An abbreviated history of Hybrids

The first electric car is claimed to be built between 1832 an 1893 in 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.

All this research lead to many new developments and vehicle releases 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.

Energy 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.

According to the Energy Information Administration (EIA) the United States imports just over 11.1 million barrels of oil per day, which amount 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, 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 seem like a great idea, however the fleets fuel economy is only part of the battle.

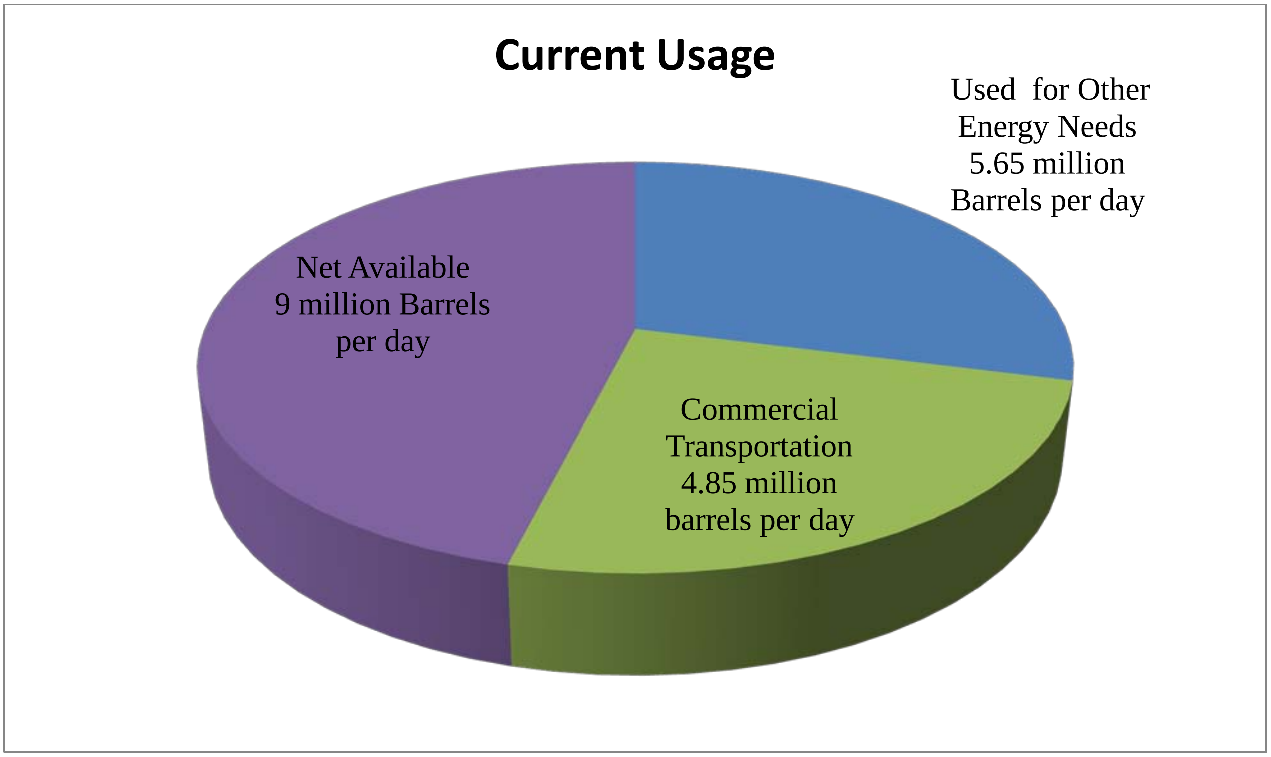
First, only 71% of the oil used in the United States is used for transportation, therefore 29%, in the best case scenario, is unchanged by increased gas mileage. With this new information, 29% of the 43% which is independently produced goes to other products and other energy production. This leaves only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

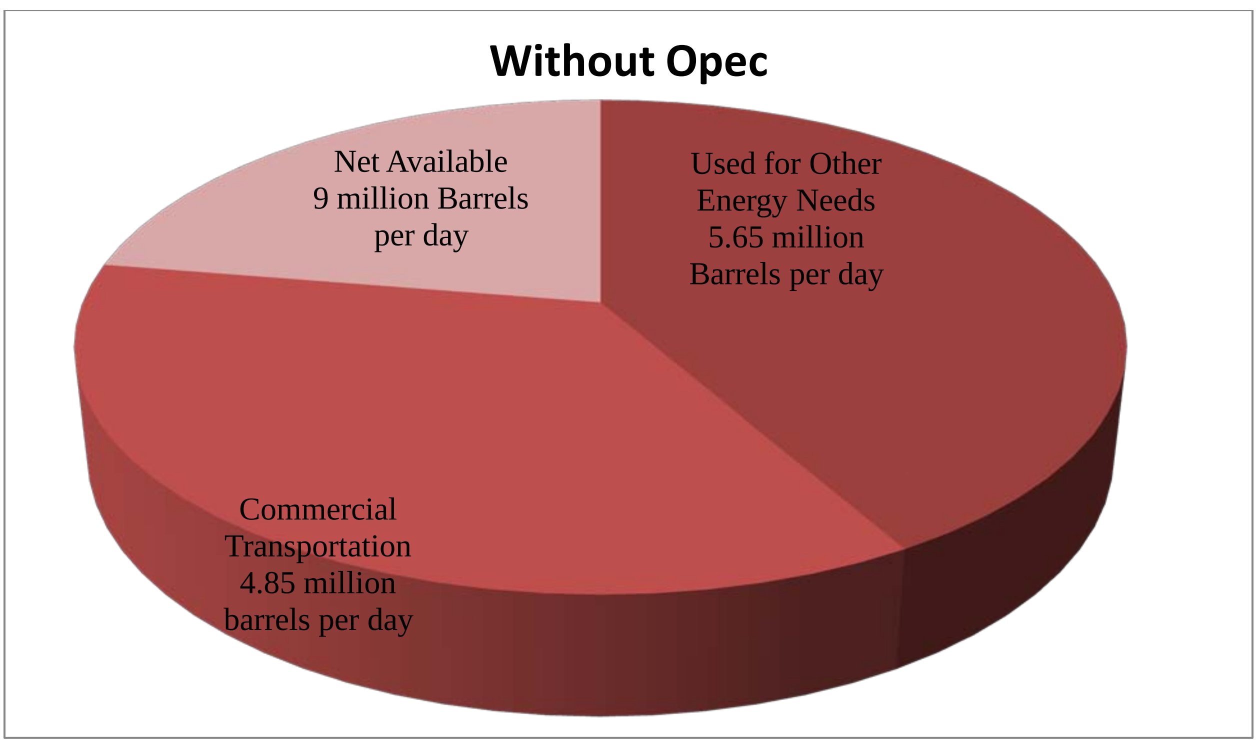
It is easier at this point to start talking about fuel usage in terms of barrels of oil per day. Right now we use 19,498,000 barrels per day. Of these, as I mentioned above, 57% or 11,100,000 barrels per day are imported, which leaves us with only 43%, 8,348,000 barrels per day to use in our vehicles. Of our total 19.5 million barrels 29%, or 5,654,420 barrels per 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 barrels per day left for vehicle usage. 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 barrels of oil used in transportation industry, 4.85 million barrels per day are unchanged and used in large trucks, boats, trains and plains. Adding this to the 5.6 million barrels per day used for power production and we come up with just over 10.2 million barrels per day which will be unchanged by more fuel efficient cars. The bottom line here is that we produce about 8.3 million barrels of oil per day and if only the consumed gasoline sector is changed, we need 10.5 million barrels of oil per 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.

What if we just didn't want to take any oil from OPEC nations? OPEC sends the US 5,954,000 barrels per day. Eliminating this eliminates 30.5% of our daily supply. 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 barrels of oil per day which should 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 an even 50 mpg. If everyone were to own a hybrid or a plug in hybrid, this number does not seem to far off. If in the future we have cars which are capable of obtaining even higher fuel economies, say 100 mpg, only half of the registered fleet would need to own them to obtain the same numbers.

All data received from the Energy Information Administration (EIA) and can be found at their website http://www.eia.doe.gov/basics/quickoil.html

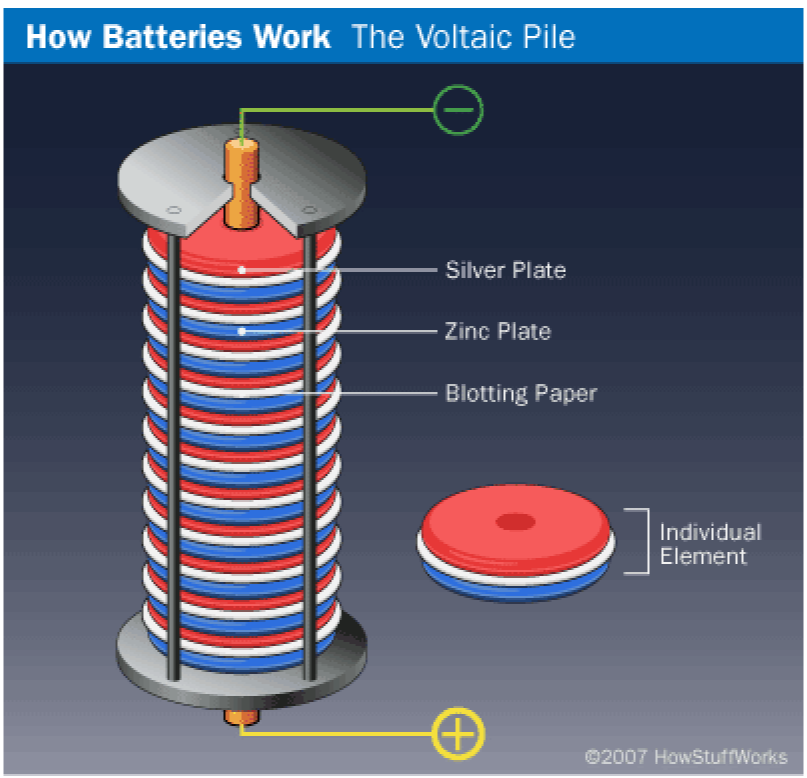

Current Usage
Used for Other Energy Needs 5.65 million Barrels per day
Net Available 9 million Barrels per day
Commercial Transportation 4.85 million barrels per day


Without Opec
Net Available 9 million Barrels per day
Used for Other Energy Needs 5.65 million Barrels per day
Commercial Transportation 4.85 million barrels per day

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

Battery Technology

The term battery comes from Benjamin Franklin, however it was not used in the sense we think of it, he was describing a series of charged glass palates. About 50 years later, in 1800, the famous Alessandro Volta invented the first of what we would call modern battery. It is called the voltaic pile, consisting of alternating zinc and silver plates with brine soaked cardboard between them (inventers).



The Volata pile is what's known as a primary battery. That is to say it is constructed to produce a charge or a prescribed length of time. Once used up the cell must be rebuilt. In modern times think of the battery powering you remote control. The contrast to this will be discussed in the near future and is known as a secondary source. It has the ability and needs to be recharged periodically to keep producing a charge. In its most basic form, think of the starter battery in your car.

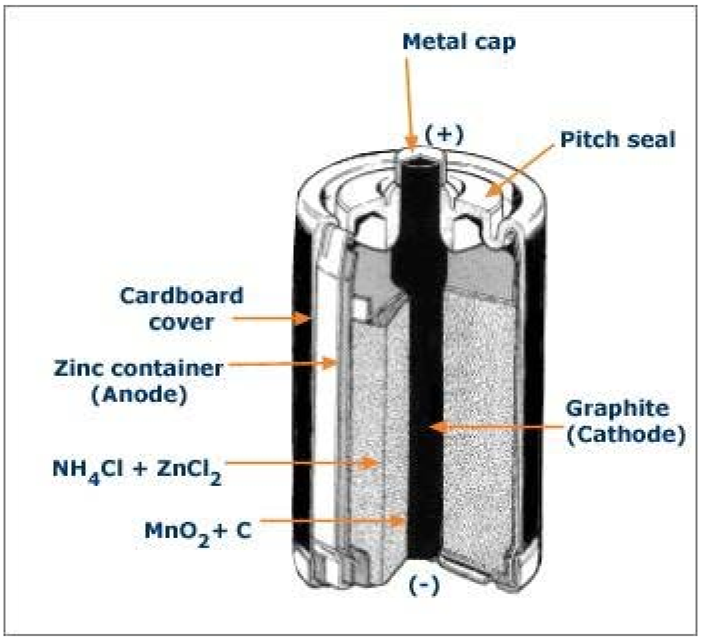
Following this, Voltas Battery provided the voltage needed to prove the concept for the electric motor, which was done in 1821 By Michael Faraday with a magnet hanging in a bath of mercury. Faraday also showed that by reversing the polarity of the current the magnet rotated in the opposite direction. This proof of concept was followed directly by the invention of a small electric motor, demonstrated by Francis Watkins in England, in 1835 (Westbrook, 2001, pp. 6-7).

Throughout the 1830s, 40s, and early 50s there are many unconfirmed reports of small carriages being propelled by the Volta pile and an electric motor. Of these, the most credible is a report is that of Moritz Jacobi and his Volta powered paddle boat operating in St Petersburg Russia in 1838 (Westbrook, 2001, p. 7). These underpowered vehicles, if they truly existed, received a very modern upgrade with the advent of the lead acid battery in 1859. Gaston Plante separated lead sheets with a cloth and submerged them in a bath of sulfuric acid. He noticed that a charge was produced while a lead sulfate formed on one of the plates. The exciting news is that when a current from the Voltaic pile was induced in the opposite direction the reaction reversed, essentially producing the first rechargeable battery (Westbrook, 2001, p. 8). We still see a slightly advanced form of this battery everyday as the starter battery in internal combustion vehicles.

Developments during the 1830s and 40s lead to the realization that an electric motor spun mechanically in reverse can produce a current. Not so useful at the time, but when combined with this new battery technology the current could now be produced and stored, with the ability to provide steady, reliable power. This lead to the formation of the electrical industry both in the United States and England. More importantly for our case, it lead to a 1/10 horse power electric carriage, made in France in 1881 by G. Trouve was the first proof of concept for the Plante cell (Westbrook, 2001, p. 10). To put this into perspective, this is still before the internal combustion was ever placed on a vehicle.

Before the death of the electric vehicle by the model T around 1912, many advances in battery technology appeared. Most prominently was the hybrid, which combined a gasoline motor with the Plante cell to improve performance and range. A curious and not particularly well documented battery was used in a carriage made for the queen of Spain in which a primary battery was used. The curious part is that the zinc electrode which was used was actually consumed, resembling a much more modern battery system which we will discuss later.

This ends the general development of both electric cars and batteries until the 1960s. Through this time the Zinc-Carbon Leclanche battery was the most widely used because of its reliable performance and relatively low cost. It is the predecessor to the modern day Duracell we are all used to. Though the chemical makeup has changed, the components and construction remain similar.



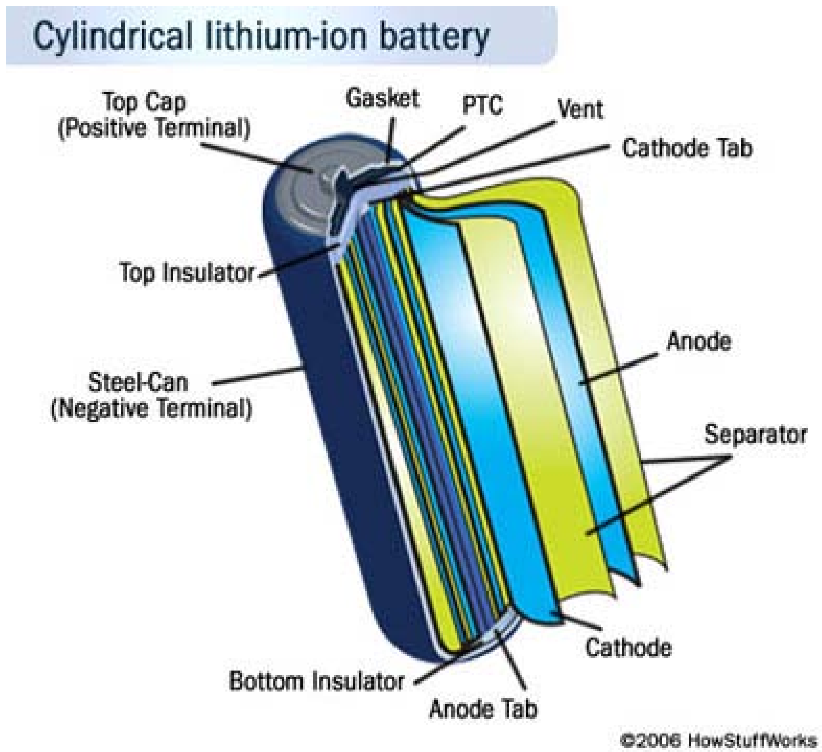
The early 1900s also ends the era of the back yard tinkerer inventing new types of batteries. From here on out is large corporations with large budgets, producing a battery for a specific application which drives advancements. Modern electric and hybrid cars generally use one of three types of batteries,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

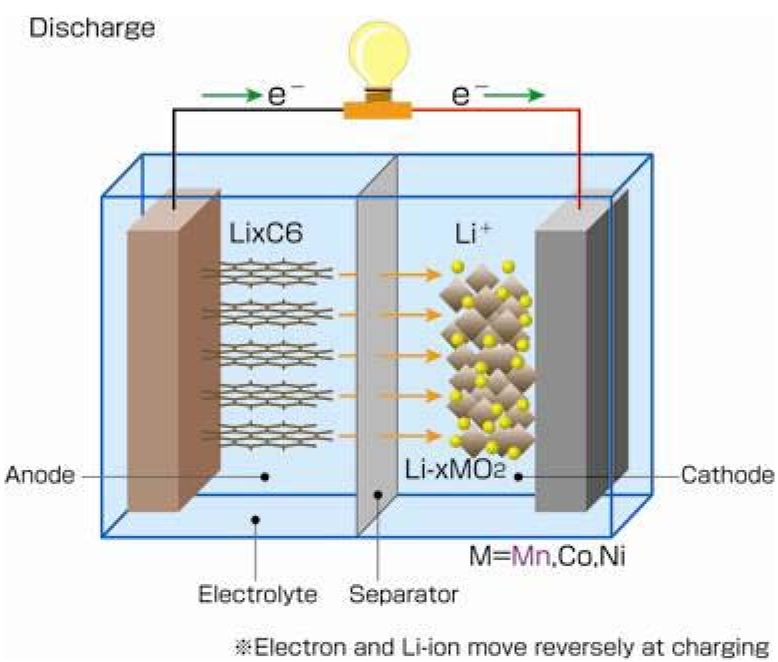
The nickel cadmium(NiCd) battery has been used in early electric models such as the Peugeot 106, which started production in 1995. These batteries are capable of an energy density of 50Wh/kg and power density of 200W/kg, a recharge cycle of around 2000, and Nissan has reported the ability to recharge 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 Nickel hydride based still, 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 min. 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).

Lithium ion batteries are what I will call the current future, meaning the technology is relatively new but is being implemented in some applications. 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.



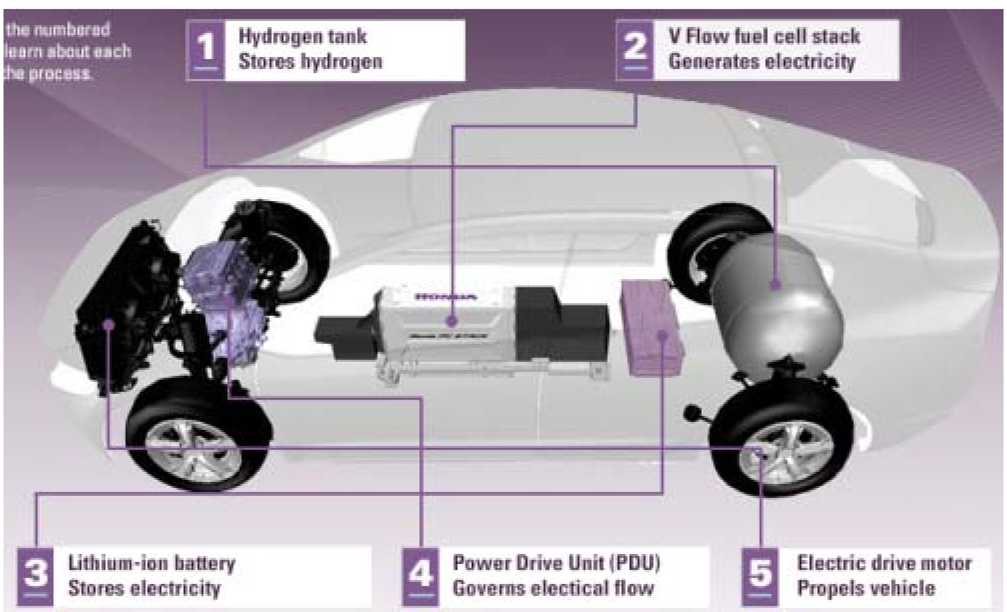


The future of battery technology is debatable. Many experts contend we have reached near the end of our ability to produce new advancements in this field. Electronics will continue to get smaller and faster, as they always have, due to advanced circuitry and smaller batteries like the lithium ion battery. 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 nano technology has some hopeful prospects, however we are nowhere near having this as available technology. The direction most foresee, and which nearly all major manufacturers are taking, is that of fuel cell vehicles ((Buchmann, 2005).

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 deg. C to work. Advances in technology have brought this temp down to 60-100 deg.C, making it feasible to put into a car (Westbrook, 2001, pp. 91-92).

The main problem with this method currently 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 to keep it a liquid at -253 deg C. The solution to these problems is to produce the hydrogen on board using a process called reformation. The most efficient for 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 and kept heated (Westbrook, 2001, p. 167).

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

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