

## Reference: Electric Vehicles

### BEGINNINGS OF THE ELECTRIC VEHICLE

The inventor of the first electric vehicle (EV) is uncertain, but several inventors have been given credit. Dating back to 1829, a Hungarian inventor named Anyos Jedlik developed a small-scale model car powered by an electric motor. In 1835, another small-scale electric car was designed by Professor Stratingh of Groningen, Holland and built by his assistant Christopher Becker. The first American to build a battery electric car was Thomas Davenport, a blacksmith from Brandon, Vermont in 1834, but the batteries were not rechargeable. Davenport was also the inventor of the first American-built DC electric motor.

### Better Batteries

More practical and more successful electric vehicles were invented by Davenport and Robert Davidson around the year 1842. Both inventors were the first to use a newly invented non-rechargeable battery. Gaston Plante, a Frenchman, invented a better rechargeable lead acid battery with increased storage in 1859 and his fellow countryman Camille Faure further improved the storage battery in 1881. Better capacity storage batteries were needed for electric vehicles to become practical.

### American Designs

It was not until 1895 that the United States began to devote attention to electric vehicles after an electric tricycle was built by A.L. Ryker, and William Morrison built an electric six-passenger wagon, both in 1891. Many innovations followed and interest in motor vehicles increased greatly in the late 1890s and early 1900s. The first commercial EV application was established as a fleet of New York City taxis built by the Electric Carriage and Wagon Company of Philadelphia in 1897.

### Increased Popularity

By the turn of the century, America was prosperous and cars, now available in steam, electric, and gasoline versions, were becoming more popular. The years 1899 and 1900 were the high point of electric cars in America, as they outsold gasoline cars ten to one. EVs dominated the roads and dealer showrooms. Some automobile companies, like Oldsmobile and Studebaker, actually started out as successful EV companies.

Electric vehicles had many advantages over their competitors in the early 1900s; they did not have the vibration, smell, and noise associated with gasoline cars. Changing gears on gasoline cars was the most difficult part of driving, while electric vehicles did not require gear changes. Although steam powered cars did not require gear shifting, they suffered from long

start-up times of up to 45 minutes on cold mornings. Steam cars had less range before needing water than an electric's range on a single charge. The best roads and infrastructure for electric vehicles were in towns, where most travel was local commuting, creating a perfect situation for limited-range electric vehicles. The electric vehicle was the preferred choice of many because it did not require the manual effort to start as with the hand crank on gasoline vehicles and there was no wrestling with a gear shifter.

### Decline of the Electric Vehicle

Over the years, the popularity of electric vehicles declined for several reasons, including:

- The improved system of roads in the U.S. in the 1920s now connected cities, bringing with it the need for longer range vehicles.
- The discovery of Texas crude oil reduced the price of gasoline to be affordable to the average consumer.
- The invention of the electric starter by Charles Kettering in 1912 eliminated the need for the hand crank.
- The initiation of the mass production of internal combustion engine vehicles by Henry Ford made these vehicles widely available and affordable in the \$500 to \$1,000 price range. By contrast, the price of the less efficiently produced electric vehicles continued to rise. In 1912, an electric roadster sold for \$1,750, while a gasoline car sold for \$650.

Electric vehicles had all but disappeared by 1935. The years following until the 1960s are considered the dead years for electric vehicle development and for their use as personal transportation.

### THE RETURN OF ELECTRIC VEHICLES

The late 1960s and early 1970s saw a rebirth of electric vehicles prompted by concerns about air pollution and the OPEC Oil Embargo. In the early 1990s a few major automakers resumed production of electric vehicles prompted by California's landmark zero emission vehicle (ZEV) mandate, which required 2% of vehicles to be ZEVs by 1998 and 10% by 2003.

These EVs were produced in very low volumes, essentially hand-built like their early predecessors. In 1995, GM announced their production prototype EV, which was initially called Impact, but renamed the EV-1. This EV was designed and developed from the ground up instead of modifying an existing vehicle. The EV-1 was a two-passenger sports car powered by a liquid-cooled alternating current motor and lead-acid batteries.

## The EV-1

The General Motors EV-1 was produced and leased by General Motors Corporation (GM) from 1996 to 1999. It was the first mass-produced and purpose-designed electric vehicle of the modern era from a major automaker. The EV-1 was made available through limited lease-only agreements, initially to residents of the cities of Los Angeles, California, and Phoenix and Tucson, Arizona. EV-1 lessees were participants in a “real-world engineering evaluation.” This was an unprofitable niche of the automobile market, and GM ended up crushing all of their electric cars, regardless of protesting customers.

The creation of an alliance of the major automakers litigated the Zero Emission Vehicle Regulation in court, resulting in a slackening of the ZEV stipulation that permitted the companies to produce super-low-emissions vehicles, natural gas vehicles, and hybrid cars in place of pure electrics. The EV-1 program was subsequently discontinued in 2002.

## Tesla Roadster

The global economic recession in the late 2000s led to increased calls for automakers to abandon fuel-inefficient SUVs, which were seen as a symbol of the excess that caused the recession, in favor of small cars, hybrid cars, and electric cars.

California electric car maker Tesla Motors began development in 2004 on the Tesla Roadster. The Roadster, launched in 2008, was the first highway capable all-electric vehicle in serial production available in the United States. The Roadster was also the first production automobile to use lithium-ion battery cells and the first production all-electric car to travel more than 200 miles per charge.

## TYPES OF ELECTRIC VEHICLES

### Hybrid Electric Vehicle

A hybrid electric vehicle (HEV) is a type of hybrid vehicle and electric vehicle that combines a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. The presence of the electric powertrain is intended to achieve either better fuel economy than a conventional vehicle or better performance. There are a variety of HEV types, 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 like 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.

### Plug-In Hybrids

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 power source. 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.

### Plug-In Electric Vehicle

A plug-in electric vehicle (PEV) is any motor vehicle that can be recharged from an external source of electricity, such as wall sockets, and the electricity stored in the rechargeable battery packs drives or contributes to drive the wheels. PEV is a superset of electric vehicles that includes all-electric or battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles.

Plug-in cars have several benefits compared to conventional internal combustion engine vehicles. They have lower operating and maintenance costs, and produce little or no local air pollution. They reduce dependence on petroleum and may reduce greenhouse gas emissions from the onboard source of power, depending on the fuel and technology used for electricity generation to charge the batteries. Plug-in hybrids capture most of these benefits when they are operating in all electric mode.

Despite their potential benefits, market penetration of plug-in electric vehicles has been slower than expected as adoption faces several hurdles and limitations. Historically, plug-in electric vehicles were significantly more expensive than conventional vehicles and hybrid electric vehicles due to the additional cost of their lithium-ion battery packs; however, this is beginning to change as battery costs fall. The cost of a similar EV/ICE is expected to reach parity by 2022.

Other factors discouraging the adoption of electric cars are the lack of public and private recharging infrastructure and, in the case of all-electric vehicles, drivers' fear of the batteries running out of energy before reaching their destination due to the limited range of existing electric cars. Plug-in hybrids eliminate the problem of range anxiety associated with all-electric vehicles, because the combustion engine works as a backup when the batteries are depleted, giving PHEVs driving range comparable to other vehicles with gasoline tanks.

## ELECTRIC VEHICLE TIMELINE

- 1834: Thomas Davenport invents the battery electric car—batteries were not rechargeable
- 1859: Gaston Plante invented rechargeable lead-acid batteries
- 1889: Thomas Edison built an EV using nickel-alkaline batteries
- 1895: First auto race in America, won by an EV
- 1896: First EV car dealer
- 1897: First vehicle with power steering—an EV with electric self-starters (20 years before appearing in gas-powered cars)
- 1898: NYC blizzard, only EVs were capable of transport on the roads. First woman to buy a car—it was an EV
- 1900: All cars produced: 33% steam cars, 33% EV, and 33% gasoline cars
- 1903: First speeding ticket—it was earned in an EV
- 1904: Only 7% of the two million miles of roads in the U.S. are better than dirt; only 141 miles, or less than one mile in 10,000 was “paved”
- 1908: Henry Ford buys his wife an EV. Many socialites of that time gave this rousing endorsement for EVs
- 1910: Motorized assembly produces gas-powered cars in volume; reducing cost per vehicle
- 1912: 38,842 EVs on the road; horse drawn “tankers” deliver gasoline to gas stations
- 1913: Self-starter for gas cars (10 years later for the Model-T)
- 1921: Federal Highway Act—By 1922, federal match (50%) for highway construction and repair (for mail delivery). Before this, roads were considered only “feeders” to railroads, and left to the local jurisdiction to fund
- 1956: National System of Interstate and Defense Highways funded 10% by states and 90% by the federal government
- 1957: Sputnik is launched; the U.S. space program initiates advanced battery research and development
- 1966: Gallup poll: 36 million really interested in EVs; at the time EVs have a top speed of 40 miles per hour and typical range is less than 50 miles
- 1967: Walter Laski founds the Electric Auto Association
- 1968 – 1978: Congress passes more regulatory statutes than ever before due to health risks associated with cars (collisions, dirty air)
- 1972: First annual (EAA) EV rally
- 1974: CitiCar debuts at Electric Vehicle Symposium in Washington, DC. By 1975, Vanguard-Sebring, maker of the CitiCar, is the sixth largest auto maker in the U.S.
- 1990: California establishes the Zero Emission Vehicle (ZEV) Mandate; requires 2% of vehicles to be ZEVs by 1998, 10% by 2003
- 1990: GM shows their production EV initially named Impact; later it was renamed the EV-1
- 1990: U.S. government spent \$194 million on energy efficient research; much less than the \$1 billion for a single day of Desert Storm, or the \$1 billion per week of 2003 Iraq conflict
- 1993: GM estimated that it would take three months to collect the names of 5,000 people interested in the EV-1—it only took one week!
- 1995: Renaissance Cars, Inc. begins production of the Tropica
- 1996: EAA helps to hatch CALSTART incubator (for EV research) in Alameda, CA
- 1996: GM begins production of the EV-1 (formerly called the Impact)
- 1997: Toyota Prius hybrid gas-electric vehicle unveiled at the Tokyo Auto Show
- 2002: Toyota RAV4-EV retail sales; their estimated two-year supply sold out in eight months
- 2003: ZEV Mandate weakened to allow ZEV credits for non-EVs. Only required 250 fuel-cell vehicles by 2009. Toyota stops production of the RAV4-EV; Honda stops lease renewals of the EV-Plus; GM does the same for the EV-1
- 2004: California electric car maker Tesla Motors began development on the Tesla Roadster, which used a Lithium-Ion battery
- 2007: GM Vice Chairman Bob Lutz said the Tesla Roadster inspired him to push GM to develop the Chevrolet Volt, a plug-in hybrid sedan
- 2010: Deliveries of the Volt began in the U.S.
- 2012: Delivery of the first Tesla Model S in June
- 2013: The Tesla Model S ranked as the top selling plug-in electric car in North America during the first quarter
- 2014: Consumers have a multitude of choices, with 23 PEVs and 36 HEVs available in the marketplace
- 2015: Global sales of the Nissan Leaf reaches over 200,000 units sold making the Leaf the world's top selling EV in history

- 2016: The Tesla Model 3 was unveiled in March with pricing starting at \$35,000 (U.S.) and an all-electric range of 215 miles (345 km)
- 2017: Consumer Reports named Tesla as the top car brand in the U.S. and ranked it eighth among global carmakers. Deliveries of the Tesla Model S passed the 200,000-unit milestone during the fourth quarter of 2017. Global sales of the Nissan Leaf achieved the 300,000-unit milestone in January 2018
- 2019: The global stock of plug-in electric passenger cars reached 5.1 million units consisting of 3.3 million all-electric cars (65%) and 1.8 million plug-in hybrid cars (35%)