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# A Brief History of Electric Vehicles

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***Abstract** – Electric vehicles are powered by electrical machines that are more efficient than any internal combustion engine. Their other main advantage is that they do not emit any harmful substances during operation. Today, they seem to be the future of transportation motorization. All automakers are concentrating on developing a variety of new models. Even if it seems to be a new technology, electric mobility has a long history, alternating glorious and disgraceful periods. The paper briefly reviews the history of electric vehicles and highlights their future.*

***Keywords**: electrical machines; electric vehicles; science history.*

## I. INTRODUCTION

Electric vehicles have a long and storied history. The interest for them largely varied over the years due to environmental issues and available energy resources.

The first electric cars were built in the 1830s, immediately after the development of the first electrical machines. In the next period, numerous electrical vehicles were constructed but without a significant breakthrough in transportation.

The real need for the first engine-based transportation was raised for a very simple reason. In the 1890s, the world's most developed cities faced serious environmental and health problems from horse manure. All vehicles at that time were horse-drawn, as shown in Fig. 1. In London alone, more than 300,000 horses roamed the streets, each producing around 10 kg of manure and 1 L of urine per day. Manure releases methane gas, which has four times the greenhouse effect of carbon dioxide. With the rapid development of industry and transportation, the disposal of this waste has become difficult [1], [2].

Fig. 1.City traffic in the 1890s [3].

In this context, the main goal of the first international conference on urban planning, held in New York in 1898, was to find solutions to circumvent this alarming problem. The final conclusion was that it is inevitable to replace the horsecars with an engine-driven carriage [4].

At that time two approaches were available: steam and electrical vehicles.

Even if the first steam cars had been constructed beginning in the 18$^{th}$ century, their wider spread due to greater series production can be dated only to the 1890s. They had some drawbacks. In cold weather, they took up to 45 minutes to warm up and needed to be topped up with large volumes of water, restricting their range [5].

At the end of the 19$^{th}$ century, there was a significant competition between steam and electric cars.

People preferred electric cars that outperformed their steam rivals. They didn't have the smell, noise, or vibration of the steam cars. Moreover, they were easier to operate, with no hand crank start, and had a much simpler gear system.

Meanwhile, several advancements had been made in the field of internal combustion engines (ICE), especially in Germany. Even if the first prototype of the gasoline car was built by Siegfried Marcus already in 1870, the first vehicle specifically designed to be driven by an ICE (a tricycle) was presented only in 1885 by Karl Friederich Benz. This was followed by the developments performed by Gottlieb Daimler and Ferdinand Porsche. The last one built the first truly commercial such car in 1899. At the time, it had very advanced solutions, such as the hub motor in its driving wheels. He was also the "father" of the hybrid vehicles, as he proposed first this technical approach in 1902 [6].

ICE cars also had a few drawbacks. It took a lot of effort to wrestle with a hand crank, and changing gears was also a difficult operation [5].

The early 1900s marked the first golden age of electric vehicles. Many automakers have come up with dozens of new, more comfortable models. In 1900 1,575 electric cars were produced lone in the USA and only 936 with ICE [1].

Electric car production peaked in 1912. At that time, only the Oliver P. Fritchle Company, one of the most significant electric vehicle manufacturers produced yearly close to 200 cars [7].

In the years after, electric cars begun to lose their share on the vehicle market due to the rapid developments of the ICE cars [7]. The percentage of

electric cars produced in the United States declined to 4% in 1925 [1].

There are some specific reasons for this fall. During the so-called Gusher era (beginning in 1895), the Texas crude oil boom led to tremendous economic change and growth in the USA [8]. The sharp drop in gasoline prices made ICE cars cheaper to own and maintain for the average consumer. More and more gas stations were opened across the countries, making ICE vehicles easier to refill. Another reason had to do with manufacturing. Ford invented the mass production of the very popular Model T in 1908, which had a major impact on the price of the cars. In 1912, a gasoline car cost as little as $650, while a similar electric car was $1,750. Another nail in the electric car coffin was the American inventor Charles Kettering's patent in 1912 for the first electric car starter. With the removal of the manual crank, gasoline cars became more attractive to drivers [7].

Cheap, plentiful gasoline and persistent ICE developments lessened the need for and interest in alternate fuel vehicles during the next 30 years. However, throughout the 1960s and 1970s, petrol prices permanently increased. The most significant shock to the oil market occurred in 1973 when OPEC declared the global oil embargo. In six months, the fuel prices increased by three times. This shock had several immediate and long-term consequences for the world economy. For the first time, humanity learned how reliant they are on limitedly available resources. In addition, the issue of ICE-related air pollution began to acquire attention [9].

Many automotive companies began to develop electric vehicles, mostly for short-distance urban mobility. Electric cars had limited performance and range at the time. In the meantime, ICE's improvements have been focused on reducing fuel consumption and emissions. All of this has led attention in electric vehicles to wane once more [10].

Beginning in the 1990s, there was a resurgence of interest in electric cars, mainly owing to tight environmental regulations. Most manufacturers began to convert their ICE models to electric or hybrid ones, allowing them to compete with gasoline-powered cars in terms of speed, performance, and range.

Electric/hybrid car flagships, such as GM's EV1 and Toyota's Prius, were developed at those times. Tesla cars became the industry norm for electric vehicles ten years later. Meanwhile, widespread of charging locations took place all around the world and intensive improvement of the batteries was achieved by the involved scientists and engineers.

Nowadays almost all the vehicle manufacturers offer a wide range of hybrids, plug-in hybrids, and full electric vehicles and they are hard-working on the development of the future such cars.

It seems that electrical transportation is the key to a more sustainable future for humanity. The most developed countries can lessen their reliance on foreign crude oil and minimize carbon pollution on the planet by switching to electric vehicles [10]. As a result, electric vehicles appear to be the way of the future. Several automakers have pledged to stop or severely limit ICE vehicle production until the 2030s. Moreover, several major cities in Europe and the USA plan to ban diesel vehicles by 2025.

The purpose of this paper is to provide a brief survey on the most significant achievements in the field of electric vehicle development from three critical times in its history: the early years, the dawn of the modern era, and the near future.

## II. THE FIRST ELECTRICAL VEHICLES

### *A. The very beginnings*

The history of electrical cars is strongly connected to that of electrical machines. In 1827 the Hungarian Benedictine monk Ányos Jedlik built the first rudimentary but working d.c. electrical machine. Only within one year, he used it to drive a simple small-scaled car model (see Fig. 2) [6].

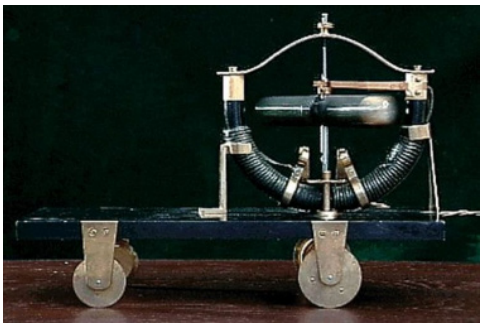


Fig. 2. The electric car model built by Á. Jedlik in 1828 [11].

Another small-scale electric cell supplied electrical vehicle (shown in Fig. 3) was built in 1835 by Sibrandus Stratingh, a professor of chemistry and technology at the University of Groningen (Netherlands) [6], [12]. It weighed about 3 kg and could move for 20 minutes with a 1.5 kg load with its fully charged cells [13].

Fig. 3. Small scale electric car model developed by S. Stratingh in 1835 [13].

Scotsman Robert Anderson is the inventor of the first full-scale electricity driven carriage (see Fig. 4). His prototype was built sometime from 1832 to 1839 in Aberdeen It used primary cells (non-rechargeable

batteries) to generate electrical power and had a maximum speed of 12 km/h [6].

Fig. 4. The first electric car built by R. Anderson [6].

### B. *The First Electric Locomotives*

During the same time, another Scotsman, Robert Davidson, also of Aberdeen, developed the first electric locomotive in 1837. Its improved variant, called *Galvani* was tested on the railway line from Edinburgh to Glasgow in 1842. The 5 t, 4.8 m long locomotive was driven by four switched reluctance motors, as can be seen in Fig. 5 [14]. With fully charged batteries it could move near 2.5 km at a 6.4 km/h speed [15].

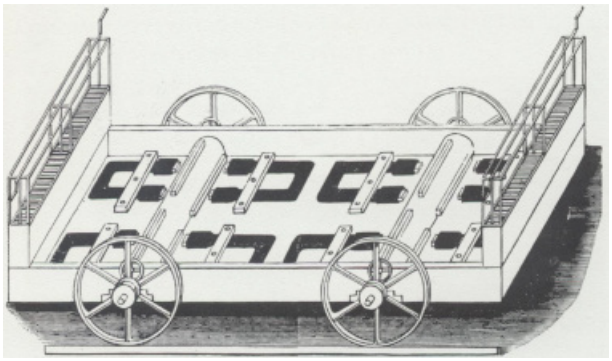


Fig. 5. The first electrical locomotive powered by switched reluctance motors [15].

In 1851 Charles Grafton Page, a senior examiner for the U.S. Patent Office built an around 12 kW electrical machine for a battery-driven electric locomotive that achieved a speed of 30.5 km/h on the Baltimore and Ohio Railway. In the linear variable reluctance motor shown in Fig. 6, the commutation was performed by the so-called circuit changers (linear commutator) [16].

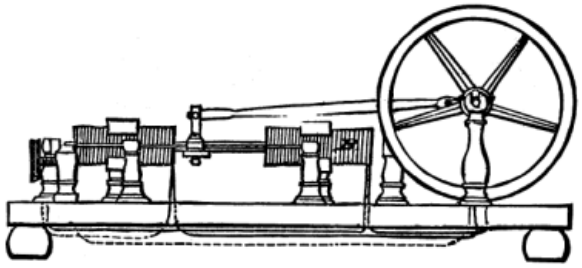


Fig. 6. The linear variable reluctance motor driving a very early electric locomotive [16].

### C. *Representative Electrical Cars from the First Golden Era*

The first successful commercially available electric cars were named in an inspired way *Electrobats*. Its first variant was built in 1894 by the combined efforts of a mechanical engineer and a chemist, Henry G. Morris and Pedro G. Salom in Chicago upon their own patented technologies. The first variant was a slow and very heavy car having steel tires. The rechargeable batteries alone weighed more than 725 kg of the 2 tons gross mass of the vehicle [2].

Thanks to the continuous research and development efforts, later *Electrobats* became lighter, faster, and less unwieldy. They had pneumatic tires and were steered by their two rear wheels. These vehicles were powered by two 1.1 kW claw pole motors. Due to their state-of-the-art batteries at the time, they could travel 40 km at an average speed of 32 km/h on a single charge.

Due to high interest in these cars, the two partners expanded their business by building several hansom variants based on the model. One of these is given in Fig. 7. These electric vehicles were also used as taxis in many cities in the USA [17], [18].

Fig. 7. An elegant model of the *Electrobat* car [19]

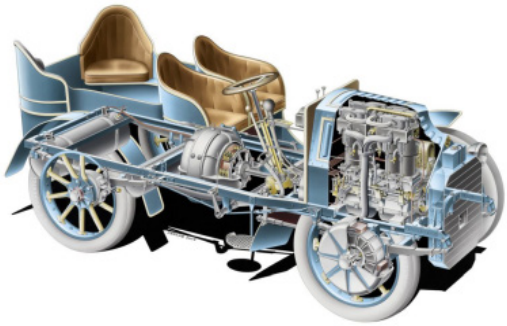
Here also the main achievements in this field of the Austrian-born Ferdinand Porsche must be mentioned. In 1899, while working at Jakob Lohner & Company, the 22-year-old brilliant designer created his first electric car. This could achieve a speed of 25 km/h. His electric cars included cutting-edge technology at the time, such as the electrical hub motor that drove the vehicle's wheels directly (as can be seen in Fig. 8).

Fig. 8. A *Lohner-Porsche Phaéton* in the Vienna Technical Museum [20].

He exhibited the world's first functioning revolutionary hybrid car with all four wheels electrically driven three years later. It was given the name *Semper Vivus*, which means "always living". Porsche increased the car's range by installing ICEs that drove the electrical generators to charge the battery, rather than relying simply on the battery. The original 74-cell accumulator was replaced with a smaller, having 44 cells to save weight and space. Two water-cooled 2.6 kW ICEs were mounted in the vehicle's center, driving the two independent 1.84 kW generators, each delivering 20 A current at 90 V voltage [21].

Later, its production-ready version was released and named *Lohner-Porsche Mixte* (see Fig. 9). Its top speed was 80 km/h [22], [23].

a) an oldtimer variant



b) its technical details

Fig. 9. The *Lohner-Porsche Mixte*, the first commercially available hybrid car [22].

Later, Ferdinand Porsche was the designer also of the iconic *Volkswagen Beetle*, which is set to make a comeback soon as an electric vehicle.

An important milestone in the development of electrical machines was the so-called *100-Mile Electric Automobile* (see it in Fig. 10).

Fig. 10. Fritchle's *Victoria*, the so-called *100-Mile Electric Automobile* [24].

This two-seat electric car weighed 1000 kg, more than 350 kg of which were in batteries. It was built in Denver in 1908 by Oliver Parker Fritchle, an early key pioneer in the field of electric vehicles. He made substantial contributions to both battery and automobile manufacturing. His name is linked to the creation of regenerative braking, too. He concentrated his developments on the endurance of newly designed electric cars. He proposed an audacious challenge in September 1908: to perform the 2,900 km trip between Lincoln and New York in an electric car with no mechanical problems. He accomplished the trip in 20 days, covering on average nearly 100 miles (160 km) a day.

### *D. Electric Racing Cars*

The first car in history to break the speed record of 100 km/h had electrical traction. The torpedo-streamlined car was called *Jamais Contente* (*Never Satisfied* in English) and is shown in Fig. 11. It was powered by two electrical machines of 25 kW (of 200 V and 124 A each) [25], [26]. The body of the vehicle was made of a light alloy, *partinium*, a very lightweight and expensive alloy of laminated aluminum, wolfram, and magnesium, not frequently used nowadays.

Fig. 11. The *Jamais Contente* electric race car in an exposition [27].

The record-breaking took place in Achères (France), on April 24, 1899 (see Fig. 12). The supercar driven by the Belgian *Camille Janetzy* reached a record speed of 105.882 km/h.

Fig. 12. The *Jamais Contente* after the record breaking [28].

Ferdinand Porsche also constructed electric race cars. One of its first variants was built in 1902, and it is given in Fig. 13. It had two 1.5 kW electrical motors in both of its front wheels. The car was energized by a huge quantity of batteries, weighing 1.800 kg [9].

a) original picture [29].

b) an oldtimer variant [30].

Fig. 13. The *Lohner-Porsche* racing car

The world's first four-wheel drive vehicle was a particular race car designed also by F. Porsche. He titled it *La Toujours Contente* (the *Always Satisfied* in English) in reference to the race car given in Fig. 11. The four 3 HP (2.23 kW) in-wheel electrical motors allowed for a top speed of about 58 km/h. After charging its 44-cell 80 V lead-acid battery, it could run for around 3 hours [31].

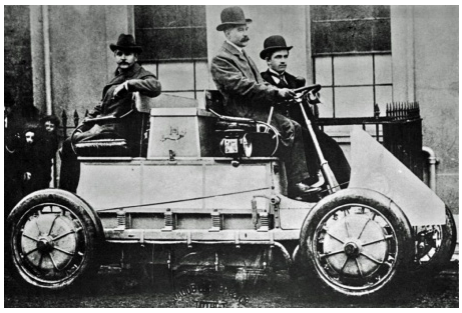


Fig. 14. The world's first four-wheel drawn car made by F. Porsche (sitting beside the driver) [31].

### *E. The First Public Electrical Vehicles*

Other vehicle types were also electrified during this time. The focus of German manufacturers was on public electric vehicles. The first electrical tramway was presented by Siemens&Halske (the predecessor of Siemens AG) at the Berlin Industrial Exhibition in 1879 [32]. Its first operational variants, capable of transporting 6 passengers, were placed into service in Lichterfelde, near Berlin, in 1881 (see Fig. 15). These were powered by drum-type d.c. machines of 7.5 kW, 180 V (supplied via the rails), and had a 2.5 km range [6].

Fig. 15. The first electric tramway in Lichterfelde (Germany) [33].

The following year the first overhead electric trolleybus, the *Electromote*, began service in Halensee (a Berlin suburb) on a 540 m long track. [6] It was designed by Werner von Siemens, who also constructed the first electric elevator.

Fig. 16. *Electromote*, the first electric trolleybus designed by Werner von Siemens [34].

The famed American inventor Thomas Alva Edison could not be left out of the electric vehicles business either. Among the numerous devices created by him, there are also electrical vehicles. After building his first electric car, the *Edison Baker*, in 1915 he presented the world's first electric bus (see Fig. 17).


Fig. 17. The first electric bus in 1915 [35].

Edison very early recognized that the batteries are the main bottleneck of the electric vehicles. He spent a lot of time researching how to make the accumulators lighter and recharge faster. He had high hopes for the nickel-iron (Ni-Fe) alkaline batteries, but there were a few bugs to smooth out. Even though their power to mass ratio was higher, they required more space and were significantly more expensive than standard lead-acid batteries. Another significant disadvantage of Ni-Fe batteries was that they released flammable hydrogen when charging, which was considered extremely dangerous [6]. As a result, lead-acid accumulators remained the most essential electrical power sources in automobiles for many years.

It's worth noting that the "hazardous" feature of Ni-Fe batteries is currently one of the most important hopes of scientists working on hydrogen fuel generation, which has the potential to transform transportation [36].

## III. THE EARLY MODERN HISTORY OF ELECTRIC CARS

As previously stated, the rise in gasoline prices that began in the 1960s and accelerated in the 1970s reawakened interest in electric vehicles after an almost 50-year hiatus. As a consequence, several electric vehicles were developed at that time. Small-size and short-range city cars were primordially targeted.

Enfield Automotive, a small British company, began serial production of a small two-seater electric car in 1966, powered by a 6 kW series-wound d.c. motor and 8 lead-acid traction batteries. The car shown in Fig. 18 had a maximum speed of 64 km/h and weighed 975 kg. It had a range of 40÷90 km when its batteries were fully charged [9].

Fig. 18. The *Enfield 8000* electric car [37].

In 1972, Sebring-Vanguard company of Florida created the *Citicar*, a compact two-door two-seat small electric automobile (see in Fig. 19). This was the first attempt in the USA to mass-produce a modern electric automobile since the golden age from the beginning of the 20th century. It weighed only 500 kg thanks to an aluminum chassis with a roll cage and an ABS plastic body. Between 1974 and 1977, 2,500 of these simple and inexpensive automobiles were sold [9], [38].

Fig. 19. 1976 Sebring-Vanguard *CitiCar* [39].

As previously stated, the electrical cars intended application field at the time was limited to specific local use. The electrified version of the popular BMW 1600, shown in Fig. 20, which is powered by a 32 kW Bosch electrical machine, is a good example. In 1972, BMW presented the Olympic stewards with two such electric cars, which they utilized to support the marathon road running and long-distance walking competitions. The car's range only slightly exceeded the 42.195 km marathon run distance [40], [41].


Fig. 20. The *BMW 1602* electric car used during the 1972 Munich summer Olympic games [42]

In the mid-1970s some automobile manufacturers attempted to convert conventional cars to electric ones, but the market was not ready for such expensive, hard to charge vehicles. Having in the mind the future need for clean vehicles not needing fossil fuels, the Japanese government began to strongly support the research in the electrical vehicles field. The results were seen in the 1990s, when Japanese automakers (such as Toyota and Nissan) dominated this market [9].

Meanwhile, in 1971, the first electric vehicle left the Earth. The *Lunar Rover*, shown in Fig. 21, a solar-powered planetary surface exploration device developed by NASA, began traveling across the Moon's surface.

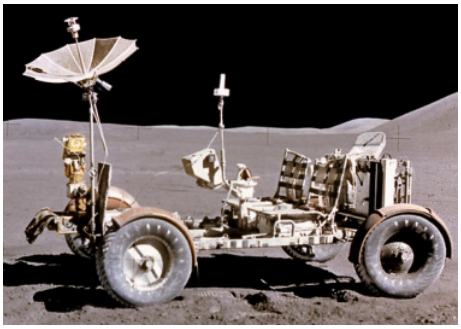


Fig. 21. The *Lunar Rover* electric vehicle taken to the Moon by the Apollo 15 mission of NASA [44].

The *Moon buggy*, as it was popularly named, weighed 210 kg and could transport a load of up to 490 kg, which included two astronauts, scientific equipment, and collected lunar samples. It had a top speed of roughly 13 km/h and a range of about 90 km. Each of its wheels had its own d.c. series wound 0.25 HP (0.19 kW) motor with a 10,000 r/min speed, connected to the wheel through an 80:1 harmonic drive. It was critical in acquiring information on our planet's natural satellite [43].

From these times the history of electrical vehicles is better-known.

## IV. THE NEAR FUTURE OF ELECTRIC CARS

Finally, two of the most futuristic electrical cars are presented just for illustrating the bright future of these vehicles.

The first one is upon the *Sedric* (*SElf-DRIving Car*) concept of the Volkswagen Group and is shown in Fig. 22. It combines wholly autonomous driving, full electric traction, and high-level digital network integration [44], [45].

Fig. 22. The *Volkswagen Sedric*, the first totally self-driving electrical vehicle [46].

The second one is the *Concept-i* by Toyota having an insanely revolutionary design, as can be seen in Fig. 23. This semi-autonomous electric car of the near future totally integrates AI for maximizing the enjoyment of driving and the safety of the driver and the passengers [47], [48].

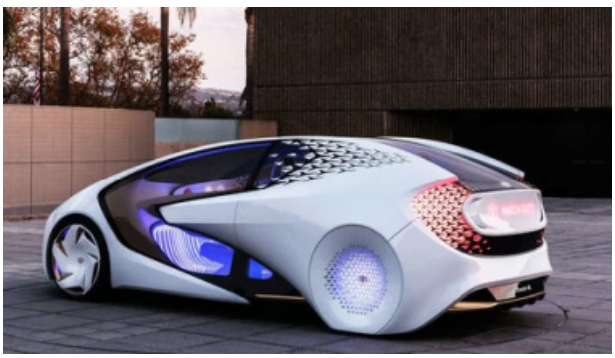


Fig. 23. The Toyota *Concept-i* future electric car [49].

Surely, the rapid improvements in the field of electrical transportation will provide soon unexpected outcomes, fundamentally altering our perception of this subject.

## V. CONCLUSIONS

Hopefully, the reader could get a comprehensive sense of the major milestones and achievements in the relatively short history of electric vehicles based on this survey. All of this points to a bright future for this vital aspect of our daily lives.

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