Hybrid electric vehicle

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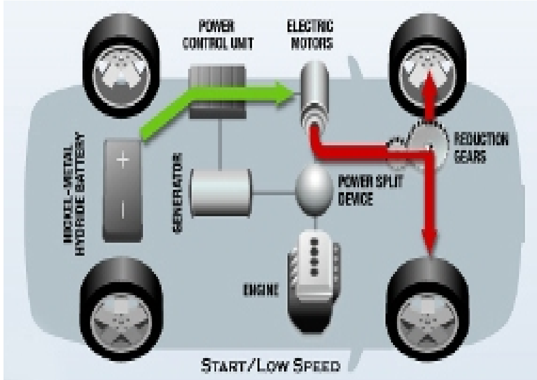
1. INTRODUCTION

A hybrid electric vehicle (HEV) is a type of hybrid vehicle and electric vehicle which combines a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. The presence of the electric power train is intended to achieve either better fuel economy than a conventional vehicle, or better performance. A variety of types of HEV exist, and the degree to which they function as EVs varies as well. The most common form of HEV is the hybrid electric car, although hybrid electric trucks (pickups and tractors) and buses also exist.

Modern HEVs make use of efficiency-improving technologies such as regenerative braking, which converts the vehicle's kinetic energy into electric energy to charge the battery, rather than wasting it as heat energy as conventional brakes do. Some varieties of HEVs use their internal combustion engine to generate electricity by spinning an electrical generator (this combination is known as a motor-generator), to either recharge their batteries or to directly power the electric drive motors. Many HEVs reduce idle emissions by shutting down the ICE at idle and restarting it when needed; this is known as a start-stop system. A hybrid-electric produces less emissions from its ICE than a comparably-sized gasoline car, since an HEV's gasoline engine is usually smaller than a comparably-sized pure gasoline-burning vehicle (natural gas and propane fuels produce lower emissions) and if not used to directly drive the car, can be geared to run at maximum efficiency, further improving fuel economy.

Ferdinand Porsche in 1901 developed the Lohner-Porsche Mixte Hybrid, the first gasoline-electric hybrid automobile in the world. The hybrid-electric vehicle did not become widely available until the release of the Toyota Prius in Japan in 1997, followed by the Honda Insight in 1999 While initially perceived as unnecessary due to the low cost of gasoline, worldwide increases in the price of petroleum caused many automakers to release hybrids in the late 2000s; they are now perceived as a core segment of the automotive market of the future. Worldwide sales of hybrid vehicles produced by Toyota, the market leader, reached 1.0 million vehicles by May 31, 2007; the 2.0 million mark was reached by August 31, 2009; and 3.0 million units by February 2011, with hybrids sold in 80 countries and regions. Worldwide sales are led by the Toyota Prius, with cumulative sales of 2.36 million by August 2011, and sold in 70 countries and regions. The United States is the largest hybrid market in the world, with 2 million hybrid automobiles and SUVs sold through May 2011, and California is the biggest regional American market. The Prius is the top selling hybrid car in the U.S. market with 1 million units sold by April 2011, and cumulative sales of the Prii in Japan reached the 1 million mark in August 2011.

2.HowHybridCarsWork.



With so much emphasis being placed on the environment hybrid cars have emerged as one of the leading ways that we as individuals can do our bit. In fact, hybrid cars have a lot more to offer than being more environmentally friendly and reducing our carbon footprint. Oil prices, and subsequently prices at the gas pump, continue to rise at alarming rates and filling up your tank costs considerably more than it did a year, six months, or even a couple of months ago. The technology is now well developed, but is recognized as being a serious advance.

2-1 How Gasoline and Electric Cars Work

to look at how hybrid cars work, we need to take a basic look at how gasoline and electric cars respectively are used to drive a car.

- In a gasoline powered car, gasoline is supplied to the engine by the fuel tank. This is then ignited and used to power the transmission which then turns the wheels giving the car motion. This is a very basic and simplistic explanation but it covers the essential steps in a car's drive train method when using a gasoline engine.

- An electric engine uses batteries to provide power to the engine. The power is again sent to the the transmission which drives the vehicle. An electric car produces no emissions because there is no combustion involved in the driving of the vehicle, however electrical batteries have a comparatively low capacity and need regular recharging. They also produce less power than a combustion engine and provide a vehicle with less performance than a strictly gasoline powered engine.

2-2 Electric Batteries and Car Engines

Electric engines tend to use the motion of the car to help recharge their batteries, in the same way that a gasoline car battery is recharged. The standard car battery, though, is only required to recharge a small portion of the components in a gasoline car and is not required to drive the vehicle. This means a smaller battery can be used and the regular driving of the vehicle ensures that the battery remains charged and serviceable.

2-3 How Hybrid Cars Work To Combine Power Sources

A hybrid car combines electric motors and a gasoline engine to give greater performance and longer traveling distances than an electric car. At the same time, it utilizes the electric batteries to greatly reduce emissions and improve fuel consumption. The end result is a vehicle that is better for the environment but still offers a viable means of transport to the owner.

2-4 Methods of Combining Gas and Electric

combining an electric motor and a gasoline engine is not as easy as putting them both under the hood and letting them do their own thing because they each require very different components to drive the transmission. Engineers and hybrid car manufacturers have developed a number of methods to get around this problem.

- The parallel hybrid offers the transmission power from both sources simultaneously. The transmission is connected directly to the gasoline engine and also to the electric motor so that when the car is driven it draws propulsion power from both these sources of energy.

- The series hybrid works very differently. The fuel tank is connected directly to a combustion engine where the gasoline is used to create combustion power. This power is not fed directly to the transmission as in a standard gasoline car. Instead, the engine is used to power a dual purpose generator. The electrical power created by this generator can then be used to either recharge the batteries or to drive the transmission and provide the car with the propulsion power it needs.

2-5 The Advantages of a Hybrid Engine

One of the biggest advantages in creating a hybrid car is that the gasoline combustion engine can be considerably smaller than the one in a standard gasoline car. This can mean fewer cylinders, lighter parts, and a more efficient engine load. This means that the car will use substantially less gasoline while being driven under normal circumstances offering better fuel consumption and less damaging emissions pumped into the atmosphere.

2-6 Increased Efficiency In Hybrid Cars

The most efficient hybrid cars not only combine two power sources to create the required drive but they utilize the advantages of a smaller engine to even further reduce gas usage. Smaller engines can be created so that there are fewer pistons, pistons have less displacement, and the engine is much lighter requiring less energy to drive it.

2-7 How Hybrid Cars Work To Use Different Energy Sources

- Generally, a hybrid car uses the petrol engine for constant and ideal driving conditions such as steady and constant speeds. Because it is much smaller, this already means a reduction in emissions while providing a more than adequate amount of power necessary to drive the car under these conditions.

- The electric motor will usually come into play when the car is put under extra pressure and requires a little extra assistance. Driving up hill, accelerating, and driving in difficult conditions will normally mean that the electric motor will give an additional push and ensure that the hybrid car has ample power to perform any task.

2-8 Further Advances in Hybrid Technology

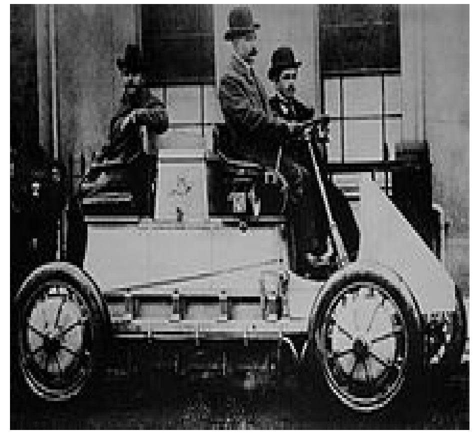
Further advances in hybrid car manufacturing have seen a number of other methods employed to improve gas consumption and reduce emissions. Lighter parts and improved aerodynamics mean less energy is required to give the car adequate performance. Regenerative braking actually captures energy that is usually dissipated as heat during the braking process. This is then used, in place of the power derived from the combustion engine, to recharge the electric batteries.

2-9Hybrid Car Technology

Hybrid cars have advanced considerably in a relatively short space of time and new techniques and processes are being evolved to further reduce both gas consumption and harmful emissions. Modern hybrid cars work in such a way that it is possible to greatly reduce your fuel consumption without having a detrimental effect on the performance or range of the car.

3. History

3.1Early days



The Lohner-Porsche Mixte Hybrid was the first gasoline-electric hybrid automobile.
In 1900, while employed at Lohner Coach Factory, Ferdinand Porsche developed the Mixte, a 4WD series-hybrid version of "System Lohner-Porsche" electric carriage previously appeared in 1900 Paris World Fair. The Mixte included a pair of generators driven by 2.5-hp Daimler IC engines to extend operating range and it could travel nearly 65 km on battery alone. It was presented in the Paris Auto Show in 1901. The Mixte broke several Austrian speed records, and also won the Exelberg Rally in 1901 with Porsche himself driving. The Mixte used a gasoline engine powering a generator, which in turn powered electric hub motors, with a small battery pack for reliability. It had a top speed of 50 km/h and a power of 5.22 kW during 20 minutes.

George Fischer sold hybrid buses to England in 1901; Knight Neftal produced a racing hybrid in 1902. In 1905, H. Piper filed a US patent application for a hybrid vehicle. The 1915 Dual Power, made by the Woods Motor Vehicle electric car maker, had a four-cylinder ICE and an electric motor. Below 15 mph (24 km/h) the electric motor alone drove the vehicle, drawing power from a battery pack, and above this speed the "main" engine cut in to take the car up to its 35 mph (56 km/h) top speed. About 600 were made up to 1918.

A Canadian company produced a hybrid car for sale in 1915. The first gasoline-electric hybrid car was released by the Woods Motor Vehicle Company of Chicago in 1917. The hybrid was a commercial failure, proving to be too slow for its price, and too difficult to service. The United States Army's 1928 Experimental Motorized Force tested a gasoline-electric bus in a truck convoy.

In 1931 Erich Gaichen invented and drove from Altenburg to Berlin a 1/2 horsepower electric car containing features later incorporated into hybrid cars. Its maximum speed was 25 miles per hour (40 km/h), but it was licensed by the Motor Transport Office, taxed by the German Revenue Department and patented by the German Reichs-Patent Amt. The car battery was re-charged by the motor when the car went downhill. Additional power to charge the battery was provided by a cylinder of compressed air which was re-charged by small air pumps activated by vibrations of the chassis and the brakes and by igniting oxyhydrogen gas. An account of the car and his characterization as a "crank inventor" can be found in Arthur Koestler's autobiography, Arrow in the blue, pages 269-271, which summarize a contemporaneous newspaper account written by Koestler. No production beyond the prototype was reported.

3-2 Predecessors of current technology

A more recent working prototype of the HEV was built by Victor Wouk (one of the scientists involved with the Henney Kilowatt, the first transistor-based electric car). Wouk's work with HEVs in the 1960s and 1970s earned him the title as the "Godfather of the Hybrid". Wouk installed a prototype hybrid drivetrain (with a 16 kilowatts (21 hp) electric motor) into a 1972 Buick Skylark provided by GM for the 1970 Federal Clean Car Incentive Program, but the program was stopped by the United States Environmental Protection Agency (EPA) in 1976 while Eric Stork, the head of the EPA at the time, was accused of a prejudicial coverup.

The regenerative braking system, the core design concept of most production HEVs, was developed by electrical engineer David Arthurs around 1978, using off-the shelf components and an Opel GT. However the voltage controller to link the batteries, motor (a jet-engine starter motor), and DC generator was Arthurs'. The vehicle exhibited 75 miles per US gallon (3.1 L/100 km; 90 mpg-imp) fuel efficiency, and plans for it (as well as somewhat updated versions) are still available through the Mother Earth News web site. The Mother Earth News' own 1980 version claimed nearly 84 miles per US gallon (2.8 L/100 km; 101 mpg-imp).

In 1989, Audi produced its first iteration of the Audi Duo (the Audi C3 100 Avant Duo) experimental vehicle, a plug-in parallel hybrid based on the Audi 100 Avant quattro. This car had a 9.4 kilowatts (12.8 PS; 12.6 bhp) Siemens electric motor which drove the rear roadwheels. A trunk-mounted nickel-cadmium battery supplied energy to the motor that drove the rear wheels. The vehicle's front roadwheels were powered by a 2.3 litre five-cylinder petrol engine with an output of 100 kilowatts (136 PS; 134 bhp). The intent was to produce a vehicle which could operate on the engine in the country, and electric mode in the city. Mode of operation could be selected by the driver. Just ten vehicles are believed to have been made; one drawback was that due to the extra weight of the electric drive, the vehicles were less efficient when running on their engines alone than standard Audi 100s with the same engine.

Two years later, Audi, unveiled the second duo generation, the Audi 100 Duo - likewise based on the Audi 100 Avant quattro. Once again, this featured an electric motor, a 21.3 kilowatts (29.0 PS; 28.6 bhp) three-phase machine, driving the rear roadwheels. This time, however, the rear wheels were additionally powered via the Torsen centre differential from the main engine compartment, which housed a 2.0 litre four-cylinder engine.

In 1992,Volvo ECC was developed by Volvo. The Volvo ECC was built on the Volvo 850 platform. In contrast to most production hybrids, which use a gasoline piston engine to provide additional acceleration and to recharge the battery storage, the Volvo ECC used a gas turbine engine to drive the generator for recharging.

The Clinton administration initiated the Partnership for a New Generation of Vehicles (PNGV) program on 29 September 1993, that involved Chrysler, Ford, General Motors, USCAR, the DoE, and other various governmental agencies to engineer the next efficient and clean vehicle.[35] The United States National Research Council (USNRC) cited automakers' moves to produce HEVs as evidence that technologies developed under PNGV were being rapidly adopted on production lines, as called for under Goal 2. Based on information received from automakers, NRC reviewers questioned whether the "Big Three" would be able to move from the concept phase to cost effective, pre-production prototype vehicles by 2004, as set out in Goal The program was replaced by the hydrogen-focused FreedomCAR initiative by the George W. Bush administration in 2001, an initiative to fund research too risky for the private sector to engage in, with the long-term goal of developing effectively carbon emission- and petroleum-free vehicles.

1998 saw the Esparante GTR-Q9 became the first Petrol-Electric Hybrid to race at Le Mans, although the car failed to qualify for the main event. The car managed to finished second in class at Petit Le Mans the same year

3-3 Modern hybrids

1997 Toyota Prius (first generation).

2000 Honda Insight (first generation).

2010 Honda Insight (second generation)

The 2010 Ford Fusion Hybrid was launched in the U.S. in March 2009

Automotive hybrid technology became widespread beginning in the late 1990s. The first mass-produced hybrid vehicle was the Toyota Prius, launched in Japan in 1997, and followed by the Honda Insight, launched in 1999 in the United States and Japan. The Prius was launched in Europe, North America and the rest of the world in 2000. The first generation Prius sedan has an estimated fuel economy of 52 miles per US gallon (4.5 L/100 km; 62 mpg-imp) in the city and 45 miles per US gallon (5.2 L/100 km; 54 mpg-imp) in highway driving. The two-door first generation Insight was estimated at 61 miles per US gallon (3.9 L/100 km; 73 mpg-imp) miles per gallon in city driving and 68 miles per US gallon (3.5 L/100 km; 82 mpg-imp) on the highway.

The Toyota Prius sold 300 units in 1997, 19,500 in 2000, and cumulative worldwide Prius sales reached the 1 million mark in April 2008. By early 2010, the Prius global cumulative sales were estimated at 1.6 million units. Toyota launched a second generation Prius in 2004 and a third in 2009.[42] The 2010 Prius has an estimated U.S. Environmental Protection Agency combined fuel economy cycle of 50 miles per US gallon (4.7 L/100 km; 60 mpg$_{\text{-imp}}$).

The Audi Duo III was introduced in 1997, based on the Audi B5 A4 Avant, and was the only Duo to ever make it into series production.[2] The Duo III used the 1.9 litre Turbocharged Direct Injection (TDI) diesel engine, which was coupled with an 21 kilowatts (29 PS; 28 bhp) electric motor. Unfortunately due to low demand for this hybrid because of its high price, only about sixty Audi Duos were produced. Until the release of the Audi Q7 Hybrid in 2008, the Duo was the only European hybrid ever put into production.

The Honda Civic Hybrid was introduced in February 2002 as a 2003 model, based on the seventh generation Civic.[44] The 2003 Civic Hybrid appears identical to the non-hybrid version, but delivers 50 miles per US gallon (4.7 L/100 km; 60 mpg_{-imp}), a 40 percent increase compared to a conventional Civic LX sedan. Along with the conventional Civic, it received styling update for 2004. The redesigned 2004 Toyota Prius (second generation) improved passenger room, cargo area, and power output, while increasing energy efficiency and reducing emissions. The Honda Insight first generation stopped being produced after 2006 and has a devoted base of owners. A second generation Insight was launched in 2010. In 2004, Honda also released a hybrid version of the Accord but discontinued it in 2007 citing disappointing sales.

The Ford Escape Hybrid, the first hybrid electric sport utility vehicle (SUV) was released in 2005. Toyota and Ford entered into a licensing agreement in March 2004 allowing Ford to use 20 patents from Toyota related to hybrid technology, although Ford's engine was independently designed and built. In exchange for the hybrid licenses, Ford licensed patents involving their European diesel engines to Toyota. Toyota announced calendar year 2005 hybrid electric versions of the Toyota Highlander Hybrid and Lexus RX 400h with 4WD-i, which uses a rear electric motor to power the rear wheels negating the need for a transfer case.

In 2006, General Motors Saturn Division began to market a mild parallel hybrids in the form of the 2007 Saturn Vue Green Line which utilized GM's Belted Alternator/Starter (BAS Hybrid) System combined with a 2.4 litre L4 engine and a FWD automatic transmission. The same hybrid powertrain was also used to power the 2008 Saturn Aura Greenline and Mailbu Hybrid models. As of December 2009, only the BAS equipped Malibu is still in (limited) production.

In 2007, Lexus released a hybrid electric version of their GS sport sedan, the GS 450h, with a power output of 335 bhp. The 2007 Camry Hybrid became available in Summer 2006 in the United States and Canada. Nissan launched the Altima Hybrid with technology licensed by Toyota in 2007.

Commencing in the fall of 2007 General Motors began to market their 2008 Two-Mode Hybrid models of their GMT900 based Chevrolet Tahoe and GMC Yukon SUVs, closely followed by the 2009 Cadillac Escalade Hybrid version. For the 2009 model year, General Motors released the same technology in their half-ton pickup truck models, the 2009 Chevrolet Silverado and GMC Sierra Two-Mode Hybrid models.

The Ford Fusion Hybrid officially debuted at the Greater Los Angeles Auto Show in November 2008,[52] and was launched to the U.S. market in March 2009, together with the second generation Honda Insight and the Mercury Milan Hybrid.

3-4 Latest developments

The 2011 Honda CR-Z hybrid was launched in Japan in February 2010, followed by the US in August 2010

The 2011 Toyota Auris Hybrid is the first mass-produced hybrid electric vehicle built in Europe. 2009–2010

The Hyundai Elantra LPI Hybrid was unveiled at the 2009 Seoul Motor Show, and sales began in the South Korean domestic market in July 2009. The Elantra LPI (Liquefied Petroleum Injected) is the world's first hybrid vehicle to be powered by an internal combustion engine built to run on liquefied petroleum gas (LPG) as a fuel. The Elantra PLI is a mild hybrid and the first hybrid to adopt advanced lithium polymer (Li–Poly) batteries. The Elantra LPI Hybrid delivers a fuel economy rating of 41.9 miles per US gallon (5.61 L/100 km; 50.3 mpg_{-imp}) and CO_2 emissions of 99 g/km to qualify as a Super Ultra Low Emission Vehicle (SULEV).

The Mercedes-Benz S400 BlueHybrid was unveiled in the 2009 Chicago Auto Show, and sales began in the U.S. in October 2009. The S400 BlueHybrid is a mild hybrid and the first hybrid car to adopt a lithium ion battery.[57][60] The hybrid technology in the S400 was co-developed by Daimler AG and BMW. The same hybrid technology is being used in the BMW ActiveHybrid 7, expected to go on sales in the U.S. and Europe by mid 2010. In December 2009 BMW began sales of its full hybrid BMW ActiveHybrid X6, while Daimler launched the Mercedes-Benz ML450 Hybrid by lease only.

Sales of the 2011 Honda CR-Z began in Japan in February 2010, followed by the U.S. in August 2010, becoming Honda's third hybrid electric car in the market. The CR-Z is scheduled to be launched in the European market also in 2010. Honda also launch in Japan the 2011 Honda Fit Hybrid in October 2010, and unveiled the European version, the Honda Jazz Hybrid, in the 2010 Paris Motor Show, which went on sale in some European markets by early 2011.

Mass production of the 2011 Toyota Auris Hybrid began in May 2010 at Toyota Manufacturing UK (TMUK) Burnaston plant and became the first mass-produced hybrid vehicle to be built in Europe.[54] Sales in the U.K. began in July 2010, at a price starting atGB£18,950 (US$27,450), GB£550 (US$800) less than the Toyota Prius. The 2011 Auris Hybrid shares the same powertrain as the Prius, and combined fuel economy is 74.3 mpg_{-imp} (3.80 L/100 km; 61.9 mpg_{-US}).

The 2011 Lincoln MKZ Hybrid was unveiled at the 2010 New York International Auto Show and sales began in the U.S. in September 2010. The MKZ Hybrid is the first hybrid version ever to have the same price as the gasoline-engine version of the same car. The Porshe Cayenne Hybrid was launched in the U.S in late 2010.

2011–2012

Volkswagen announced at the 2010 Geneva Motor Show the launch of the 2012 Touareg Hybrid, which went on sale on the U.S. in 2011. VW also announced plans to introduce diesel-electric hybrid versions of its most popular models in 2012, beginning with the new Jetta, followed by the Golf Hybrid in 2013 together with hybrid versions of the Passat. Other gasoline-electric hybrids released in the U.S. in 2011 are the Lexus CT 200h, the Infiniti M35 Hybrid, the Hyundai Sonata Hybrid and its siblling the Kia Optima Hybrid.

The 2012 Toyota Prius v was launched in Japan and the U.S. in 2011.

The Peugeot 3008 HYbrid4 will be launched in the European market in the second half of 2011 and is expected to become the world's first production diesel-electric hybrid. According to Peugeot the new hybrid delivers a fuel economy of up to 62 miles per US gallon (3.8 L/100 km; 74 mpg_{-imp}) and CO_2 emissions of 99g/km on the European test cycle.

The Toyota Prius v, launched in the U.S. in October 2011, is the first spinoff from the Prius family. Sales in Japan began in May 2011 as the Prius Alpha. The European version, named Prius +, is scheduled to be launched by mid 2012. The Prius Aqua will be launched in Japan in December 2011, and is scheduled to be released as the Toyota Prius c in Australia during the first quarter of 2012, and in the U.S. in the second quarter of 2012. The Toyota Yaris HSD Concept was introduced at the March 2011 Geneva Motor Show and is expected to go on sale in Europe in 2012.

Other hybrids scheduled to be released in the U.S. during the second half of 2011 are the Audi Q5 Hybrid and the BMW 5 Series ActiveHybrid. The Audi A6 Hybrid and Ford C-Max Hybrid are slated for market launch in the U.S. in 2012.

4. Terminology

4-1 Types of powertrain

The Toyota Highlander Hybrid has a series-parallel drivetrain

The Saturn Vue Green Line is a mild hybrid.

The 2005-06 Chevrolet Silverado Hybrid is a mild hybrid using the electric motor mainly to power the accessories

The BMW Concept 7 Series ActiveHybrid is a mild hybrid with an electric motor designed to increase power and performance.

Hybrid electric vehicles can be classified according to the way in which power is supplied to the drivetrain:

- In parallel hybrids, the ICE and the electric motor are both connected to the mechanical transmission and can simultaneously transmit power to drive the wheels, usually through a conventional transmission. Honda's Integrated Motor Assist (IMA) system as found in the Insight, Civic, Accord, as well as the GM Belted Alternator/Starter (BAS Hybrid) system found in the Chevrolet Malibu hybrids are examples of production parallel hybrids. Current, commercialized parallel hybrids use a single, small (<20 kW) electric motor and small battery pack as the electric motor is not designed to be the sole source of motive power from launch. Parallel hybrids are also capable of regenerative braking and the internal combustion engine can also act as a generator for supplemental recharging. Parallel hybrids are more efficient than comparable non-hybrid vehicles especially during urban stop-and-go conditions and at times during highway operation where the electric motor is permitted to contribute.

- In series hybrids, only the electric motor drives the drivetrain, and the ICE works as a generator to power the electric motor or to recharge the batteries. The battery pack can be recharged through regenerative braking or by the ICE. Series hybrids usually have a smaller combustion engine but a larger battery pack as compared to parallel hybrids, which makes them more expensive than parallels. This configuration makes series hybrids more efficient in city driving. The Chevrolet Volt is a series plug-in hybrid, although GM prefers to describe the Volt as an electric vehicle equipped with a "range extending" gasoline powered ICE as a generator and therefore dubbed an "Extended Range Electric Vehicle" or EREV.

- Power-split hybrids have the benefits of a combination of series and parallel characteristics. As a result, they are more efficient overall, because series hybrids tend to be more efficient at lower speeds and parallel tend to be more efficient at high speeds; however, the power-split hybrid is higher than a pure parallel. Examples of power-split (referred to by some as "series-parallel") hybrid powertrains include current models of Ford, General Motors, Lexus, Nissan, and Toyota.

4-2Types by degree of hybridization

- Full hybrid, sometimes also called a strong hybrid, is a vehicle that can run on just the engine, just the batteries, or a combination of both. Ford's hybrid system, Toyota's Hybrid Synergy Drive and General Motors/Chrysler's Two-Mode Hybrid technologies are full hybrid systems. The Toyota Prius, Ford Escape Hybrid, and Ford Fusion Hybrid are examples of full hybrids, as these cars can be moved forward on battery power alone. A large, high-capacity battery pack is needed for battery-only operation. These vehicles have a split power path allowing greater flexibility in the drivetrain by interconverting mechanical and electrical power, at some cost in complexity.

- Mild hybrid, is a vehicle that can not be driven solely on its electric motor, because the electric motor does not have enough power to propel the vehicle on its own. Mild hybrids only include some of the features found in hybrid technology, and usually achieve limited fuel consumption savings, up to 15 percent in urban driving and 8 to 10 percent overall cycle. A mild hybrid is essentially a conventional vehicle with oversize starter motor, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly. The motor is often mounted between the engine and transmission, taking the place of the torque converter, and is used to supply additional propulsion energy when accelerating. Accessories can continue to run on electrical power while the gasoline engine is off, and as in other hybrid designs, the motor is used for regenerative braking to recapture energy. As compared to full hybrids, mild hybrids have smaller batteries and a smaller, weaker motor/generator, which allows manufacturers to reduce cost and weight.

  Honda's early hybrids including the first generation Insight used this design, leveraging their reputation for design of small, efficient gasoline engines; their system is dubbed Integrated Motor Assist (IMA). Starting with the 2006 Civic Hybrid, the IMA system now can propel the vehicle solely on electric power during medium speed cruising. Another example is the 2005-2007 Chevrolet Silverado Hybrid, a full-size pickup truck. Chevrolet was able to get a 10% improvement on the Silverado's fuel efficiency by shutting down and restarting the engine on demand and using regenerative braking. General Motors has also used its mild BAS Hybrid technology in other models such as the Saturn Vue Green Line, the Saturn Aura Greenline and the Mailbu Hybrid.

4-3 Plug-in hybrids (PHEVs)

The Chevrolet Volt is a plug-in hybrid able to run in all-electric mode up to 35 miles.

A plug-in hybrid electric vehicle (PHEV), also known as a plug-in hybrid, is a hybrid electric vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric powersource. A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine; and of an all-electric vehicle, also having a plug to connect to the electrical grid. PHEVs have a much larger all-electric range as compared to conventional gasoline-electric hybrids, and also eliminate the "range anxiety" associated with all-electric vehicles, because the combustion engine works as a backup when the batteries are depleted.

Chinese battery manufacturer and automaker BYD Auto released the F3DM PHEV-62 (PHEV-100 km) hatchback to the Chinese fleet market on December 15, 2008, for 149,800 yuan (US $22,000).[21][22] General Motors launched the 2011 Chevrolet Volt series plug-in in December 2010. The Volt displaced the Toyota Prius as the most fuel-efficient car sold in the United States

5. Technology

The varieties of hybrid electric designs can be differentiated by the structure of the hybrid vehicle drivetrain, the fuel type, and the mode of operation.

In 2007, several automobile manufacturers announced that future vehicles will use aspects of hybrid electric technology to reduce fuel consumption without the use of the hybrid drivetrain. Regenerative braking can be used to recapture energy and stored to power electrical accessories, such as air conditioning. Shutting down the engine at idle can also be used to reduce fuel consumption and reduce emissions without the addition of a hybrid drivetrain. In both cases, some of the advantages of hybrid electric technology are gained while additional cost and weight may be limited to the addition of larger batteries and starter motors. There is no standard terminology for such vehicles, although they may be termed mild hybrids.

5-1 Engines and fuel sources

5-1-1 Fossil fuels

Free-piston engines could be used to generate electricity as efficiently as, and less expensively than, fuel cells.[105]

Gasoline

Gasoline engines are used in most hybrid electric designs, and will likely remain dominant for the foreseeable future. While petroleum-derived gasoline is the primary fuel, it is possible to mix in varying levels of ethanol created from renewable energy sources. Like most modern ICE powered vehicles, HEVs can typically use up to about 15% bioethanol. Manufacturers may move to flexible fuel engines, which would increase allowable ratios, but no plans are in place at present.

Diesel

Diesel-electric HEVs use a diesel engine for power generation. Diesels have advantages when delivering constant power for long periods of time, suffering less wear while operating at higher efficiency. The diesel engine's high torque, combined with hybrid technology, may offer substantially improved mileage. Most diesel vehicles can use 100% pure biofuels (biodiesel), so they can use but do not need petroleum at all for fuel (although mixes of biofuel and petroleum are more common, and petroleum may be needed for lubrication). If diesel-electric HEVs were in use, this benefit would likely also apply. Diesel-electric hybrid drivetrains have begun to appear in commercial vehicles (particularly buses); as of 2007, no light duty diesel-electric hybrid passenger cars are currently available, although prototypes exist. Peugeot is expected to produce a diesel-electric hybrid version of its 308 in late 2008 for the European market.

PSA Peugeot Citroën has unveiled two demonstrator vehicles featuring a diesel-electric hybrid drivetrain: the Peugeot 307, Citroën C4 Hybride HDi and Citroën C-Cactus. Volkswagen made a prototype diesel-electric hybrid car that achieved 2 L/100 km (140 mpg_{-imp}; 120 mpg_{-US}) fuel economy, but has yet to sell a hybrid vehicle. General Motors has been testing the Opel Astra Diesel Hybrid. There have been no concrete dates suggested for these vehicles, but press statements have suggested production vehicles would not appear before 2009.

At the Frankfurt Motor Show in September 2009 both Mercedes and BMW displayed diesel-electric hybrids.

Robert Bosch GmbH is supplying hybrid diesel-electric technology to diverse automakers and models, including the Peugeot 308.

So far, production diesel-electric engines have mostly appeared in mass transit buses.

FedEx, along with Eaton Corp. in the USA and Iveco in Europe, has begun deploying a small fleet of Hybrid diesel electric delivery trucks. As of October 2007, Fedex operates more than 100 diesel electric hybrids in North America, Asia and Europe.[111]

Liquefied petroleum gas

Hyundai Elantra LPI Hybrid.

Hyundai introduced in 2009 the Hyundai Elantra LPI Hybrid, which is the first mass production hybrid electric vehicle to run on liquefied petroleum gas (LPG).

Hydrogen

Hydrogen can be used in cars in two ways: a source of combustible heat, or a source of electrons for an electric motor. The burning of hydrogen is not being developed in practical terms; it is the hydrogen fuel-cell electric vehicle (HFEV) which is garnering all the attention. Hydrogen fuel cells create electricity fed into an electric motor to drives the wheels. Hydrogen is not burned, but it is consumed. This means molecular hydrogen, H_2, is combined with oxygen to form water. $2H_2$ ($4e^-$) + O_2 --> $2H_2O$ ($4e^-$). The molecular hydrogen and oxygen's mutual affinity drives the fuel cell to separate the electrons from the hydrogen, to use them to power the electric motor, and to return them to the ionized water molecules that were formed when the electron-depleted hydrogen combined with the oxygen in the fuel cell. Recalling that a hydrogen atom is nothing more than a proton and an electron; in essence, the motor is driven by the proton's atomic attraction to the oxygen nucleus, and the electron's attraction to the ionized water molecule.

An HFEV is an all-electric car featuring an open-source battery in the form of a hydrogen tank and the atmosphere. HFEVs may also comprise closed-cell batteries for the purpose of power storage from regenerative braking, but this does not change the source of the motivation. It implies the HFEV is an electric car with two types of batteries. Since HFEVs are purely electric, and do not contain any type of heat engine, they are not hybrids.

5-1-2 Biofuels

The Ford Escape Hybrid was the first hybrid electric vehicle with a flex-fuel engine capable of running on E85 fuel.

Demonstration Ford Escape E85 flex-fuel plug-in hybrid

Hybrid vehicles might use an internal combustion engine running on biofuels, such as a flexible-fuel engine running on ethanol or engines running on biodiesel. In 2007 Ford produced 20 demonstration Escape Hybrid E85s for real-world testing in fleets in the U.S. Also as a demonstration project, Ford delivered in 2008 the first flexible-fuel plug-in hybrid SUV to the U.S. Department of Energy (DOE), a Ford Escape Plug-in Hybrid, capable of running on gasoline or E85.

The Chevrolet Volt plug-in hybrid electric vehicle would be the first commercially available flex-fuel plug-in hybrid capable of adapting the propulsion to the biofuels used in several world markets such as the ethanol blend E85 in the U.S., or E100 in Brazil, or biodiesel in Sweden. The Volt will be E85 flex-fuel capable about a year after its introduction.

5-2 Electric machines

In *split path* vehicles (Toyota, Ford, GM, Chrysler) there are two electrical machines, one of which functions as a motor primarily, and the other functions as a generator primarily. One of the primary requirements of these machines is that they are very efficient, as the electrical portion of the energy must be converted from the engine to the generator, through two inverters, through the motor again and then to the wheels.Most of the electric machines used in hybrid vehicles are brushless DC motors (BLDC). Specifically, they are of a type called an interior permanent magnet (IPM) machine (or motor). These machines are wound similarly to the induction motors found in a typical home, but (for high efficiency) use very strong rare earth magnets in the rotor. These magnets contain neodymium, iron and boron, and are therefore called Neodymium magnets. The magnet material is expensive, and its cost is one of the limiting factors in the use of these machines.

5-3 Design considerations

In some cases, manufacturers are producing HEVs that use the added energy provided by the hybrid systems to give vehicles a power boost, rather than significantly improved fuel efficiency compared to their traditional counterparts. The trade-off between added performance and improved fuel efficiency is partly controlled by the software within the hybrid system and partly the result of the engine, battery and motor size. In the future, manufacturers may provide HEV owners with the ability to partially control this balance (fuel efficiency vs. added performance) as they wish, through a user-controlled setting. Toyota announced in January, 2006 that it was considering a "high-efficiency" button.

5-4 Conversion kits

One can buy a stock hybrid or convert a stock petroleum car to a hybrid electric vehicle using an aftermarket hybrid kit .

6. Environmental impact

6-1 Fuel consumption.

Current HEVs reduce petroleum consumption under certain circumstances, compared to otherwise similar conventional vehicles, primarily by using three mechanisms:

1. Reducing wasted energy during idle/low output, generally by turning the ICE off
2. Recapturing waste energy (i.e. regenerative braking)
3. Reducing the size and power of the ICE, and hence inefficiencies from under-utilization, by using the added power from the electric motor to compensate for the loss in peak power output from the smaller ICE.

Any combination of these three primary hybrid advantages may be used in different vehicles to realize different fuel usage, power, emissions, weight and cost profiles. The ICE in an HEV can be smaller, lighter, and more efficient than the one in a conventional vehicle, because the combustion engine can be sized for slightly above average power demand rather than peak power demand. The drive system in a vehicle is required to operate over a range of speed and power, but an ICE's highest efficiency is in a narrow range of operation, making conventional vehicles inefficient. On the contrary, in most HEV designs, the ICE operates closer to its range of highest efficiency more frequently. The power curve of electric motors is better suited to variable speeds and can provide substantially greater torque at low speeds compared with internal-combustion engines. The greater fuel economy of HEVs has implication for reduced petroleum consumption and vehicle air pollution emissions worldwide

6-2 Noise

Reduced noise emissions resulting from substantial use of the electric motor at idling and low speeds, leading to roadway noise reduction, in comparison to conventional gasoline or diesel powered engine vehicles, resulting in beneficial noise health effects (although road noise from tires and wind, the loudest noises at highway speeds from the interior of most vehicles, are not affected by the hybrid design alone).

Reduced noise may not be beneficial for all road users, as blind people or the visually impaired consider the noise of combustion engines a helpful aid while crossing streets and feel quiet hybrids could pose an unexpected hazard. The U.S. Congress and the European Commission are exploring legislation to establish a minimum level of sound for plug-in electric and hybrid electric vehicles when operating in electric mode, so that blind people and other pedestrians and cyclists can hear them coming and detect from which direction they are approaching. Tests have shown that vehicles operating in electric mode can be particularly hard to hear below 20 mph (32 km/h). In January 2010 the Japanese Ministry of Land, Infrastructure, Transport and Tourism issued guidelines for hybrid and other near-silent vehicles.

A 2009 study conducted by the U.S. National Highway Traffic Safety Administration found that crashes involving pedestrian and bicyclist have higher incidence rates for hybrids than internal combustion engine vehicles in certain vehicle maneuvers. These accidents commonly occurred on in zones with low speed limits, during daytime and in clear weather.

Even though no specific national regulation has been enacted in most countries as of mid 2010, some carmakers announced they have decided to address this safety issue shared by regular hybrids and all types of plug-in electric vehicles, and as a result, the upcoming Nissan Leaf and Chevrolet Volt, both due in late 2010, and the new Nissan Fuga hybrid and the Fisker Karma plug-in hybrid, both due in 2011, will include synthesized sounds to alert pedestrians, the blind and others to their presence. There is also after market technology available in California to make hybrids sound more like conventional combustion engine cars when the vehicle goes into the silent electric mode (EV mode). On August 2010 Toyota began sales in Japan of an onboard device designed to automatically emit a synthesized sound of an electric motor when the Prius is operating as an electric vehicle at speeds up to approximately 25 kilometres per hour (16 mph). Toyota plans to use other versions of the device for use in gasoline-electric hybrids, plug-in hybrids, electric vehicles as well as fuel-cell hybrid vehicles planned for mass production

6-3 Pollution

Battery toxicity is a concern, although today's hybrids use NiMH batteries, not the environmentally problematic rechargeable nickel cadmium. "Nickel metal hydride batteries are benign. They can be fully recycled," says Ron Cogan, editor of the Green Car Journal. Toyota and Honda say that they will recycle dead batteries and that disposal will pose no toxic hazards. Toyota puts a phone number on each battery, and they pay a $200 "bounty" for each battery to help ensure that it will be properly recycled.

Economic and environmental performance comparison among several popular hybrid models available in the U.S

Vehicle	Year model	EPA City mileage (mpg)	EPA Highway mileage (mpg)	Annual fuel cost [(1)] (USD)	Carbon footprint (Ton/yr of CO_2)	EPA Air Pollution Score[(2)]
Toyota Prius	2010	51	48	$732	3.7	N/A
Toyota Prius	2009	48	45	$794	4.0	8
Ford Fusion Hybrid	2010	41	36	$937	4.7	N/A
Honda Civic Hybrid	2009	40	45	$871	4.4	9
Honda Insight	2010	40	43	$893	4.5	N/A
Nissan Altima Hybrid	2009	35	33	$1,076	5.4	N/A
Toyota Camry Hybrid	2009	33	34	$1,076	5.4	8
Ford Escape Hybrid[(3)] 2WD	2009	34	31	$1,146	5.7	8
Chevrolet Malibu Hybrid	2009	26	34	$1,263	6.3	6
Saturn Vue Hybrid	2009	27	32	$1,307	6.6	N/A

Vehicle	Year model	EPA City mileage (mpg)	EPA Highway mileage (mpg)	Annual fuel cost [(1)] (USD)	Carbon footprint (Ton/yr of CO_2)	EPA Air Pollution Score[(2)]
Toyota Highlander Hybrid	2009	27	25	$1,409	7.1	8
Chevrolet Silverado Hybrid[(4)] 2WD	2009	21	22	$1,742	8.7	6
Cadillac Escalade Hybrid 2WD	2009	21	22	$1,742	9.2	6
Chevrolet Tahoe Hybrid 2WD	2009	21	22	$1,742	8.7	6
Lexus GS Hybrid 450h	2009	20	25	$1,905	8.1	N/A
Dodge Durango HEV	2009	20	22	$1,914	8.7	N/A
Lexus GS Hybrid 600h	2009	20	22	$2,085	8.9	8.0

Source: U.S. Department of Energy and U.S. Environmental Protection Agency[135]
Notes: (1) Estimates assumes 45% highway driving, 55% city driving, and 15,000 miles (24,000 km) per year,$2.68/gal
(2) All states except California and Northeastern states.
(3) Performance is the same for the Mazda Tribute Hybrid 2WD and the Mercury Mariner Hybrid 2WD
(4) Performance is the same for the GMC Sierra Hybrid 2WD, the Chevrolet Tahoe Hybrid 2WD, and the GMC Yukon Hybrid 2WD.

7. Hybrid Premium and Showroom Cost Parity

Fuel use in vehicle designs

Vehicle type	Fuel used
All-petroleum vehicle	Most use of petroleum
Regular hybrid electric vehicle	Less use of petroleum, but non-pluginable
Plug-in hybrid vehicle	Residual use of petroleum. More use of electricity
All-electric vehicle	Most use of electricity

HEVs can be initially more expensive (the so-called "hybrid premium") than pure fossil-fuel-based ICE vehicles (ICEVs), due to extra batteries, more electronics and in some cases other design considerations (although battery renting can be used to reach the cost parity). The trade-off between higher initial cost (also called showroom costs) and lower fuel costs (difference often referred to as the payback period) is dependent on usage - miles traveled, or hours of operation, fuel costs, and in some cases, government subsidies. Traditional economy vehicles may result in a lower direct cost for many users (before consideration of any externality).

Consumer Reports ran an article in April 2006 stating that HEVs would not pay for themselves over 5 years of ownership. However, this included an error with charging the "hybrid premium" twice. When corrected, the Honda Civic Hybrid and Toyota Prius did have a payback period of slightly less than 5 years. This includes conservative estimates with depreciation (seen as more depreciation than a conventional vehicle, although that is not the current norm) and with progressively-higher gas prices. In particular, the Consumer Reports article assumed $2/U.S. gallon for 3 years, $3/U.S. gallon for one year and $4/U.S. gallon the last year. As recent events have shown, this is a volatile market and hard to predict. For 2006, gas prices ranged from low $2 to low $3, averaging about $2.60/U.S. gallon.

A January 2007 analysis by Intellichoice.com shows that all 22 currently available HEVs will save their owners money over a five year period. The most savings is for the Toyota Prius, which has a five year cost of ownership 40.3% lower than the cost of comparable non-hybrid vehicles.

A report in the *Greeley Tribune* says that over the five years it would typically take for a new car owner to pay off the vehicle cost differential, a hybrid Camry driver could save up to $6,700 in gasoline at current gasoline prices, with hybrid tax incentives as an additional saving.

In countries with incentives to fight against global warming and contamination and promote vehicle fuel efficiency, the pay-back period can be immediate and all-combustion engine vehicles (ACEVs) can cost more than hybrids because they generate more pollution.

Toyota and Honda have already said they've halved the incremental cost of electric hybrids and see cost parity in the future (even without incentives).

8. Raw materials shortage

The rare earth element dysprosium is required to fabricate many of the advanced electric motors and battery systems in hybrid propulsion systems.

However, nearly all the rare earth elements in the world come from China,[165] and one analyst believes that an overall increase in Chinese electronics manufacturing may consume this entire supply by 2012. In addition, export quotas on Chinese rare earth exports have resulted in a generally shaky supply of those metals.

A few non-Chinese sources such as the advanced Hoidas Lake project in northern Canada and Mt Weld in Australia are currently under development, however it is not known if these sources will be developed before a shortage hits.

9. Vehicle types:

9-1 Motorcycles

Companies such as Zero Motorcycles and Vectrix have market-ready all-electric motorcycles available now, but the pairing of electrical components and an internal combustion engine (ICE) has made packaging cumbersome, especially for niche brands.

Also, eCycle Inc produces series diesel-electric motorcycles, with a top speed of 80 mph (130 km/h) and a target retail price of $5500.

Peugeot HYmotion3 compressor, a hybrid scooter is a three-wheeler that uses two separate power sources to power the front and back wheels. The back wheel is powered by a single cylinder 125 cc, 20 bhp (15 kW) single cylinder motor while the front wheels are each driven by their own electric motor. When the bike is moving up to 10 km/h only the electric motors are used on a stop-start basis reducing the amount of carbon emissions.

SEMA has announced that Yamaha is going to launch one in 2010, with Honda following a year later, fueling a competition to reign in new customers and set new standards for mobility. Each company hopes to provide the capability to reach 60 miles (97 km) per charge by adopting advanced lithium-ion batteries to accomplish their claims. These proposed hybrid motorcycles could incorporate components from the upcoming Honda Insight car and its hybrid powertrain. The ability to mass-produce these items helps to overcome the investment hurdles faced by start-up brands and bring new engineering concepts into mainstream markets

9-2 Automobiles and light trucks

9-3 Taxis In 2000 North America's first hybrid electric taxi was put into service in Vancouver, British Columbia, operating a 2001 Toyota Prius which traveled over 332,000 kilometres (206,000 mi) before being retired. Many of the major cities in the world are adding hybrid taxis to their taxicab fleets, led by San Francisco and New York City. By 2009 15% of New York's 13,237 taxis in service are hybrids, the most in any city in North America, and also began retiring its original hybrid fleet after 300,000 and 350,000 miles (480,000 and 560,000 km) per vehicle. Other cities where taxi service is available with hybrid vehicles include Tokyo, London, Sydney, Melbourne, and Rome.

Toyota Camry hybrid-electric taxi

9-4 Buses

Hybrid technology for buses has seen increased attention since recent battery developments decreased battery weight significantly. Drivetrains consist of conventional diesel engines and gas turbines. Some designs concentrate on using car engines, recent designs have focused on using conventional diesel engines already used in bus designs, to save on engineering and training costs. Several manufacturers are currently working on new hybrid designs, or hybrid drivetrains that fit into existing chassis offerings without major re-design. A challenge to hybrid buses may still come from cheaper lightweight imports from the former Eastern block countries or China, where national operators are looking at fuel consumption issues surrounding the weight of the bus, which has increased with recent bus technology innovations such as glazing, air conditioning and electrical systems. A hybrid bus can also deliver fuel economy though through the hybrid drivetrain. Hybrid technology is also being promoted by environmentally concerned transit authorities.

9-5 Trucks

In 2003, GM introduced a hybrid diesel-electric military (light) truck, equipped with a diesel electric and a fuel cell auxiliary power unit. Hybrid electric light trucks were introduced in 2004 by Mercedes Benz (Sprinter) and Micro-Vett SPA (Daily Bimodale). International Truck and Engine Corp. and Eaton Corp. have been selected to manufacture diesel-electric hybrid trucks for a US pilot program serving the utility industry in 2004. In mid 2005 Isuzu introduced the Elf Diesel Hybrid Truck on the Japanese Market. They claim that approximately 300 vehicles, mostly route buses are using Hinos HIMR (Hybrid Inverter Controlled Motor & Retarder) system. In 2007, high petroleum price means a hard sell for hybrid trucks and appears the first U.S. production hybrid truck (International DuraStar Hybrid).

Hino hybrid diesel-electric truck.

Other vehicles are:

- Big mining machines like the Liebherr T 282B dump truck or Keaton Vandersteen LeTourneau L-2350 wheel loader are powered that way. Also there was several models of BelAZ (7530 and 7560 series) in USSR (now in Belarus) since the middle of 1970th.
- NASA's huge Crawler-Transporters are diesel-electric.
- Mitsubishi Fuso Canter Eco Hybrid is a diesel-electric commercial truck.
- Azure Dynamics Balance Hybrid Electric is a gasonline-hybrid electric medium dutry truck based on the Ford E-450 chassis.
- Hino Motors (a Toyota subsidiary) has the world's first production hybrid electric truck in Australia (110 kW/150 hp diesel engine plus a 23 kW/31 hp electric motor).

Other hybrid petroleum-electric truck makers are DAF Trucks, MAN AG with MAN TGL Series, Nissan Motors and Renault Trucks with Renault Puncher.

Hybrid electric truck technology and powertrain maker: ZF Friedrichshafen.

By a voice vote, the United States House of Representatives approved the Heavy Duty Hybrid Vehicle Research, Development, and Demonstration Act of 2009 (for heavy duty plug-in hybrid vehicles) authored by representative James Sensenbrenner.

9-6 Locomotives

In May 2003, JR East started test runs with the so called NE (new energy) train and validated the system's functionality (series hybrid with lithium ion battery) in cold regions. In 2004, Railpower Technologies had been running pilots in the US with the so called Green Goats, which led to orders by the Union Pacific and Canadian Pacific Railways starting in early 2005.

Railpower offers hybrid electric road switchers, as does GE. Diesel-electric locomotives may not always be considered HEVs, not having energy storage on board, unless they are fed with electricity via a collector for short distances (for example, in tunnels with emission limits), in which case they are better classified as dual-mode vehicles.

9-7 Marine and other aquatic

Producers of marine hybrid propulsion:

9-8 Aircraft

Boeing has stated that for the subsonic concept, hybrid electric engine technology is a clear winner. Hybrid electric propulsion has the potential to shorten takeoff distance and reduce noise

With my best regards
Reedar kamal Salih