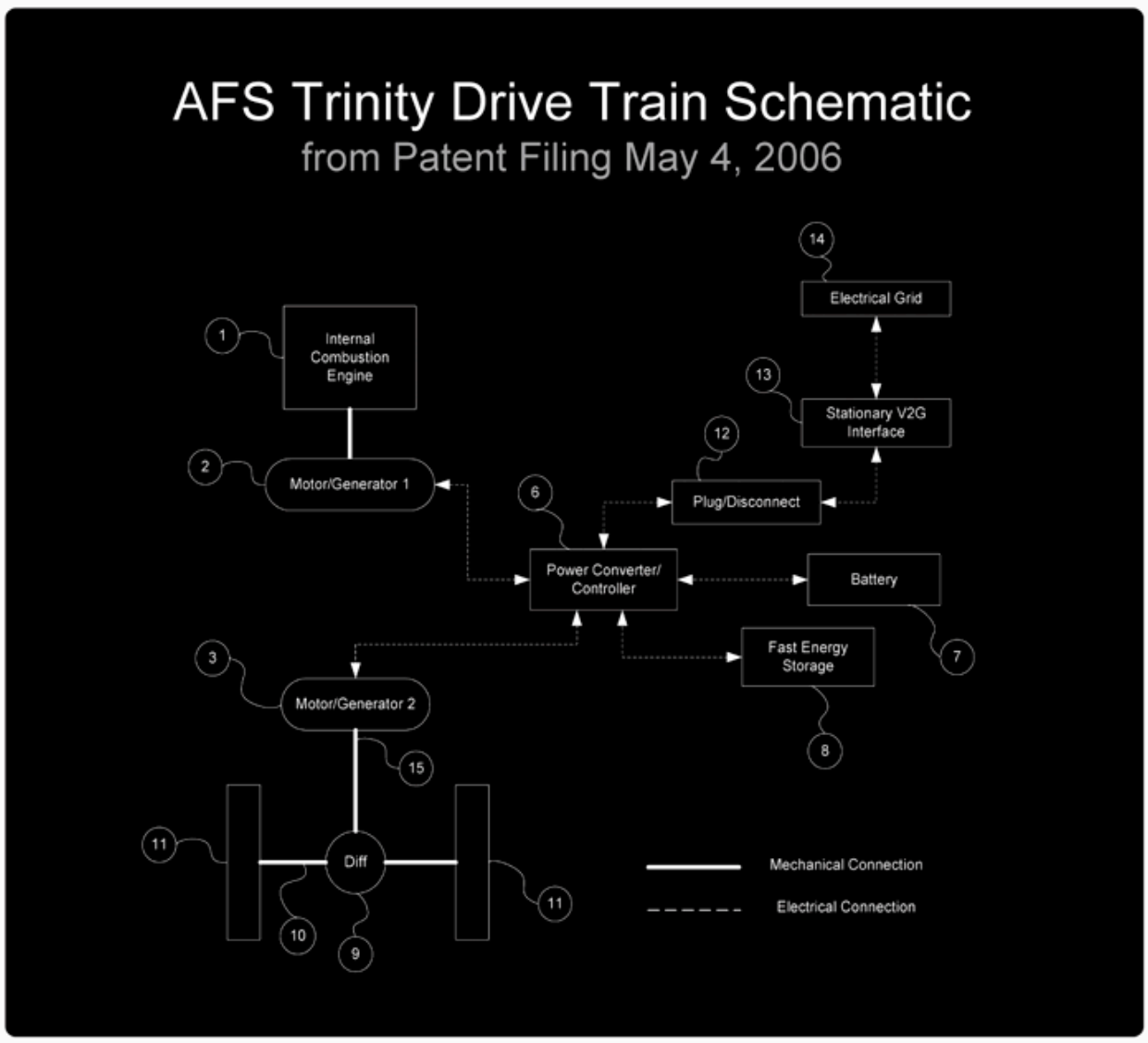
AFS Trinity Extreme Hybrid™
- Range in all-electric mode (without engine): 40 miles
- Highway speeds up to 88 mph in all-electric mode
- Fuel economy: 150 mpg on average
- 10 year/150,000 mile battery life

CalCars Prius+ Plug-in Conversion*
- Range in all-electric mode (without engine): 15 miles
- Top speed in all-electric mode: 34 mph
- Fuel economy: 100 mpg on average
- Unspecified (unknown) battery life





*Other Prius+ converters include Hymotion, ElectroEnergy/CalCars, EnergyCS/Amberjac & Edrive Systems. Toyota showed a Plug-in prototype at the 2007 Tokyo Auto Show. It had a 6 mile EV range and needed its engine for rapid acceleration. The only other plug-in hybrids of which AFST is aware are non-operational concept cars.


AFS Trinity Drive Train Schematic
from Patent Filing May 4, 2006
14
Electrical Grid
1
Internal Combustion Engine
13
Stationary V2G Interface
12
2
Motor/Generator 1
6
Plug/Disconnect
Power Converter/ Controller
Battery
7
3
Fast Energy Storage
Motor/Generator 2
8
15
11
Diff
11
10
9
Mechanical Connection
Electrical Connection

Appendix L

Specifications of popular HEVs, PHEVs and EVs

HEVs

2010 Toyota Prius
Power: 1.8L 4-cylinder 98 HP Gasoline Engine, 80 HP Electric Motor
Fuel Economy: 51 city mpg, 48 hwy mpg
Capacity: Seats 5, Passenger Vol. 93.7 ft^3, Cargo Vol. 21.6 ft^3
Base MSRP: $22,800

2010 Honda Insight
Power: 1.3L 4-cylinder 98 HP Gasoline Engine, 13 HP Electric Motor
Fuel Economy: 40 city mpg, 43 hwy mpg
Capacity: Seats 5, Passenger Vol. 85 ft^3, Cargo Vol. 15.9 ft^3
Base MSRP: $19,800

2010 Lexus HS250h
Power: 2.4L 4-cylinder 147 HP Gasoline Engine, 40 HP Electric Motor
Fuel Economy: 35 city mpg, 34 hwy mpg
Capacity: Seats 5, Passenger Vol. 90.2 ft^3, Cargo Vol. 12.1 ft^3
Base MSRP: $34,200

2010 Ford Fusion Hybrid
Power: 2.5L 4-cylinder 155 HP Gasoline Engine, 106 HP Electric Motor
Fuel Economy: 41 city mpg, 36 hwy mpg
Capacity: Seats 5, Passenger Vol. 100.3 ft^3, Cargo Vol. 16.5 ft^3
Base MSRP: $27,950

2010 Toyota Camry
Power: 2.5L 4-cylinder 147 HP Gasoline Engine, 40 HP Electric Motor
Fuel Economy: 33 city mpg, 34 hwy mpg
Capacity: Seats 5, Passenger Vol. 101.4 ft^3, Cargo Vol. 10.6 ft^3
Base MSRP: $19,395

2010 Lexus RX400h
Power: 3.5L V6 245 HP Gasoline Motor, 44 HP Electric Motor
Fuel Economy: 30 city mpg, 28 hwy mpg
Capacity: Seats 5, Passenger Vol. 102 ft^3, Cargo Vol. 40 ft^3
Base MSRP: $44,275

2010 Ford Escape Hybrid
Power: 2.5L 4-cylinder 153 HP Gasoline Motor, 94 HP Electric Motor
Fuel Economy: 34 city mpg, 31 hwy mpg
Capacity: Seats 5, Passenger Vol. 99.5 ft^3, Cargo Vol. 27.8 ft^3
Base MSRP: $29,860

PHEVs

Chevy Volt
Power: 149 HP Electric Motor, 1.4L 4-cylinder 71 HP Gasoline Engine (used to charge battery only)
Battery Size: 16 kWh
Capacity: Seats 4
Base MSRP: low $30,000 range
Available: 2010

Ford Escape PHEV
Power: unknown
Battery Size: 10 kWh
Capacity: assumed to be similar to Ford Escape Hybrid
Base MSRP: unknown
Available: 2012

Toyota Prius PHEV
Power: unknow
Battery Size: 5.2 kWh
Capacity: assumed to be similar to standard Toyota Prius hybrid
Base MSRP: unknown
Available: 2011

EVs

Leaf
Power: 107 HP Electric Motor
Battery Size: 24 kWh
Capacity: Seats 5
Base MSRP: ~$30,000
Available: 2010

Focus EV
Power: 141 HP Electric Motor
Battery Size: 23 kWh
Capacity: assumed to be similar to standard Ford Focus
Base MSRP: unknown
Available: 2011