A Final Project Submitted to the Faculty of the Luxury and Fashion Management Department in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Luxury and Fashion Management Savannah College of Art and Design

By

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# Will Luxury Lead

# Sustainable Energy by 2030?

by

Lester Bailey Jr.

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## Literature Review

Luxury has been the forefront of the industry for many years. They have been the first to market features in a vehicle that many entry vehicles feature later in production. For many years, the automotive industry has made many attempts to sustain energy and decrease pollution. Since the first production of the automobile in 1769, manufacturers have been using different methods of energy. The first passenger vehicle produced with an internal combustion engine was the German built Mercedes-Benz in 1885 by its inventor Karl Benz. He developed the one cylinder two-stroke gasoline engine in 1879. With technology and the development of the internal combustion engine and Mercedes-Benz as the world leader of luxury, does the luxury industry really need to keep their focus on sustainable energy? The first vehicle was invented in 1769 by Nicholas-Joseph Cugnot of Lorraine, France. This vehicle was steam powered with only a top speed of two miles per hour and was the first automobile to be utilized by a human. Due to its poor weight distribution and weighing about two tons, this vehicle was deemed as unstable. This disadvantage caused this vehicle the inability to climb hills but it became a pain to ignite the fire every 15 minutes to produce the steam needed to power the vehicle.

The next vehicle developed by Francois Isaac de Rivas in 1804 with an internal combustion engine that was fueled by hydrogen and oxygen. The internal combustion engine is also known as the reciprocating engine or the piston engine due to the use of pistons to convert pressure in a rotating motion. This particular engine uses spark plugs, air and gas to provide energy to the vehicle. Though this engine didn't initially gain commercial success, it was used in later years and is the engine in which most manufactures use in the in our present day.

Even though electric vehicles have been a feature entry level manufacturers have marketed, luxury vehicles have taken the lead in increasing the mileage range of electric vehicles. Over the past few years, research work has been done with Fuel Cell and Electric Vehicles technology, however, HEV technology and autonomous vehicles has been around over a century. In 1905, H. Piper an American engineer developed and patented an electric motor with a top speed of 25 mph in 10 seconds.

Electric vehicles became dormant for about 60 years until the 1970's. The interest for EV's revived when the oil crisis became an issue and the government financed manufacturers along with the improvement of several experimental EV's. As EV concepts were developed, the development of EV technology began to cease as the oil crisis became abundant. Nearly two decades later, EV technology development resurrected in 1993 when the federal government announced the Partnership for a New Generation of Vehicles (PNGV). This program consisted of the "Big 3" American automakers: Ford, GM, and Chrysler where they developed precise goals for the development of zero emission vehicles (ZEVs) using plug-in and fuel cell technologies. While PNGV's objective is to development ZEV's, manufacturers in Japan and Europe main focus was to develop and improve the design to make EV's commercially marketable.

With this vision, the first commercially successful sustainable energy vehicles were hybrids, the use of gasoline and electric motors, the Honda Insight and the Toyota Prius. Hybrids have done well since their introduction in the late 1990's and make up 40 % of sales in the marketplace according to analysts R. L. Polk and Ronnie Williams. Currently, the recent

attention on the energy and oil crisis has provided a more thorough look at broadening the range of hybrids, EV's and fuel cell vehicles.

The purpose of developing sustainable energy for luxury vehicles is to develop vehicles with a design that is cost effective along with features that can exceed performance and range that entry level vehicles don't possess. With the technology development of luxury EV's and fuel cells, it will improve energy consumption, emissions, and social impacts. Many factors have taken place in the development of EV's and fuel cells since the development such as the engine size, electric motor size, battery pack capacity, battery types and the best fuel cells to utilize in luxury vehicles. The parameters used to see how a sustainable vehicle includes a 0-60 mph acceleration time, 50-70 mph acceleration time, 0-30 mph all electric acceleration time, sustained grade ability, and top speed. For the concept, a mid-sized vehicle platform is used and designs are gauged by how much the carbon emissions are reduced along with gasoline consumption. Once the construction and methodology is industrialized, the practice is then adapted for other classes of vehicles.

There are few luxury companies that are against the idea of sustainable energy (Uren, 2012). Ferrari, McLaren, Aston Martin and Lotus plan to use hybrid technology for their vehicles but have plans to produce power to the vehicle, making them much faster than by utilizing gasoline engines. After speaking with Carson White, a salesman for Lamborghini of Atlanta stated "Hybrids just aren't cool, and these cars aren't saving gas. Consumers look for performance, not how much gas they can save".

## Abstract

As a leader in the supply chain sector, globally luxury brands have been one of the major influences in the automobile industry globally. In the last decade, many efforts have been made to produce vehicles utilizing sustainable energy. During this research, many sources in relation to luxury, sustainable energy and automobile manufacturers that are planning to produce energy efficient vehicles were gathered. This paper explains if luxury will lead the development of sustainable energy vehicles by 2030. Aggressive marketing by auto manufacturers have played a major role by advancing technology and demand. More importantly, the major companies in the luxury automotive sector have taken the lead of planning and producing vehicles that are more sustainable and better for the environment that will decrease the amount of pollution globally. This final project is an informative report on how marketable sustainable luxury vehicles are pushing other manufacturers to go green.


Key words: Luxury, Energy, Pollution, Environment, Oil, Gas, Automobile, Manufacturers

## Introduction

Frequently trends begin with luxury companies and trickle down to the general public. However, in the automotive industry this was not the case. Now luxury automotive is leading sustainability initiatives, but only after the trickle-up affect has influenced their direction With the advent of the hybrid concept by companies like Honda, this initiative's business strategy was totally targeting the "tree huggers" - those who embrace the environment, and only support socially and environmentally responsible brands. With that perspective and image being at the forefront, the luxury target consumers, influencers and early adopters were neglected, and there were sustainable luxury gaps in that product category that weren't being addressed . Because of this phenomenon, luxury sales were generated from less sustainable models and categories. Would this have been the case if the sustainability initiatives had followed trickle-down theory? What if these concepts had been introduced by McLaren or Maserati first? Luxury would have lead sustainable initiatives from the beginning. Their influential clout of luxury brand image and voice would have amplified, and reverberated, throughout the auto industry faster. (Burns, 2005).

Now having reached a crisis level with pollution and the environment,, luxury manufacturers have finally reacted to luxury consumers' growing concerns, and have developed many ways to "Go Green" while maintaining the codes and expectations of a luxury brand. In a very competitive sector, with new brands constantly launching globally, manufacturers are under government mandates to improve sustainable engineering and operations across the board, as well as meet internal cost-cutting requirements. Creating energy-efficient vehicles not only responds to the desires and demand from new luxury consumers, but plays a major role in

meeting these crucial environmental mandates and cutting production costs. In addition, it lowers the consumer/manufacturer expense associated with routine maintenance of luxury vehicles.

According to FuelEconomy.gov, automotive transportation makes up one-quarter of total global energy use. Gasoline engines use 14-26 percent to run, making them very inefficient. Total global energy use is projected to increase to 50 percent by 2030, and another 80 percent by 2050, without the predictions of new laws and regulations in place. With the emerging markets' lack of regulation, and resistance from developed countries, this is a disastrous prognosis. We may be out of oil and gas fuel by 2050. Therefore, the expansion of alternative and advanced fuels such as electric, biofuels and fuel cell research and development of sustainable automobiles is critically important. It increases the urgency for that powerful voice and leadership of luxury automobile companies to lead.

Globally, besides the absolutes of the energy supply crisis, pollution has reached a catastrophic level in many cities, countries and regions, and is swiftly becoming intolerable. Pressure on governments translates to pressure on automakers and industry. It's clear that the only solution is to change from traditional energy sources to sustainable renewable energy sources (Petersen, 2014). It has to start with reducing greenhouse gas emissions and decreasing the dependence of foreign oil from oil producing countries.

Global warming is a global issue that scientists have been researching over the last few decades. Many have argued that the research associated with sustainable energy has many setbacks, such as not being able to produce enough Lithium-ion batteries to sustain electric

vehicles or building enough solar panels to build solar powered vehicles. On the other hand, there are some that believe that the current oil crisis isn't as serious as the media portrays.

As technology advances as the future progresses, there are many areas for improvement and skepticism over the longevity of electric vehicles (EV). Will luxury manufacturers effectively prove to the emerging luxury consumer that sustainable energy is the path to go? By 2030, there are three objectives that must be met:

- Ensuring universal access to modern energy services.
- Doubling the global rate of improvement in energy efficiency.
- Doubling the share of renewable energy in the global energy mix.

With the exception of Tesla, a luxury brand, entry-level EVs produced by other manufacturers such as Ford, Nissan and Toyota haven't been able to compete with vehicles that have internal combustion engines (ICE). It's true that EV's have the savings energy potential, but it is possible that fuel cells could be the next source of sustainable energy that competes with the mileage range of ICE's. According to Bain.com, the luxury car market is has increased 10 percent since 2013, which has been motivated by emerging markets. Clearly luxury vehicles are a symbol of social status, and manufacturers have made them available with a many of personalization, regardless of the price tag (Bain, 2014). With much influence, luxury manufacturers could lead the development of sustainable energy and influence other manufacturers to adapt similar principles by the year 2030.

# Target Audience

Women cover a large percentage of the target audience for sustainable vehicles. Since the release of the Fisker Karma, more women were attracted by sustainable luxury vehicles. Fisker used the media for its advertisements that created the Alter-Ego women that wanted to "go-green" but didn't want the entry level vehicle. A few years ago, Bentley introduced the option out an initiative to attract more female clientele. They offered a strategy that allowed women to bring in a tube of lipstick to their local Bentley dealership and they would match the color and paint their new Bentley in that color. When the target audience was presented with the reiteration of images in the media, these images become a desired part of the individual's character, which cultivates a new Alter-Ego, Ego, and identity to the viewer.

Highly competitive luxury automakers such as: Rolls Royce, Apple, Mercedes-Benz all have exciting sustainable vehicles in development. Tesla, Ferrari and Porsche have introduced their own line of vehicles that utilize sustainable energy in response to the growing alarm and new priorities of a new kind of luxury consumer who is more concerned about the more critical juncture of the environment, urgency and needs for alternative fuel. The next step is to project luxury manufacturers to produce sustainable energized vehicles to decrease pollution by using fuel cell research and increase the production of electric vehicles.

## Sustainable Energy

**Sustainable energy** is the form of energy obtained from non-exhaustible resources, such that the provision of this form of energy serves the needs of the present without compromising the ability of future generations to meet their needs. ("Energylinx")

According to un.org, by 2030 the world will have an essential way of providing sustainable, affordable and reliable sources that will provide a cleaner environment. It involves a much needed change and the two areas of benefits it would stem from is energy access and energy efficiency. There are four major innovation trends taking shape in the automobile industry to address sustainable energy opportunities and market development:

- Technology advancements to traditional internal combustion engine by increasing fuel efficiency by the use of turbocharge engines and downsizing the liter per cylinder.
- Hybrid technology becoming more advanced and used in larger vehicles.
- Vehicles becoming much lighter in weight by using aluminum or carbon fiber.
- Research and developing the use of alternative and advanced fuels such as electric, sustainable biofuels, and fuel cells.

The United Nations Secretary – General Ban Ki-moon, created the Sustainable Energy for All program. The program was launched to find conclusions on how to increase energy requirements; focus on the development of sustainable energy for all methods of transportation; and the improvement of air quality. Manufacturing automobiles uses a significant amount of energy during production. Furthermore, the use of the vehicle once a consumer takes ownership plays an even bigger role depending on its use. Vehicles are becoming lighter and more efficient

than they were years ago due to the use of materials. Along with lighter materials are the use of renewable or alternative fuels, energy consumption has improved tremendously.

## Design



*Fig. 1 Cadillac Aera courtesy of Cadillac*

As the awareness for sustainable energy becomes more popular, manufacturers are planning to use lighter materials in order to make vehicles lighter. In order for sustainable energy to be effective, automobiles must weigh at least 1,000 pounds by 2025 and average 54.5mpg (Tuttle, 2012). According to Autos.com vehicles currently weigh between 3,000-12,000 pounds and average 15-26mpg. When the Range Rover HSE was redesigned in 2014, the company made sure that the new model weighed 926 less than the previous model year. Toyota even resigned the current Prius to be 500 pounds lighter than the previous model to provide better fuel effecieny. "Over the next several years, light-weighting of vehicles will be a major focus area to improve fuel economy," Jon Lauckner, GM's chief technology officer, said simply while recently announcing a major weight-reducing initiative by GM (Tuttle, 2012).

Luxury manufactures have plan use earth's elements as inspiration for future designs. The goal is to make vehicles as natural as possible so they will only need to recharge the fuel cell every 1,000 miles. The power source is by compressed air shot through a rotary actuator in each wheel. The future of zero emission luxury vehicles will have fuel cell or electric drive units and turbo vacuums with regeneration tanks to provide similar performance of current vehicles. The use of lighter materials will benefit acceleration and cornering which would provide a high-torque ratio for electric motors that would deliver the capability of flying rather than driving. The use of vegetable based polymers will be used for the exterior body panels instead of aluminum or steel. Mercedes-Benz is also working on the Biome concept with is developed from the Ecosystem. The intended weight of the Biome is 927 pounds. The vehicle gathers solar energy and stores it in a fluid called BioNectar4534 which delivers power (Pinter, 2010). The Biome can be plugged into trees through a receptor to harvest their excess solar energy. Biofibre a scientific method of reproducing DNA will be grown and used to build the Biome in a Mercedes-Benz nursery. At the end of its lifespan, the vehicle could be recycled. The iV is a super light-weight sports tourer based on a frame derived from fast growing ivy and re-enforced with spider silk composite. The process would be 100% sustainable and carbon-neutral. The canopy would collect solar energy via an innovative photovoltaic material for the electric drive.

Other plans for sustainable vehicles would be to use hub-less wheels which will utilize a magnetic hovering integrated suspension and force system. The technology used to build frames if the future is a knitting process called Smart Granny Robots (SGR). The knitting process will allow the construction of intricate shapes using the least amount of material. Recycled plastics

for body panels with “clip on” options will make it easy for consumers to customize the vehicle to their liking. Toyota is currently working on the Nori concept. The frame and body could be structured and one is made from seaweed and carbon fibre. The design of the Nori is to offer digital content and graphic patterns that could be programmed and displayed on the body panels. The inspiration of the design is a clam shell and is powered by compressed electric and air motors that could be recharged by a simple air pump.

## Red Flags

Environmental red flags are raised long before a vehicle is produced. Factors include fuel cost, air quality, impact, production and destruction. There’s so much energy it takes just to make the parts for a vehicle before it gets to the factory or even on the road. However, for the most part we’ve resolved the recycling crisis and most of what we drive today are recycled materials. 75% of the average car can be recycled and car graveyards are becoming a thing of the past. The environmental impact of a vehicle contributes to one-third of all U.S. air population. Smog, carbon monoxide and many other toxins once extracted in the air lead to people inhaling them. Automobiles contribute about 80 to 90% due to the fuel consumption, emissions air pollution and greenhouse gasses which cause global warming. However, the only way to prevent exhaust pollution is by how much a person drives. The process of extracting petroleum from the earth and shipping fuel can cause much damage to the local ecosystems and cause oil spills. Unconventional sources such as fuel sands, fuel cells, solar and electric energy can assist with the fuel efficiency over the years. (Silex, 2013)

# Toyota Mirai Fuel Cell



*Fig 2. Toyota Mirai Courtesy of Toyota*

**Debut:** Los Angeles Auto Show
**Estimated Availability:** 2016 (as a 2017)
**Estimated Price:** $57K
**Features:** Fuel Cell Technology

Many luxury manufacturers are developing vehicles that promote sustainable energy. Toyota/Lexus are the first in the luxury market that will offer a fuel cell vehicle to be released around 2016. Hydrogen powered, Mirai's innovative development was financed and supported by the Japanese government (Voelcker, 2014).

The selling price for the Toyota Mirai is $57,500 U.S. dollars prior to any government fees are applied to the sale price. The initial release will be September 2015 to Europe, UK, Germany and Denmark. For the U.S., California will receive the Toyota Mirai first and sales will expand to other countries by 2017. The fuel cell engine will produce and estimate of 113 kW and the battery would consist of a 1.6 kWh Nickel-metal hydride that ranges 400 miles. The Toyota Mirai (4-door) is considered to be a family sedan. (Scanlon, 2014)

# Lexus LS-Fuel Cell



*Fig 3. Lexus LS460 Courtesy of Lexus*

**Debut: N/A**
**Estimated Availability:** 2016 (as a 2017)
**Estimated Price:** Unknown
**Features:** Luxury Fuel Cell Technology

Lexus is currently working on the next generation of it LS-series flagship to be released as a hydrogen fuel cell vehicle. There will be a larger grill on the Lexus in order to accommodate the fuel-cell powertrain for better cooling of the fuel-cell stack, electric motor and additional electronics. The weight and distribution of the next generation Lexus LS will be lighter by a few hundred pounds than the current Lexus LS Hybrid to accommodate the fuel cell. The fuel cell will be housed under the front seat and the hydrogen tanks are located in between the rear seat and trunk. Over the past 10 years, Toyota and Lexus have successfully shared the powertrain and other components of its vehicles, especially with the hybrids. (Fuel Economy, 2015)

# Mercedes-Benz Fuel Cell



*Fig 4. Mercedes-Benz F015 Courtesy of Mercedes-Benz*

**Debut:** Las Vegas, NV
**Estimated Availability:** 2030
**Estimated Price:** Unknown
**Features:** Luxury Fuel Cell Technology, Autonomous

Mercedes-Benz is known for luxury and performance. Therefore it's no surprise that the Mercedes-Benz F015 concept car houses a fuel cell power plant that produces 231hp with a top speed of 137mph making 0-60 in 4.9 seconds, making it the fastest fuel cell vehicle so far. It's not only a fuel cell vehicle—it's self-driving as well. Again this is a concept, but the goal of this research vehicle is to establish a connection between the vehicle, passengers and the outside world. Its tag line is, "Luxury in Motion," and even though it's not ready for production, Mercedes-Benz would like the consumer to envision mobile living in the year 2030 (MBUSA, 2015)

The F-Cell Plug-in Hybrid will combine electricity and on-board generation powered with a high voltage Li-sulfur battery and hydrogen. The Mercedes-Benz F015 was inspired by the 2011 F125 concept. The Mercedes-Benz F015 is even more sustainable because of the materials used to build this vehicle. The Smart Body Structure (SBS) developed by Mercedes-

Benz and currently used for the Smart car consists of aluminum and high-strength steel that would make it 40% lighter than any vehicle produced today (Kahn, 2015). Mercedes-Benz would like for the F015 to be the vehicle that an individual can retreat within during a commute and aims to create a stress-free environment as traffic is navigated. Time, space, efficiency and stress free are the operative words that dictate where the worlds' most noted luxury brand are headed. (Green Car Congress, 2015)

## Google EV



*Fig 5. Google EV Courtesy of Google*

**Debut:** Los Angeles
**Estimated Availability:** 2020
**Estimated Price:** Unknown
**Features:** Electric Vehicle, Autonomous

While on the topic of self-driving electric vehicles, Google has been planning to build a self-driving EV from the ground up. For the past four years, Google has partnered with Lexus, Toyota and Audi by making modifications to the software and hardware to make sure that the actual prototype is a success. The testing has been taking place in California, and the plan is to

build about 200 of the autonomous driving EV's. The vehicles will consist of the lithium ion battery that most EV's need to operate, however the steering wheel, gas and brake pedals are non-existent. For safety measures, the Google EV will have manual controls in case of emergencies. The top speed of the Google EV is set at 25 mph and the shell is made of mostly plastic. It has a 360 view camera and radar so it can determine how to stop, go and park as well. While they are still in the development phase, Google is promoting its EV by transforming mobility for millions of people and improving road safety. They feel as if this vehicle will revolutionize travel for those who are unable to drive such as disabled persons. The Google EV is legal in California, Michgan, Nevada and Florida for testing purposes. Unlike Apple who is partnering with Tesla, Google has decided to develop their EV with a fresh canvas with the resemblance of a Little Tikes toy car. Google isn't planning on really becoming the next luxury brand to build a vehicle but to make a commute more economic and enjoyable. (Kahn, 2009)

**Benefits of Autonomous Vehicles** (Hars, 2015)

- Autonomous vehicles could greatly decrease greenhouse gas emissions in urban traffic because Car-sharing services could offer local mobility for a highly competitive price based on a fleet of smaller, lighter cars which therefore cause fewer emissions
- Local car sharing fleets would be ideal adopters for alternative, low-emission drives (electric cars, hydrogen, fuel cells). Because of their higher utilization levels, higher initial capital costs for the new technology as compared to the gasoline engine would not matter as much.
- Autonomous cars used for local trips would be an ideal application for getting electric cars into operation in high numbers. Increased use of car-sharing for local transport

reduces the overall demand for vehicles which in turn reduces greenhouse gas emission for manufacturing automobiles.

- Especially in emerging nations which don't yet have a large percentage of car ownership driverless cars could be the basis for a much more effective transport system which uses a combination of shared driverless vehicles for short distances and buses, trains etc. for medium and long distance travel. Autonomous cars would establish an optimal link between individual and mass transit; small, local driverless vehicles could serve as feeders for the last mile by transporting individuals to/from local bus stations, train stations etc.
- Driverless cars use roads more efficiently (fewer emissions because of less road construction), can reduce emissions by driving in convoys and don't induce traffic jams.
- Overall, autonomous vehicles could be a major technology to fight against climate change. The technology can even pay for itself: It is probably the only technology which lowers overall costs (of mobility, maintaining the infrastructure etc.).

## Apple EV



*Fig 6. Apple iCar Courtesy of Forbes Magazine and Apple*

**Debut:** Unknown
**Estimated Availability:** Unknown
**Estimated Price:** Unknown
**Features:** Luxury Electric Vehicle, iOS operating system

Thus far, the current outlook for electric vehicles is positive. With current low oil prices, the fuel savings benefits are offered by electric vehicles with this method of sustainable energy. The recent demand of EV's growth is positive—especially with new automobiles waiting to be released and put on the market. In recent times, luxury, technology and sustainable energy recently have operated in a triangle because the push to save our solar system and decrease pollution has been a topic for years. Many pioneers from various companies have been hired to make EV's become a reality. For instance, Steve Zadesky was hired by Apple after leaving Ford as an engineer to develop the iPod and iPhone. Johann Jungwirth was hired by Apple after resigning from Mercedes-Benz as the chief executive of research and development team of North America. Along with Elon Musk of Tesla, Zadesky and Jungwirth hired a team of 1,000 employees to develop the plans for the Apple electric car. (Pagliery, 2015)

Apple, the headliner for the technology sector, and Tesla, the headliner for electric vehicles, have been working diligently on making a vehicle for the Apple customer. Being that Apple is very secretive about their products, there is very little information found on what the Apple car will look like. However, we are aware that the plans for the Apple car is to operate on electric and solar power. Apple has already announced plans to invest $850 million into a solar power plant in California to power its operations. Before his passing, Steve Jobs mentioned the making of an iCar. He felt that the Tesla roadster was one of the best cars ever built, but his partner Miller Drexler was against the idea. Jobs believed that Tesla had the right platform for the design and the best engineering out of all the other manufacturers. Consumers can expect to see the Apple car in the near future, but the price to be anything but cheap. (Woodyard, 2015)

# Tesla Model 3




*Fig. 7 Tesla Model 3 Courtesy of Popular Mechanics and Tesla*

**Debut:** Los Angeles Auto Show
**Estimated Availability:** 2008-Present
**Estimated Price:** $70K+
**Features:** Luxury Electric Vehicle

Tesla, an American brand, has proven itself as the leading luxury electric brand. Currently they are competing with German luxury manufacturers and even the Italian luxury brand Maserati. Even though its competitors offer hybrids, they have yet to produce a fully-electric vehicle. However, when it comes to performance and price they compete well. Tesla's motto is to have luxury and performance while going green. It's a market that was untapped for a while because electric vehicles have been offered mostly by entry level automakers in the past. So is it safe to say that luxury EV's will continue to head in the direction of sustainable energy until fuel cells are mass produced? Research has proven that EV's have decreased the amount of pollution because they are zero emission vehicles. Therefore, the lower amount of emissions the better the environment. (Yarow, 2015)

Tesla has is currently working on several prototypes to expand its lineup along with the Tesla Model S. The Tesla Model 3 will be the entry level to the Tesla lineup to make it more attainable for middle class consumers. It isn't set for release until 2017, but its something to look forward to because the current Tesla Model S is priced $100k+. The Tesla Model 3 will be a competitor for the BMW 3-Series and priced around $35k with a 200 mile range on a fully charged battery. (Market Reports, 2015)

On the other hand an SUV is in the works. The Tesla Model X is based on the Model S. The iconic dual-motor by Tesla, will be the first battery electric vehicle to be produced that will attract many consumers with the all-wheel drive crossover. It's no surprise that electric cars have the most undesired looks and limited sizes. Tesla plans to continue and embrace elegant designs especially with the Model X when it's released mid-September. Its biggest competitor will be the Porsche Cayenne, so expect the price tag to be a little hefty but still less than the Model S. The space-age design offered by Tesla along with the latest battery technology, telemetrics and driver assistance from collision avoidance to autopilot features, it's clear they are moving in the right direction. The prediction is the Model X will convince competing auto manufacturers to produce efficient battery-powered sedans and subcompacts in order to create a better environment while driving a luxury vehicle. Musk said that the company will begin accepting online customization orders in July. "This is really a great car. I mean, because it has such a low center of mass, it handles like a sports car even though it's an SUV," Musk said. "The performance is just surreal. Nothing else is comparable" (Welch, 2015).

Tesla built 11,160 cars, in the first quarter of this year, averaging more than 1,000 vehicles per week. By the end of next quarter ending in June, Tesla plans to build an estimate of 12,500 vehicles and deliver 10,000-11,000 vehicles. While demand is very high for Tesla vehicles, the company lost $154 million in the period ending on March 31, 2015. The company plans to distribute around 55,000 vehicles overall in 2015 (Kelly, 2015)

**Tesla Model S at a glance** (US News, 2015)

**Acceleration and Power**

- The 2015 Model S 70D has two electric motors that provide 329 horsepower. It earns an EPA rating of 101/102 mpg-equivalent (mpg-e) city/highway and has a 240-mile range. The Model S 85 has a single electric motor and 362 horsepower, and it is rated at 88/90 mpg-e and a 265-mile range. The 85D model has two electric motors that produce 422 horsepower, and it is rated at 95/106 mpg-e and has a range of 270 miles. A single-speed transmission is standard on all models.
- The high-performance Model S P85D model has two electric motors that generate 691 horsepower. According to Tesla, the P85D has a top speed of 155 mph and accelerates from 0 to 60 mph in 3.1 seconds.
- Reviewers report that the Model S has exhilarating power in all driving situations, especially when starting from a stop. They comment that the high-performance P85D model feels as quick as some high-performance supercars, although they add that continual enthusiastic driving will drain the batteries quickly. They note that the Model S is incredibly quiet at speed.

**Alternative Fuels/Charging**

- The 2015 Tesla Model S is equipped with a charger that has adaptors for 110- and 240-volt outlets, as well as an adaptor for public charging stations. The Model S gets 3 miles of range for each hour of charging with a standard 110-volt outlet, according to Tesla, while a 240-volt outlet gets the Model S up to 29 miles of range for each hour it charges. An available dual charger provides 58 miles of range per hour of charge time when using a 240-volt outlet. Tesla also has supercharger stations throughout the country that provide 170 miles of range in 30 minutes. Supercharging capability and lifetime Supercharger access are standard on all models.

**Handling and Braking**

- The Tesla Model S comes standard with all-wheel drive (the Model S 85 has rear-wheel drive). It also has an optional Smart Air Suspension system that raises and lowers the car's height based on driving conditions for a smoother, more streamlined ride. Test drivers think the Model S has incredibly poised handling when cornering, thanks in part to its low center of gravity. They add that the steering is precise, the ride is smooth and that the Model S' brakes bring the car to a stop quickly.

# BMW i3




*Fig. 8 BMW i8 and BMW i3 Courtesy of Drive Inside and BMW*

**Debut:** 2013 Los Angeles Auto Show
**Estimated Availability:** Fall 2014
**Estimated Price:** $41K
**Features:** Luxury Electric, Vegan

It's a no brainer to think after Tesla did so well with their EV's that BMW wouldn't follow pursuit. BMW took it an even step further to make its EV more quirky than Tesla and even more sustainable to build. Alone, BMW is the most sustainable automobile manufacturer than any other auto company on the market. The BMW i3 made its debut fall 2014 as a 2015 model. The i3 is made of recycled carbon fiber materials and does not have an option for leather. It's the ideal car for the PETA/vegan connoisseur that wants a luxury car. BMW has put a lot of thought into the i3 because they want to make sure they surpass the Tesla mileage wise. The i3 can give as much as 117 mpg on a single charge compared to the Tesla that only provides about 97mpg. BMW didn't plan to make the i3 Tesla's direct competitor (Elliot, 2015).

Instead the BMW i8 was created as the Tesla Model S' direct competitor due to performance. The difference between the Tesla Model S and the BMW i8, is the i8 is indeed a hybrid sports car. BMW chose to release the cars around the same time to remain conscious of those that want an economical luxury car and to set a trend for the hybrid sports cars. Either way, BMW is doing extremely well with both vehicles. The i8 is priced around $137k while the i3 is priced fully equipped at $52k with all of the upgrades a BMW 3 series. Features such as rain-sensor wipers, heated seats, navigation and the list can go on. What BMW has made available to its clients is the ability to has a supercharged battery pack to charge it's vehicles in few hours less than the normal four hour charge station that can be installed in your own home. The layout of the i3 is 30 to 50 percent less than similar vehicles in its class. According to Jalopik.com they explain why the BMW i3 is sustainable:

- The carbon emissions produced by the extraction of raw materials and manufacture were reduced by recycling and the energy efficient production process.
- A greenhouse potential is reduced by 30 percent by using energy from the EU 25 electricity mix, which takes account of all electricity generation in the European Union.
- For BMW this has been improved by more than 50 percent in comparison to conventional automobiles since the BMW i3 is power-driven by energy generated from renewable materials, such as wind or solar power. It is possible for Germany to meet the target of generating 35 percent of its electricity from renewables by 2020.

- The leather if equipped is tanned with olive-leaf extract instead of dye, and the wood is environmentally refined from qualified gardeners in Europe along with the tangible use of natural fibers in the instrument panel and the door panels benefit sustainability.
- 25 percent by weight of each of the plastics used in the interior and the thermoplastics in the exterior have been derived from recycled material or renewable raw materials.
- Most of the lightweight alloy components of the BMW i3 are made up of so-called secondary aluminum. This is not obtained from aluminum ore but from melted production scrap and can be produced using up to 95 percent less energy.
- Primary aluminum also makes a contribution since it is produced using energy generated from renewable resources.
- Around ten percent of the CFRP used in the passenger cell is made of recycled materials. For example, offcuts from the manufacture of CFRP components can be returned to the production stages in a process specially developed for BMW
- Finally, the carbon-fibre plant located at Moses Lake (USA) which produces the raw material for all the components manufactured from CFRP in the BMW i3 uses 100 percent of the energy from locally generated hydropower, while the electricity at the Leipzig production plant also comes exclusively from renewable energy sources.

# Rolls-Royce EV




*Fig. 9 Rolls Royce Phantom EV Courtesy of Rolls Royce*

**Debut:** Unknown
**Estimated Availability:** Unknown
**Estimated Price:** Unknown
**Features:** Luxury Electric Vehicle, Fuel Cell Technology

On a higher end of luxury, Rolls Royce is considering on becoming more sustainable with their engineering. A company known for their V12 engines and handcrafted vehicles has decided that going green is the way to go for the Ghost and Phantom trim lines. The plan isn't to reinvent the brand, but to partner with Lotus instead of its parent company BMW to build its battery pack and electrical components and assemble them to fit where the front mounted engine is housed. (Sherman, 2011)

With any vehicle, there are many what-ifs to consider. Concerns such as roadside assistance if an owner is stranded with a dead battery or if the electrical grid malfunctions have been given much thought. Rolls Royce has taken many options into consideration prior to launching the idea of an electric vehicle. They have even considered working on a miniature fuel cell with an emergency canister of pressurized nitrogen as a backup system if the electric motor

does fail. The exterior won't consist of any major changes and Rolls Royce plans to keep it that way.

For starters, there won't be any exhaust pipes obviously because the goal is to be fully electric. The gas cap filler flap is transparent, which showcases the charging connection socket and the LEDs that glow blue during charging, green when the battery is replenished, and red in the event of electrical issue. If a wireless charging station is used, a successful connection is indicated with a purple LED. A second set of LED indicators is located on the center console inside of the vehicle. A wired wall plug is 96 percent efficient, and a fully integrated wireless system would be close to 89 percent efficient. Similar to wifi, the wireless system sends power through the air and sends data back and forth. You can check the charge progress from a smartphone and once the vehicle is fully charged, the system will shut off. The recharge ritual takes up to eight hours on 220 volts or up to 20 hours on 110 volts.

## BMW i8 Hybrid



*Fig. 10 BMW i8 Courtesy of BMW*

**Debut:** 2013 Frankfurt Auto Show
**Estimated Availability:** 2015
**Estimated Price:** $137K
**Features:** Luxury Hybrid Supercar

In the high performance sector, supercars should be the first in line to go green but they are taking it slow. Most manufacturers like Ferrari, Lamborghini or Maserati don't want to be known for taking the sustainable energy route because their vehicles are rare but they'll make an attempt as a hybrid first before they go fully electric. As mentioned before the BMW i8 is the most sustainable energy is considered a supercar hybrid at the time. It is labeled as the car with multiple personalities because it has three transmissions and three settings for each mode Eco, Comfort and Sport. While the i8 is in Eco mode, it is very quiet because there is no sound or vibration during a city commute which makes it a more enjoyable experience. The power of the front mounted electric engine is plenty. It's housed between the front wheels while the lithium-ion battery pack is mounted between the seats and dishes out 129-hp alone with a top speed of 75mph. Depending on the acceleration, the gas engine will switch on or off on demand when the car has been placed in the comfort mode. There may be a slight delay when the gas engine responds because the comfort mode doesn't operate in full throttle like it would in sport mode. Once in sport mode the car comes to full life allowing the gas and electric engine to come together as one providing 357-hp even changes the instrumentation cluster to glow red instead of blue. (Quiroga, 2015)

The beautiful thing about the BMW i8 is if you leave the vehicle in sport mode the battery pack will recharge even if you forget to plug the vehicle. A vehicle produced with this much power, heavily competes with high performance vehicles with gasoline engines even within the BMW lineup. The difference is the i8 is in fact a high performance hybrid with a three-cylinder engine, two electric motors and two transmissions that shift effortlessly seamless.

Just shy of 3400 pounds the i8 handles curves just like if not better than any BMW on the road. The benefit of this supercar is that the electric motor assists with braking the vehicle before the driver applies the brake pedal to come to a complete stop and generates electricity to the battery pack. Tesla however perfected the regeneration process of the battery pack even while braking the vehicle. Last but not least, for a supercar like the BMW i8 it ranges 26mpg, something even a Corvette can maintain. While BMW is still developing their sustainable vehicles, Porsche is ahead of the automotive industry with plans to make a fuel cell vehicle based on the 918 Spyder.

**The BMW i8 at a glance** (Russell, 2013)

- First plug-in hybrid vehicle from the BMW Group and world's most forward-looking sports car; revolutionary interpretation of BMW's hallmark driving pleasure; groundbreaking premium character clearly defined in terms of sustainability.
- 2+2-seater with LifeDrive architecture developed specifically for BMW i, aerodynamically groundbreaking body design and visionary interior design deliver an intense driving experience; Life module passenger cell made from carbon-fiber-reinforced plastic (CFRP); drive system technology, high-voltage battery, chassis, and crash and structural functions integrated into the aluminum Drive module; curb weight: 3,285 lbs (1,490 kg); Cd: 0.26; very low center of gravity (below 18 inches/460 millimeters); well-balanced weight distribution.
- Emotion-led visual impression based around established BMW i design language; classical sports car proportions and fresh interpretation of BMW design features; doors open upwards like wings; clean lines, plus surface design (external and internal) based on the layering

principle; full-LED headlights as standard, innovative laser headlights – unique worldwide – available as an option where regulations allow.

- Plug-in hybrid system developed and produced by the BMW Group represents the latest development stage of Efficient Dynamics; debut for three-cylinder gasoline engine with BMW TwinPower Turbo technology, displacement: 1.5 liters, output: 170 kW/228 hp, maximum torque: 320 Nm (236 lb-ft); power sent to the rear wheels via a six-speed automatic gearbox; model-specific hybrid synchronous electric motor, output: 96 kW/129 hp, maximum torque: 250 Nm (184 lb-ft); power channeled through the front wheels via a two-stage automatic transmission; lithium-ion high-voltage battery with liquid cooling and usable capacity of 5 kWh.
- First combination of BMW TwinPower Turbo and BMW eDrive technology plus intelligent energy management produce system output of 266 kW/357 hp (max. torque: 570 Nm / 420 lb-ft) and give the BMW i8 the performance characteristics of a pure-bred sports car (0 –60 mph in 4.2 seconds) combined with fuel economy and emissions comparable to a small car - EU fuel consumption: 2.5 litres per 100 km / 94 mpg (US); “glued-to-the-road” AWD driving experience with torque distribution geared towards optimized dynamics.
- Driving Experience Control switch and eDrive button allow driver to choose from five driving modes; range of up to 35 kilometers (22 miles) on electric power alone and a top speed of 120 km/h (75 mph); COMFORT mode offers optimum balance between dynamics and efficiency; combined range in everyday conditions: over 500 kilometers (310 miles); SPORT mode with ultra-intense boost function provided by the electric motor; ECO PRO mode can be used in both all-electric mode and hybrid mode.

- Sophisticated chassis technology featuring a double-wishbone front axle and a five-link rear axle; Electric Power Steering; Dynamic Damper Control comes as standard; 20-inch light-alloy wheels are standard.
- Intelligent lightweight construction with elements including a CFRP passenger cell, doors with a CFRP-aluminum structure, an instrument panel with magnesium support, an aluminum chassis and a partition between the passenger compartment and boot made from thin glass; comprehensive safety concept and an ultra-torsionally stiff passenger cell.
- Extensive standard equipment includes the Navigation system Professional with proactive drive system for all-electric driving, fully-digital instrument display, BMW iDrive with freestanding Control Display and leather sports seats; choice of four exterior paint finishes and four interior equipment variants.
- Wide range of BMW ConnectedDrive features: Park Distance Control, cruise control system with braking function, rain sensor and Intelligent Emergency Call function, driver assistance package with High Beam Assistant, a rear view camera, Surround View, Speed Limit Info including No Passing Info display, and Collision Warning with pedestrian recognition and braking function; also available are the Head-Up Display, BMW Online Entertainment, Concierge Services, Real Time Traffic Information and mobility services developed specifically for BMW i, e.g. intermodal route guidance as standard.
- Services specifically developed for BMW i as part of the 360° ELECTRIC program: BMW i Charging Station for convenient battery charging at home, ChargeNow card giving customers a cash-free payment option at public charging stations as well as innovative mobility services such as MyCityWay and ParkatmyHouse; flexible sales concept enables made-to-measure mobility solutions.

- All-embracing sustainability concept running like a thread through the value chain; carbon fiber production and vehicle assembly using 100-per cent renewable electricity; high proportion of recycled materials; use of materials manufactured and treated in an environmentally friendly manner.

## Porsche 918



*Fig. 11 Porsche 918 Courtesy of Porsche*

**Debut:** 2013 Frankfurt Auto Show
**Estimated Availability:** 2014
**Estimated Price:** $1million
**Features:** Luxury Hybrid Supercar

Ulrich Hackenburg of the Volkswagen Group shared that Porsche will soon develop a fully electric and fuel cell vehicle in the near future. The VW group has already started producing hybrids and has plans for EV's with the VW e-Golf and Audi e-Tron. If the EV's and fuel cell vehicles are released, the VW group will debut them in California first because allowing access to the rest of the world for testing purposes. It took Porsche many years to develop the 918 Spyder plug-in hybrid. The price is just little under $1million but is a direct competitor to the Bugatti Veyron. The gasoline engine is a rear mounted V-8 with the electric motors placed on each axle producing a total of 898hp from the seven speed transmission. (Top Speed, 2013)

The lithium-ion battery pack is placed behind the passenger to allow perfect body/weight distribution. Unlike the BMW i8, the Porsche 918 offers one powertrain mode but offers a seamless transition between electric and gasoline power sources.

**Porsche 918 Hybrid at a glance** (Left Lane News, 2014)

- **Standard and Optional Equipment**

  The 918 comes standard with power windows with one-touch operation, a digital radio, a rain-sensing windshield wiper, electric and heated door mirrors, a reverse camera, an 11-speaker Burnmester surround sound system, LED headlights, leather upholstery on the dash, the center console and the door panels and Alcantara upholstery on the headliner.

  The highlights include button-activated front axle lift system that reduces the risk of scraping the car on ramps and driveways, bespoke paint colors, a carbon fiber interior package, carbon floormats with bespoke piping and colored seat belts.

- **Weissach Package**

  For an extra $95,000, buyers can order the Weissach Package that lowers the 918's weight to 3,615 pounds thanks to additional carbon fiber parts and special magnesium wheels. The package also adds six-point seatbelts and Alcantanra upholstery instead of leather, and it gives buyers access to special colors inspired by historic Porsche race cars and optional film-coating instead of paint.

- **Occupant Safety**

  All 918s are equipped with front, side, thorax and head airbags in addition to Porsche's Stability Management (PSM) system, which groups driving aids such as traction control

and stability control. PSM can be deactivated in two stages or set to a sport mode for spirited driving. A tire repair system with a sealing compound replaces the spare wheel.

- **Key Competitors**

  Ferrari LaFerrari and the McLaren P1

## Ferrari LaFerrari




*Fig. 12 Ferrari LaFerrari Courtesy of Ferrari*

**Debut:** 2013 Geneva Auto Show
**Estimated Availability:** 2015
**Estimated Price:** $1.5million
**Features:** Luxury Hybrid Supercar

All hail to the KING!!! Ferrari, known as the best of exotic sports cars has developed the Ferrari LaFerrari. Though Ferrari doesn't want to market the LaFerrari as the hybrid exotic car, it is what it is. The LaFerrari, houses its legendary V-12 engine that produces 789-hp. But with the addition of an electric motor, it'll give this car an additional 161-hp boost. Like Porsche, Ferrari's goal is to offer a vehicle to perform like a Bugatti without the price tag and better fuel economy. (Loveday, 2013)

Based on what we know of a hybrid, it's clear the perception of owning one is "cool". That's one reason why Ferrari doesn't want to market the LaFerrari as a hybrid, but they know deep inside, consumers want a vehicle that offers better fuel economy and the government wants emissions to eventually become obsolete.

The Samsung sourced 2.2-kWh lithium-ion battery pack electric motor in the LaFerrari is designed to only operate during low speeds so for cruising purposes. You can barely notice when it's in use until you hear a major difference in sound once the gasoline engine takes over at full throttle. Currently it's one of the most powerful luxury supercars on the market but since the electric mode is so limited for average person to use, it's pointless to promote the sustainability of the LaFerrari. Like the Tesla, BMW and Porsche the battery is recharged during braking or while cornering while the vehicle is in motion. Most cars only send power to the wheels while cornering, but with hybrids the power is redistributed to the battery as well.

**Ferrari LaFerrari at a glance** (Left Lane News, 2014)

- **F1-Sourced Tech**

  The LaFerrari's HY-KERS hybrid drivetrain is modeled after the system found in Ferrari's Formula 1 cars. Attached to the floorboards, the 132-pound battery pack helps lower the LaFerrari's center of gravity and enabled engineers to place 59-percent of the car's weight on the rear axle. The battery pack is recharged during braking - even when ABS kicks in - as well as when excess torque is being produced such as during hard cornering. The electric motors powered by the pack lower gas mileage and improve

performance but they cannot drive the car by themselves like the ones found in competing cars built by Porsche and McLaren.

- **Cheating The Wind**

  A blend of form and function, the LaFerrari was conceived to be as aerodynamic as possible with the help of a wind tunnel typically used to design Formula 1 cars. It borrows some styling cues from the Enzo, its predecessor, and others from current members of the Ferrari lineup like the F12 Berlinetta. It boasts an aggressive appearance with large air dams up front, a F1-like nose cone and a wide rear end characterized by two round tail lamps and four exhaust tips. Active aerodynamic devices such as diffusers on both ends, a spoiler out back and guide vanes integrated into the underbody generate downforce when needed and help the LaFerrari cheat the wind. A wide array of sensors work to deploy the devices automatically without any input from the driver.

- **Driver-Focused Cockpit**

  The LaFerrari's cockpit is accessed via doors that swing upwards. Continuing the Formula 1-inspired theme, the steering is commanded with a flat-bottomed steering wheel that groups every major command including switches for the turn signals, the headlights and the windshield wipers, a knob that enables the driver to select from five different driving modes and a button used to start the engine. The climate control knobs are conveniently located on the dashboard. The car is equipped with a digital instrument cluster consisting of two high-definition color screens and a large tachometer mounted front and center. The driver can configure the information displayed by the two screens. Interestingly, the LaFerrari's driver seat is tailor-made and cannot be adjusted, but the driver can change the position of the pedals and the steering wheel. Ferrari used input

from drivers Fernando Alonso and Felipe Massa to create a driving position that is similar to that of a single-seater race car.

- **Key Competitors**

  Porsche 918 Spyder and McLaren P1.

## Global EV Sales



*Fig. 13 China Courtesy of Daily Insider*

China has made a big investment for the plans of charging infrastructure and the exemption of EVs in major cities as well as countries such as the UK, Spain, Norway and the Netherlands. With this plan, the global automotive sales forecast by the end of 2015 is to have 430,000 EV units sold. The estimated sales by the end of 2014 were less than 1% because they are still relatively new compared to the sales internal combustion engine vehicles. The estimated sales of registered EV's for 2015 will be about 1.13 million for China, Europe, Japan and the U.S. (Edelstein, 2015)

China's current five-year energy plan set forth the goal of reaching 11.4 percent of renewable energy by 2015. Bearing in mind that China should have passed the 10 percent mark by 2013, According to Melanie Hart, it's not certain that target will be met. However, the government plans to keep its commitment to clean energy, rather than not follow through. "Chinese leaders have decided they can't continue on their current path," Hart said. "If change hurts, so be it. They just cannot afford to slow down."

With the new climate agreement, there were signs that China recognized the consequences of business as usual and were adamant about making changes. This new commitment to improve the environment is mirrored throughout the country's new policies, Hart said (Kroh, 2014). China spent $175 billion on clean energy projects in the first three quarters of 2014 which was a 16 percent jump from the previous year, according to figures from Bloomberg New Energy Finance. A total of $54.2 billion has been invested in China's renewable energy market in 2013, which is beyond any other countries investments.

The Chinese solar investment reached $12.2 billion by fall 2014 and the country could very well add more than 14 gigawatts (GW) of solar capacity this year, almost one-third of the worldwide total. China plans to exceed its goal by installing 100 GW of wind capacity by 2015; according to Renew Economy predicts China may exceed that target by as much as 30 percent. Moving forward, the U.S. will guarantee that China is using and paying for American nuclear technology and making sure technology proven. The increased obligation to carbon-free electricity will have a significant ripple effect on other countries. A strong commitment from China puts substantial pressure on other developing nations to follow suit. "In general, large-

scale deployment of renewables anywhere in the world helps bring down costs everywhere," Hart said. "So significant deployment of renewables in the U.S. and China in the years ahead can help bring down costs in many other countries, if China can do it, anybody can do it," Hart said.

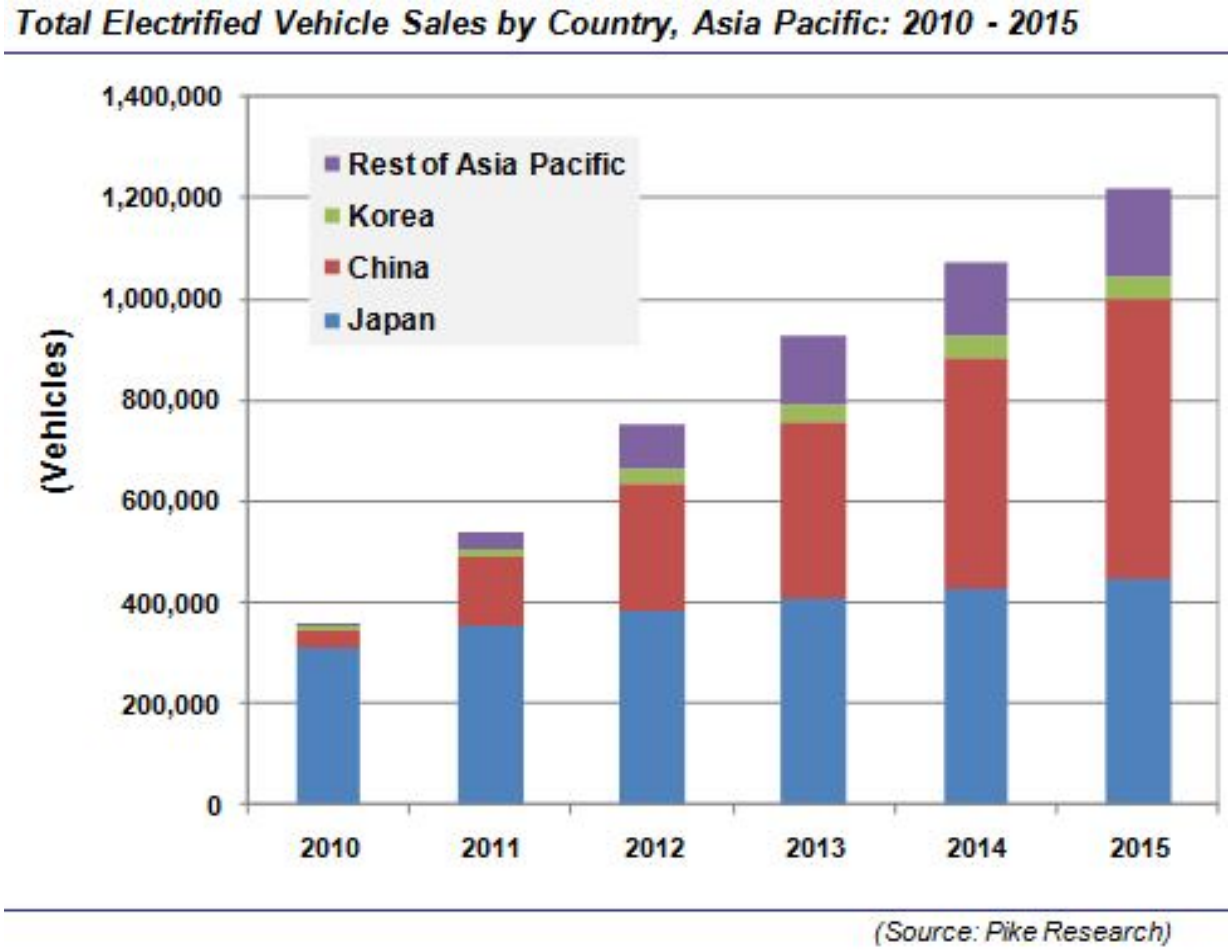



*Fig. 14 Pike Research*

In 2014 EV's and plug-in hybrids were registered totaling 324,000 units. The countries included were key markets of Europe, China, Japan and the US. Normally vehicle data consists of the last 10 years of sales. Because electric vehicles have only been available for the last few years, only limited data is provided. Therefore the electric vehicle convoy at the end of 2014 was estimated and based upon data from 2010-2015 registrations, which gives a total number of

700,000 EV's by the end of 2014. It is therefore very difficult to envisage there being more than another 50-100,000 units on the road globally by end 2015, giving us a global total of 1.2 million units. Though it may sound like a significant number but with vehicle sales set to exceed 90 million units in 2015, EVs may account for just 0.5% of all vehicle sales.

***ECV Registrations and Parc, 2014-2015***

| All ECVs | 2014 Registrations | 2014 Parc | 2015 Registrations | 2015 Parc |
|---|---|---|---|---|
| US | 118,773 | 290,773 | 160,000 | 448,519 |
| China | 74,763 | 113,355 | 110,000 | 222,238 |
| EU+EFTA | 97,791 | 197,791 | 125,000 | 321,177 |
| Japan | 32,418 | 106,542 | 35,000 | 140,834 |
| Total | 323,745 | 708,461 | 430,000 | 1,132,769 |

Source: ACEA, CAAM, EVObsession.com, Euromonitor International

*Fig. 15 Courtesy of Euromonitor*

# Pro's and Con's of owning an EV, ICE, Hybrid or Fuel Cell Vehicle

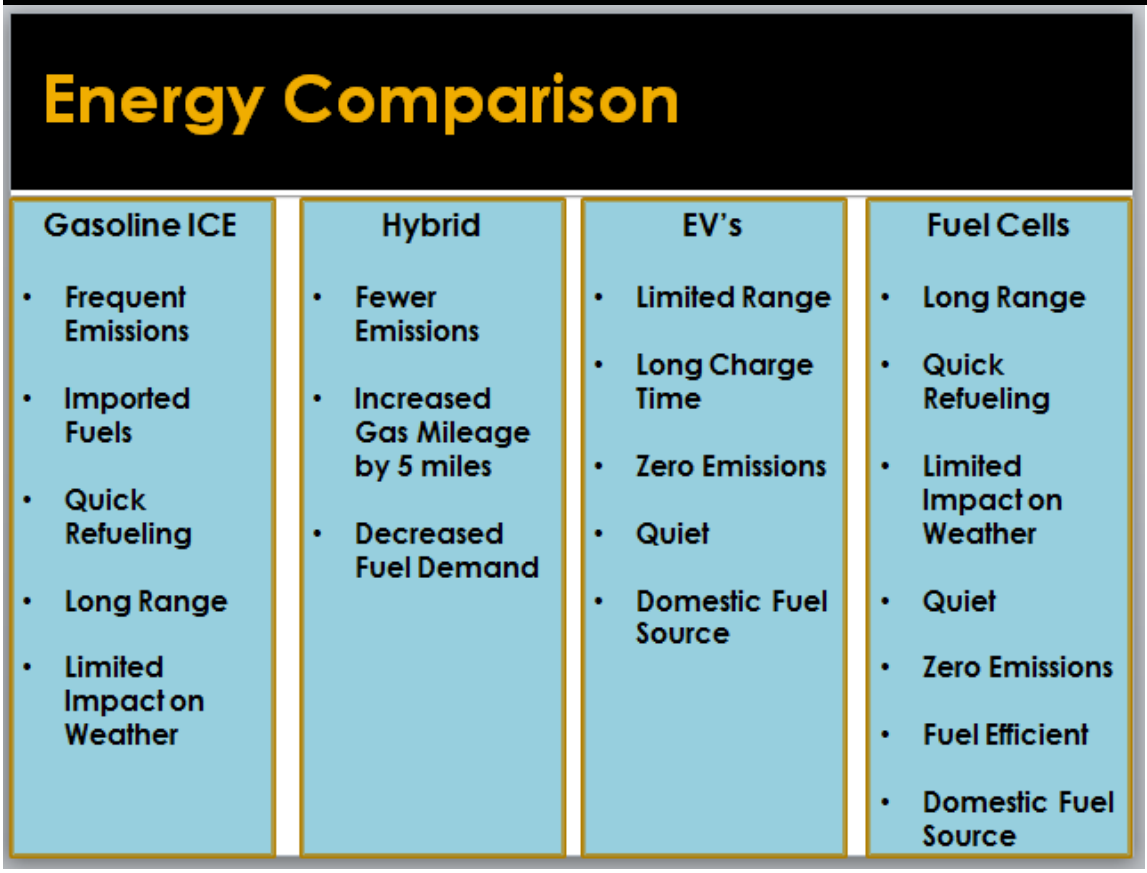



*Fig. 16 Courtesy of Consumer Reports*

## Pro's

### *Quiet and Fast*

For an EV, while most would think they have little to no power, they are quiet, and very fast compared to a vehicle that has an internal combustion engine that utilizes gasoline. Surprisingly the torque and power is immediately delivered to the wheels first instead of the engine which gives a better driving experience along with a smooth ride.

### *Home Recharging*

It's convenient to just plug in your vehicle in the comfort of your home or garage in less than 15 seconds instead of having to visit a gas station again and sit at the pump for five or ten minutes. By the next

morning your EV is fully charged and ready for its daily commute. Most EV's range between 80-250 miles per charge depending on the model and can take anywhere from 4 to 6 hours to charge.

***Cheaper to Operate***

Being that electricity is inexpensive in most countries, it's an advantage because of its efficiency compared to gasoline engines. The average cost per mile to fuel an EV is one-third vs. one-quarter the cost of gasoline.

***No Tailpipe Emissions***

EV's also don't have exhaust systems, so they provide don't need oil changes. Scheduled maintenance is reduced tremendously and they're zero emission vehicles. The only required maintenance is to rotate the tires, replace the brakes and keep the vehicle itself clean. EV's also have a smaller environmental impact because they provide the benefit of improving air quality for the population.

## Con's

***Limited Range***

While the Tesla Model S remains in the luxury sector, it can range 265 miles on a single charge with its 85-kilowatt-hour-battery. Per manufacturer, EV's are slowly improving the range per full charge so they can complete with the range of an internal combustion engine. However, most can afford the entry level vehicles, such as the Nissan Leaf and Toyota Rav 4 which range between 80-100 miles and can take several hours to refuel. EV's are best for individuals that have a short commute so they don't have to worry much about the range before refueling is needed. Currently a vehicle averages 24.1 miles per gallon with a tank that can hold between 12-

18 gallons of gas ranging about 290 miles. Since Tesla was the first to break the mold of the 100-mile range of an average EV, they managed to do so just with adding a few more lithium-ion battery packs to compete with gasoline engines. (Kong, 2013)

General Motors will be the next in line to unveil the 2017 Chevrolet Bolt that ranges more than 200 miles on a single charge. Unlike the Tesla's Model S entry level price of $70,000 the Chevrolet Bolt will be priced less than half of the Tesla to attract middle class buyers. Chevrolet plans to promote to those that want a better range of fuel economy without the price of a luxury EV. The downfall is that there may not be enough battery packs to be produced and manufactured for cars, cell phones, laptops and other electronics that utilize this type of sustainable energy.

***Long Refueling Time***

Major concerns consist of the refueling time of an EV. For every 20-25 miles is an hour of charge time for the average EV (Tesla is 58 miles per hour of charge time) from a 240 volt source of electricity. So unlike driving to the gas pump and filling your car in five to ten minutes, EV's aren't advised for long distance trips. The charge time versus travel time doesn't equal. Therefore it limits owners to recharge their vehicles each night or at each destination where charging stations are available. Charging stations such as public DC Quick Chargers have the ability to charge a vehicle in 20 to 25 minutes are becoming more available in different regions depending on the population of EV's. In the United States, the average person drives 40 miles per day and only 7% of cars are on the road for more than 100 miles a day. So for the majority the EV is ideal depending on the commute.

***Higher Cost***

The average price of an electric car is $30k-$40k which can make them more expensive that the average vehicle depending on the class. A Nissan Leaf (EV) with is in the same class as a Ford Focus (gasoline) and Honda Fit (gasoline) may cost about $10k-15k more than those that have gasoline engines. However, there are incentives for competitive leasing and or rebates up to $10k for EV's. The least expensive EV on the market is the Mitsubishi i-MiEV which is priced around $24K but the gas range is average of the EV sector. The other benefit of owning or leasing an EV is that most get a tax credit up to $7,500 per consumer.

***Lack of Consumer Choice***

Currently there are only about 20 manufacturers with EV's and hybrids on the market at the time. The numbers are increasing but there aren't really a wide range of choices, therefore they stand out more than any other vehicle on the market along with the price. In America, more than 140,000 EV's and 150,000 hybrid vehicles have been sold since 2010. The sales are far more now than when General Motors released the General Motors EV1 in 1996 and only 1,117 were produced and leased. The reason behind the ceased project was because at the time the government was afraid to mandate electric vehicles due to the possible decrease of jobs in the oil industry. EV's will gain more popularity in due time especially in the luxury sector because people will spend an extra dollar in order to save a few dollars. By 2025 the goal is to have all vehicles with zero emissions, so there is still work to do.

## Fuel Cell Vehicles

Other sources of sustainable energy that many companies are working on are fuel cells. This is the prediction of the future of manufactured vehicles. So far, Fuel Cell Vehicles (FCV's) are making consumers less independent of traditional gasoline which has contributed to global warming and the sudden climate changes. The goal of the FCV is to emit harmful tailpipe emissions by running on hydrogen instead of gasoline. Vehicles equipped with the fuel cell technology would include a fuel cell stack that would convert electricity by the stored hydrogen gas and oxygen to drive the electric motor to impel the vehicle. (Energy, 2015)

There's a range of how fuel cells can be used which include material handling, stationary, portable, emergency backup power applications and transportation. The benefit fuel cells have over the internal combustion-based technologies is that they don't have any emissions during operation that release air pollutants that cause health problems. During operation, only the hydrogen is used as the fuel, fuel cells which release heat and water. Fuel cells have been noted to be very quiet during operation due to having fewer moving parts. Another benefit of fuel cell technology is that they won't lose power or need recharging and will produce electricity and heat as long as hydrogen is supplied.

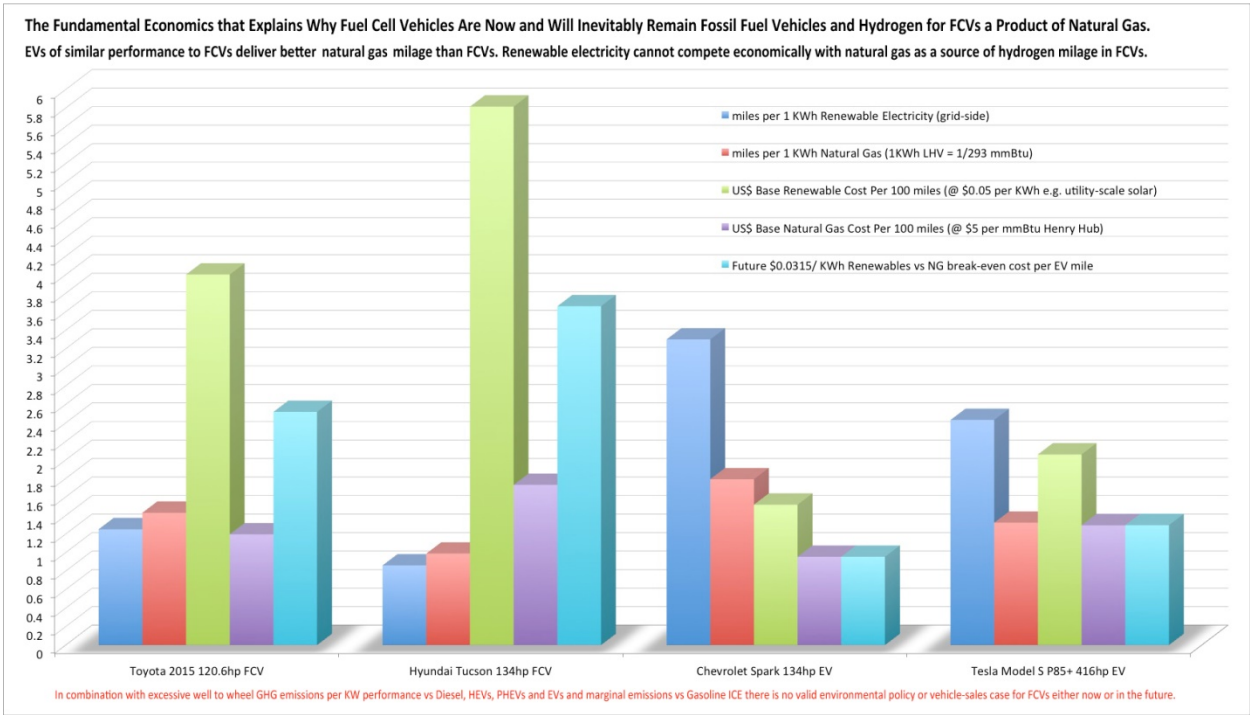



*Fig. 17 Courtesy of the Department of Energy*

A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. Activated by a catalyst, hydrogen molecules separate into protons and electrons, which take different paths throughout the fuel cell to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat.

Performance and durability of fuel cells are a major concern. The average lifespan of a fuel cell vehicle is about 5,000 hours per the Department of Energy under normal operating conditions during stop and go traffic and anything that can cause stress on the chemicals used, stability of mechanical parts and components of the fuel cell system.

**PEM Fuel Cell**

There are many types of fuels cells that are currently under research to see which would be best for sustainable energy for automobiles. They types are: Polymer electrolyte membrane (PEM) fuel cells, Direct methanol fuel cells, Alkaline fuel cells, Phosphoric acid fuel cells, Molten carbonate fuel cells, Solid oxide fuel cells and Reversible fuel cells. They way fuel cells are categorized depends on the type of electrolytes and how they work. The major factor is the electro-chemical reaction that takes place inside of the fuel cell along with the catalyst, temperature of operation and fuel types in which would make to cell beneficial over time. The PEM fuel cells consist of water, hydrogen and oxygen and operate at low temperatures.

The benefits of the PEM fuel cell are simple, there aren't any corrosive fluids, the warm up time is significantly low, the power to weight ratio is good and the wear and tear is low which makes the components of the cell much more durable. The downfall can be the cost to produce this type of fuel cell with can be an added cost to a vehicle instead of a gasoline engine. The additional material used to make the fuel cell is the platinum catalyst which is sensitive to carbon monoxide poisoning. If the catalyst is used it would activate a reactor that would reduce the CO in the hydrogen that was derived from hydrocarbon fuel.

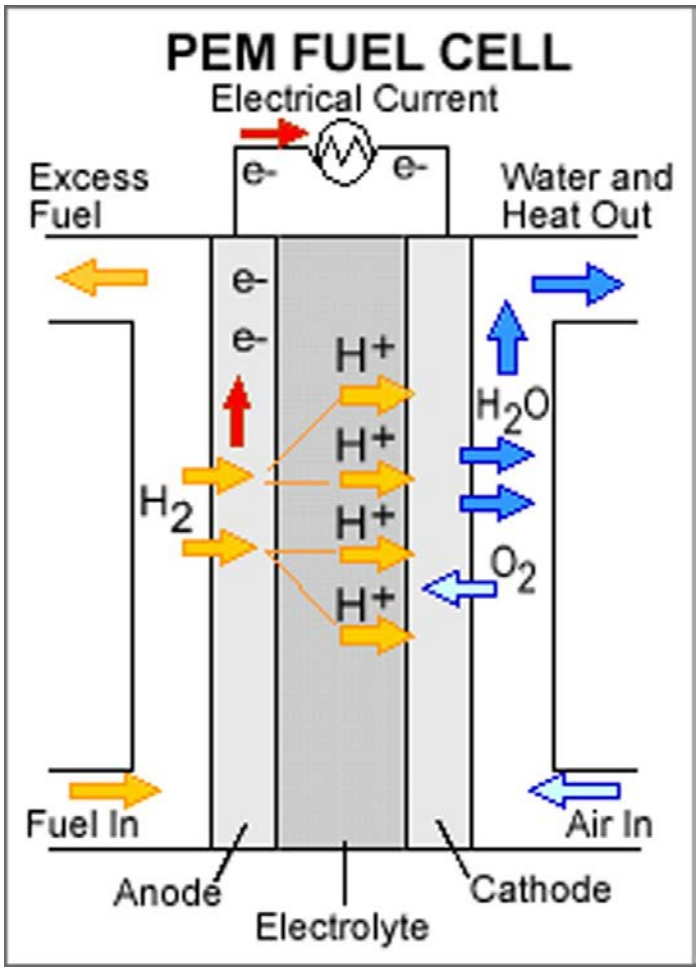



*Fig. 18 Courtesy of Energy.gov*

**DMFC Fuel Cell**

While most fuel cells are generated by oxygen, Direct Methonol Full Cells (DMFC) are powered by pure methanol. The formula is methanol and water which is then fed to the fuel cell terminal. The benefit of the DMFC is that they don't have as many problems with fuel storage that other fuel cells have because of the higher concentration of methanol than hydrogen but less than gasoline or diesel fuel. It's also easier to transport because it's a liquid, like gasoline.

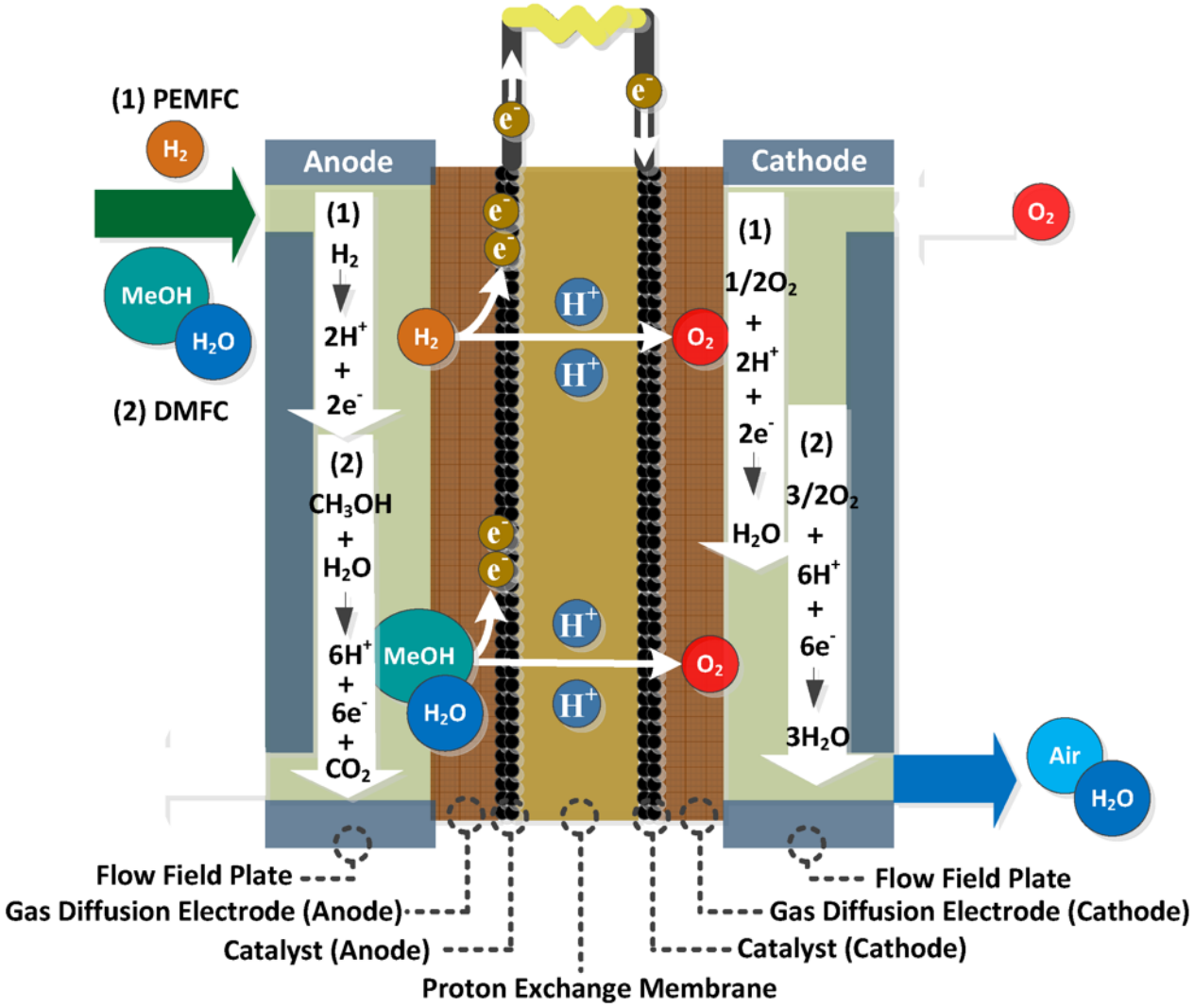



*Fig. 19 Courtesy of Energy.gov*

## AFC Fuel Cell

The first type of fuel cell technology was the Alkaline Fuel Cell (AFC) and was used for the U.S. space program NASA 0in the 1960's to create electrical energy and water on Project Apollo. The components used for the fuel cell are potassium hydroxide, water and metals used in the catalyst in the anode and cathode. The temperature during operation can reach as high as 250 degrees, but as technology advances the highest temperature recorded is 158 degrees.

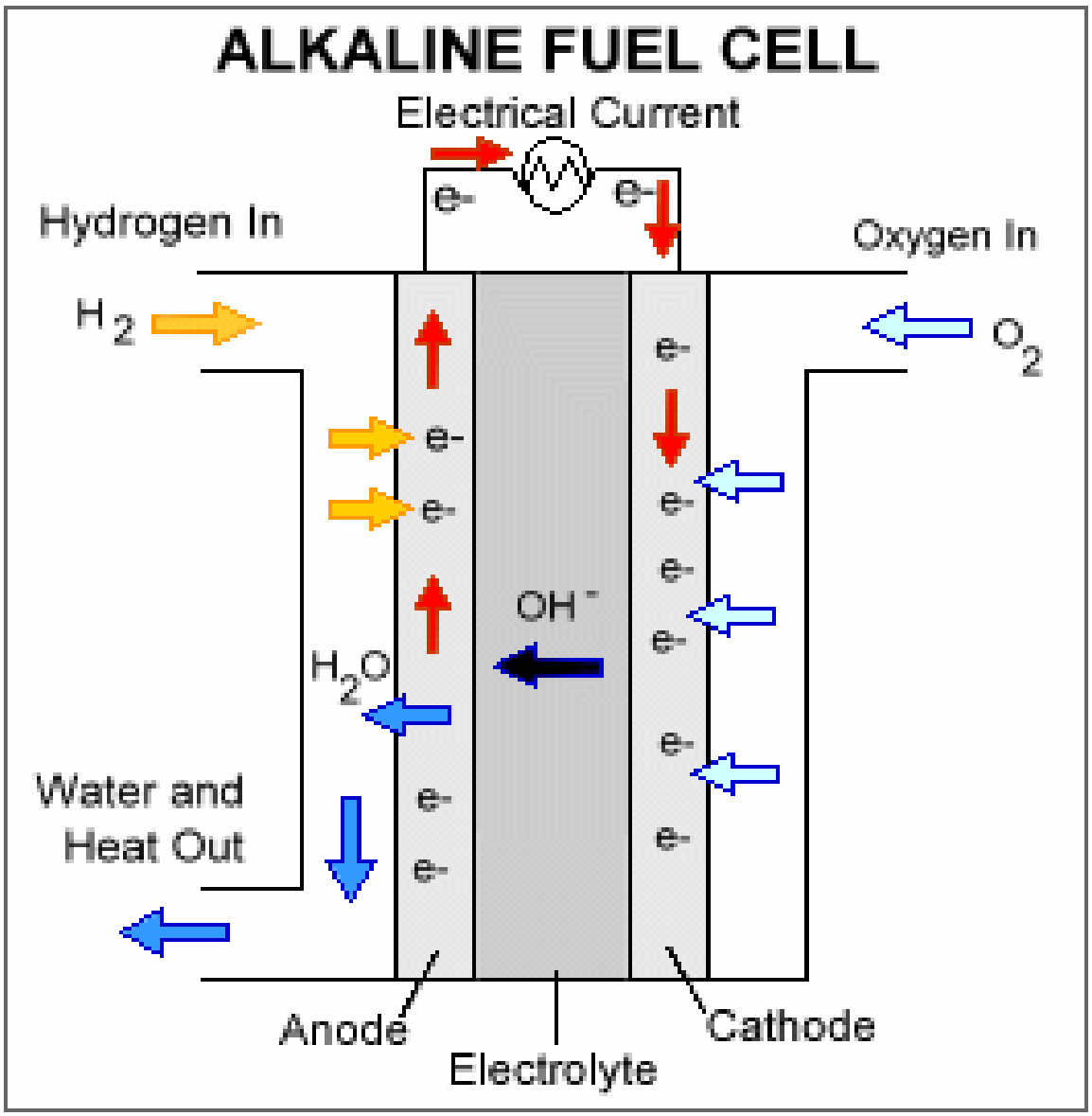



*Fig. 20 Courtesy of Energy.gov*

The AFC and PEM have similar characteristics in operation. Where they differ, is that they use an alkaline membrane instead of acid. The hindrance of the AFC is if a small amount of carbon dioxide (CO2) is in the air, it can be detrimental to the operation of the fuel cell. In order for the AFC to work properly, the hydrogen and oxygen used in the cell have to be purified for maximum performance. If not, it can be an expensive repair or it can affect the life span of the

fuel cell. The average life expectancy is an estimated 40,000 hours. AFC's are the least expensive types of fuel cells to manufacture however, it has yet to become stable due to the durability of materials used but has the most significance in fuel cell technology.

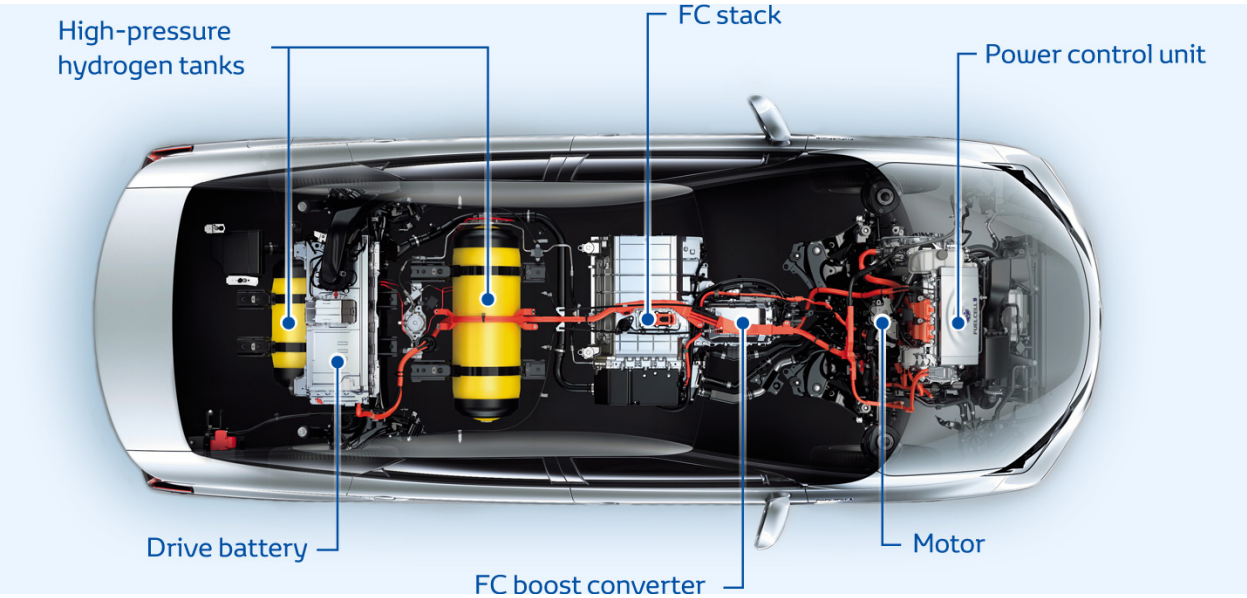



*Fig. 21 Courtesy of Energy.gov*

**PAFC Fuel Cell**

Phosphoric acid fuel cells were the first to be used commercially and mainly used for mass transportation such as buses. PAFC's consist of phosphoric acid as the electrolyte which is enclosed in a Teflon-bonded silicon carbide matrix with a platinum catalyst. The cell operates between 150 to 210 degrees where the water is converted into steam. They have been known to be the most forbearing of contaminates in fossil fuels that have been restructured into hydrogen compared to those in PEM cells. Again we are reminded that PEM cells are sensitive to carbon monoxide because if it happens to leak in the platinum catalyst the CO2 can decrease the efficiency of the fuel cell. Therefore PAFC's are CO2 tolerant and can handle up to 1.5% of

carbon dioxide CO, meaning that the options of fuels are wider. For instance if gasoline is used in the cell, the sulfur has to be extracted.

PAFC's have been known for their efficiency with an estimate of 85% when they are co-generated with electricity and heat. If they were used to generate electricity alone they PAFC's efficiency would only consist of 37%-42%, just slightly higher than a combustion based power plant. The PAFC's are quite costly because of the platinum catalyst but are less powerful than other fuel cells mentioned, due is large size and weight.

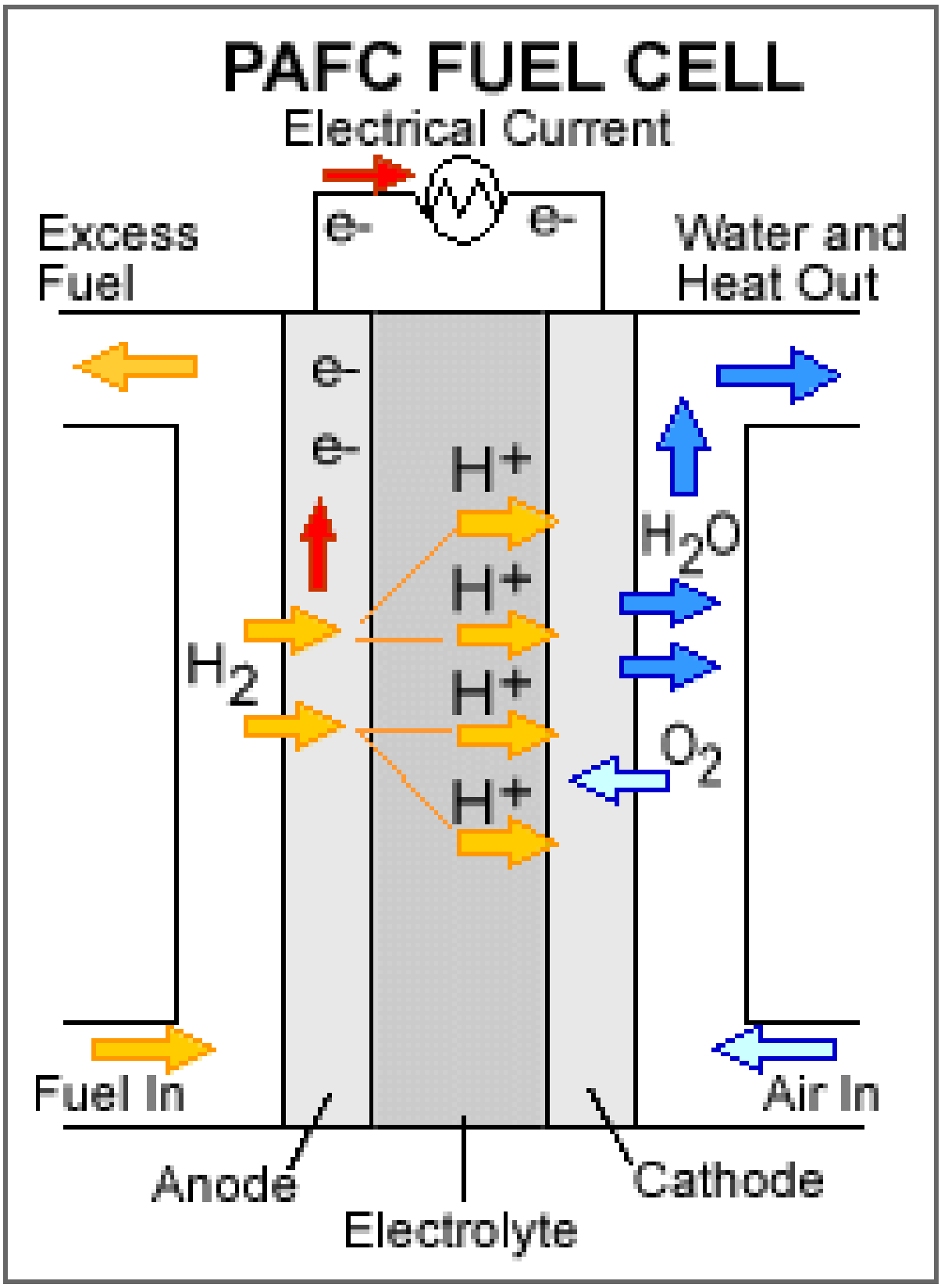



*Fig. 22 Courtesy of Energy.gov*

# Conclusion

Luxury will definitely lead manufacturers with sustainable energy by the year 2030. I believe Apple will become the headliner of the automotive industry because of their already set practices of sustainability for building their products. This niche market wants a luxury brand they can purchase that is unattainable to most and available to them first. If apple plans to build a vehicle with EV or fuel cell technology, along with the use of sustainable materials to customize a vehicle to due to preference, Apple will be the influential manufacturer for entry level brands. Many luxury brands such as Gucci, Cartier and Bvlgari have partnered with luxury auto manufacturers such as Cadillac, Lincoln and Fiat to design the interiors of their vehicles in the past. Apple could also do the same by partnering with Stella McCartney to design some of the interiors of the Apple iCar. This would be a great idea with PETA activist because they are against the use of animals being used for luxury goods. By 2030 the idea of having a vehicle that is sustainable yet marketable definitely is a nice approach towards the future.

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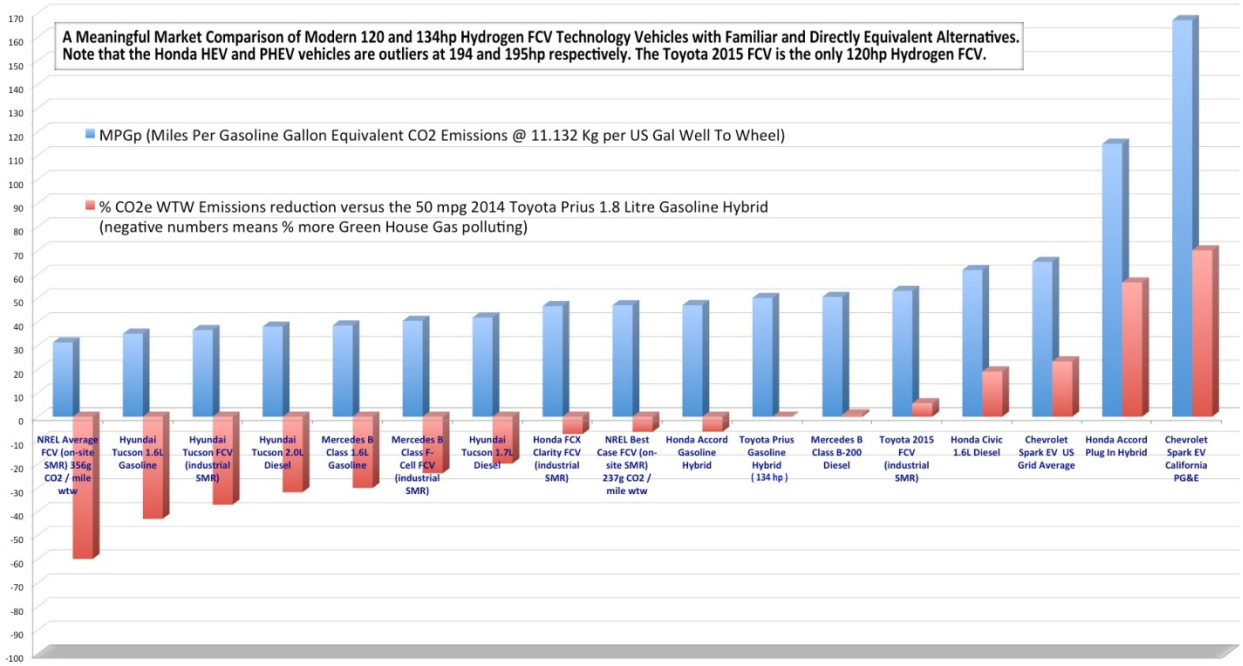
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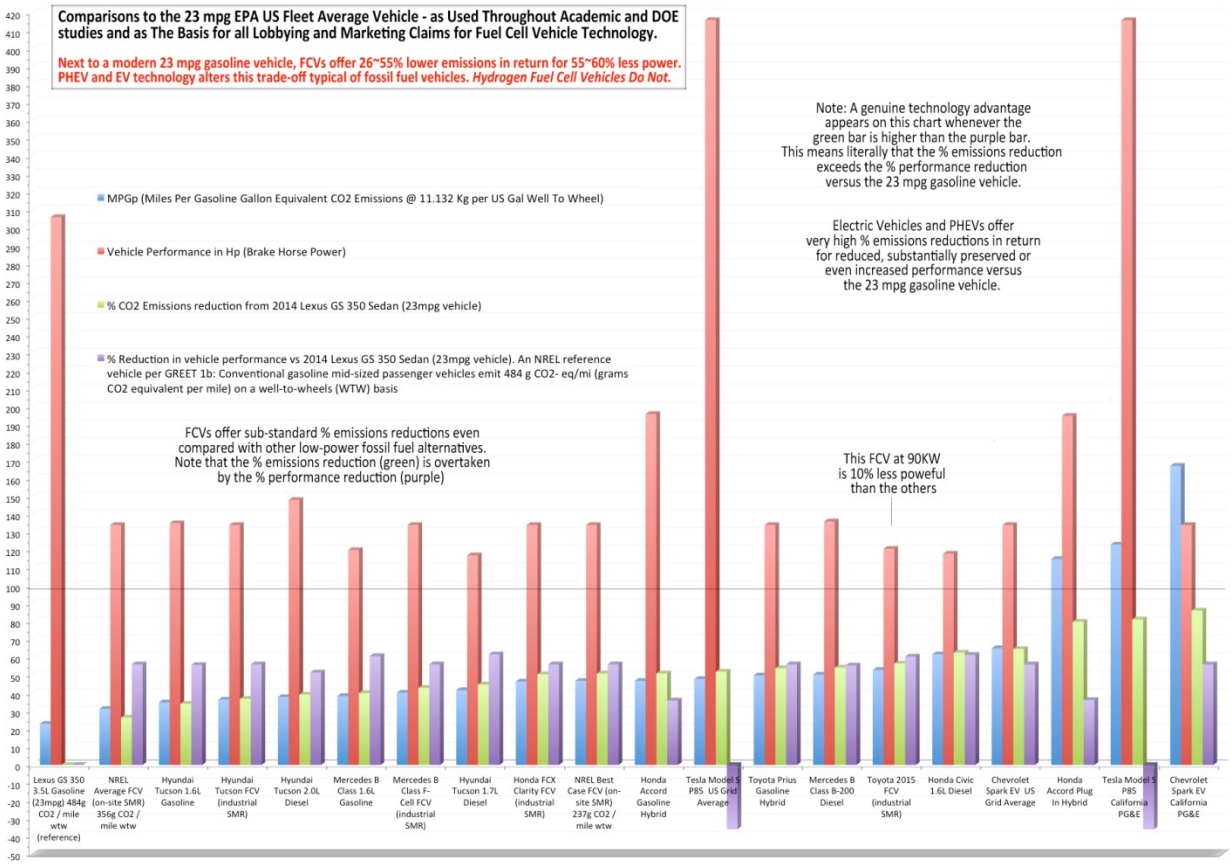
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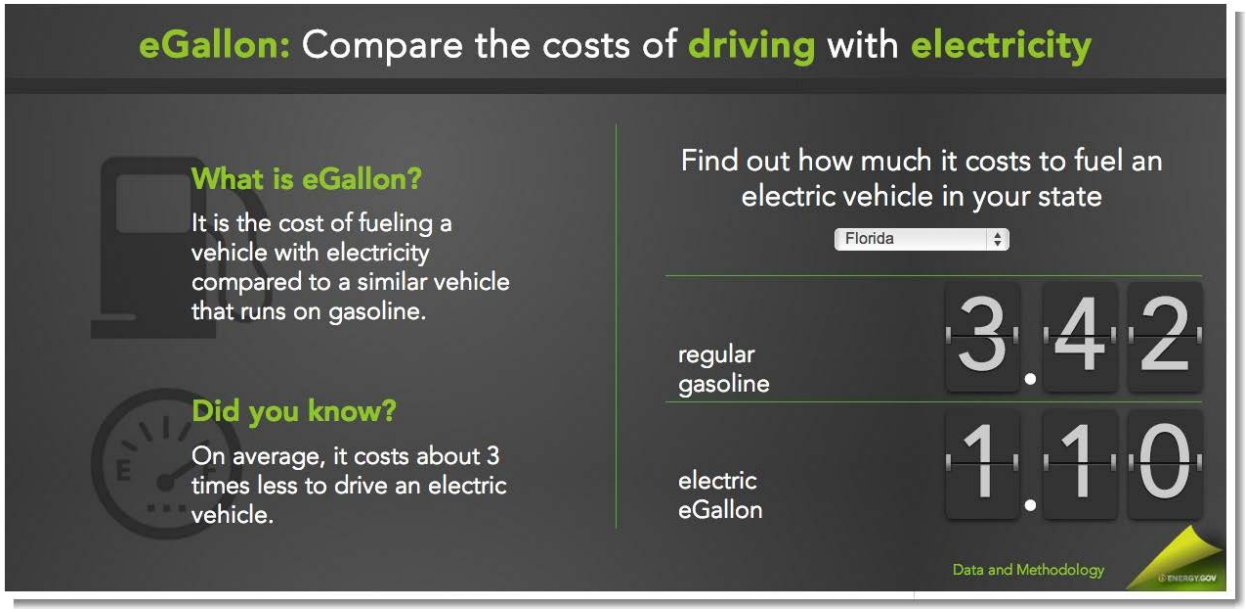
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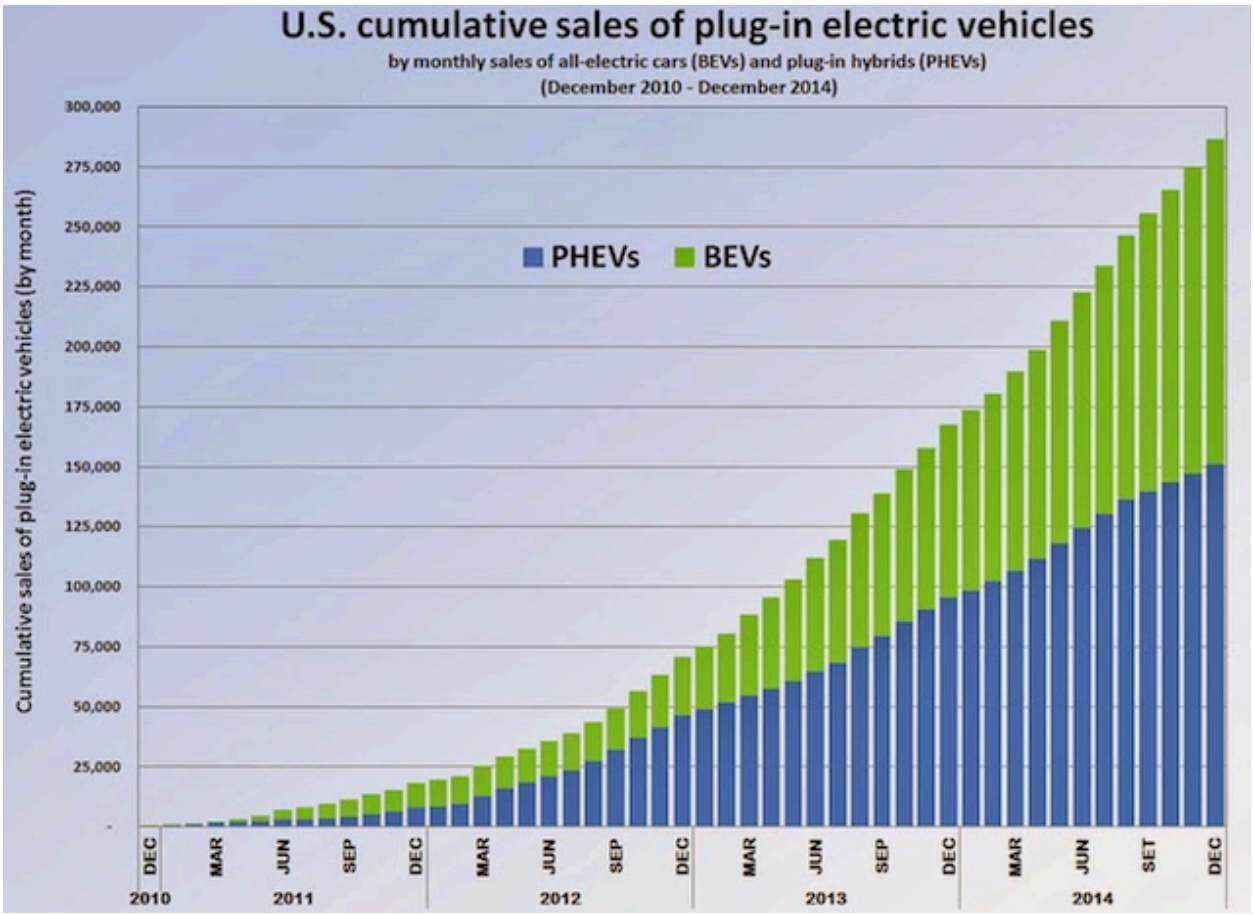
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A Meaningful Market Comparison of Modern 120 and 134hp Hydrogen FCV Technology Vehicles with Familiar and Directly Equivalent Alternatives.
Note that the Honda HEV and PHEV vehicles are outliers at 194 and 195hp respectively. The Toyota 2015 FCV is the only 120hp Hydrogen FCV.
MPGp (Miles Per Gasoline Gallon Equivalent CO2 Emissions @ 11.132 Kg per US Gal Well To Wheel)
% CO2e WTW Emissions reduction versus the 50 mpg 2014 Toyota Prius 1.8 Litre Gasoline Hybrid
(negative numbers means % more Green House Gas polluting)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
NREL Average FCV (on-site SMR) 356g CO2 / mile wtw
Hyundai Tucson 1.6L Gasoline
Hyundai Tucson FCV (industrial SMR)
Hyundai Tucson 2.0L Diesel
Mercedes B Class 1.6L Gasoline
Mercedes B Class F-Cell FCV (industrial SMR)
Hyundai Tucson 1.7L Diesel
Honda FCX Clarity FCV (industrial SMR)
NREL Best Case FCV (on-site SMR) 237g CO2 / mile wtw
Honda Accord Gasoline Hybrid
Toyota Prius Gasoline Hybrid ( 134 hp )
Mercedes B Class B-200 Diesel
Toyota 2015 FCV (industrial SMR)
Honda Civic 1.6L Diesel
Chevrolet Spark EV US Grid Average
Honda Accord Plug In Hybrid
Chevrolet Spark EV California PG&E


Comparisons to the 23 mpg EPA US Fleet Average Vehicle - as Used Throughout Academic and DOE studies and as The Basis for all Lobbying and Marketing Claims for Fuel Cell Vehicle Technology.
Next to a modern 23 mpg gasoline vehicle, FCVs offer 26~55% lower emissions in return for 55~60% less power. PHEV and EV technology alters this trade-off typical of fossil fuel vehicles. Hydrogen Fuel Cell Vehicles Do Not.
MPGp (Miles Per Gasoline Gallon Equivalent CO2 Emissions @ 11.132 Kg per US Gal Well To Wheel)
Vehicle Performance in Hp (Brake Horse Power)
% CO2 Emissions reduction from 2014 Lexus GS 350 Sedan (23mpg vehicle)
% Reduction in vehicle performance vs 2014 Lexus GS 350 Sedan (23mpg vehicle). An NREL reference vehicle per GREET 1b: Conventional gasoline mid-sized passenger vehicles emit 484 g CO2- eq/mi (grams CO2 equivalent per mile) on a well-to-wheels (WTW) basis
Note: A genuine technology advantage appears on this chart whenever the green bar is higher than the purple bar. This means literally that the % emissions reduction exceeds the % performance reduction versus the 23 mpg gasoline vehicle.
Electric Vehicles and PHEVs offer very high % emissions reductions in return for reduced, substantially preserved or even increased performance versus the 23 mpg gasoline vehicle.
FCVs offer sub-standard % emissions reductions even compared with other low-power fossil fuel alternatives. Note that the % emissions reduction (green) is overtaken by the % performance reduction (purple)
This FCV at 90KW is 10% less poweful than the others
Lexus GS 350 3.5L Gasoline (23mpg) 484g CO2 / mile wtw (reference)
NREL Average FCV (on-site SMR) 356g CO2 / mile wtw
Hyundai Tucson 1.6L Gasoline
Hyundai Tucson FCV (industrial SMR)
Hyundai Tucson 2.0L Diesel
Mercedes B Class 1.6L Gasoline
Mercedes B Class F-Cell FCV (industrial SMR)
Hyundai Tucson 1.7L Diesel
Honda FCX Clarity FCV (industrial SMR)
NREL Best Case FCV (on-site SMR) 237g CO2 / mile wtw
Honda Accord Gasoline Hybrid
Tesla Model S P85 US Grid Average
Toyota Prius Gasoline Hybrid
Mercedes B Class B-200 Diesel
Toyota 2015 FCV (industrial SMR)
Honda Civic 1.6L Diesel
Chevrolet Spark EV US Grid Average
Honda Accord Plug In Hybrid
Tesla Model S P85 California PG&E
Chevrolet Spark EV California PG&E


eGallon: Compare the costs of driving with electricity
What is eGallon?
It is the cost of fueling a vehicle with electricity compared to a similar vehicle that runs on gasoline.
Did you know?
On average, it costs about 3 times less to drive an electric vehicle.
Find out how much it costs to fuel an electric vehicle in your state
Florida
regular gasoline
3.42
electric eGallon
1.10
Data and Methodology


U.S. cumulative sales of plug-in electric vehicles
by monthly sales of all-electric cars (BEVs) and plug-in hybrids (PHEVs)
(December 2010 - December 2014)
Cumulative sales of plug-in electric vehicles (by month)
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000
-
PHEVs
BEVs
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SET
DEC
2010
2011
2012
2013
2014