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Resources



Electric Cars

Since the invention of the first electric motor strong enough to do work in 1834 people have been dreaming of electric powered transportation. Electric cars, trains and trolleys are older than most people think. In this page we focus on the electric car, but do discuss trains and trolleys since their roots are connected.

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1.) Historical Timeline:

This timeline includes not just landmark electric cars in history, but development of key components in the development of electric vehicles.

Galen Handy - expert in American electric cars has prepared the following timeline and car descriptions:

1821 - Michael Faraday creates the first weak experimental electromagnet

1831 - [Joseph Henry](#) a math professor in Albany NY, builds the first electric motor in his quest to understand electro-magnetism. It is

modeled along the lines of the "walking beam" used on early steam engines and resembles an electric teeter-totter.

1834 - Inspired by reading of Joseph Henry's efforts [Thomas Davenport](#) develops the first rotary electric motor and builds a miniature electric railcar running in a circle on a tabletop; it is not strong enough to carry the weight of its own battery. His invention failed to interest investors. This might have been due to a lack of imagination among his audience, but practical minded people would point out the dependency on relatively expensive single use batteries, as neither practical rechargeable batteries, nor distributed electric power are available. He creates a proof of concept, which is generally ignored until after the Civil War.

1851 - The US Senate funds a prototype electric locomotive, which made a test run from Washington DC to Baltimore MD, a distance of about 40 miles (64 km). [Charles Grafton Page](#), a US patent examiner, designs it and uses his Washington connections to get funding. The motor was like an electric steam engine with a solenoid and iron slug rather than a cylinder and piston. The effort fails when the clay separators in the primary battery cells crack and the solenoid coils overheat and short out as the insulation fails. Steam remains more practical for large-scale power at this point.

1854 – Wilhelm J. Sinsteden invents the rechargeable, lead, sulfuric acid, and lead-oxide battery

1859 - Gaston Planté improves the lead acid cell to the point of commercial viability with telegraph system use in mind. The original Planté design had smooth, untreated lead plates separated by parchment paper and felt. They had to be cycled (recharged) many times before building up a sufficient peroxide coating on the positive plate to develop full useful capacity.

1869 - Zenobe-Theophile Gramme patents the first practical dynamo in Paris.

1876 - Nikolaus August Otto patents a practical four-stroke engine, designed for stationary use, in Germany. The engine is made to run with help from his engineer Gottlieb Daimler.

1880 – January 17th: Thomas Alva Edison is awarded a carbon-filament vacuum tube light bulb patent. This incandescent light becomes popular over the next three decades as the lamps become more affordable. The commercial generation and distribution of electricity for lighting, and light rail, built the necessary infrastructure for electric cars. Edison had to fight for clear patent rights, and eventually the strongest plaintiffs merged to become General Electric.

1881 – Camille A. Faure, in France, and Charles F. Brush, in the US, independently come up with the idea of using a lead oxide paste to increase the capacity of the original 1859 Planté battery by a threefold capacity, greatly increasing the potential for battery traction vehicles, if the paste would stay on the plates. Charles Jeantaud builds a battery electric vehicle in France. The car was made from a Tilbury style buggy, with a Gramme motor, and a Fulmen battery. Over the next twelve years, he continued to modify this platform, installing a British motor in 1887, and a Swiss motor with a tubular plate battery built by Tonate Thommasi in 1893.

1883 - the Brighton Electric Railway, engineered by Magnus Volk, opens in England. The route is only a quarter mile long at first. This is the first commercial electric streetcar.

1886 - N. S. Possons has an electric tricycle built for the Brush Electric Co of Cleveland Ohio. It has a Swan incandescent electric headlight and features the Brush Company's rechargeable battery powering a Brush motor.



Above: Frank Sprague, pioneer of trolleys and electric cars

1886 - [Frank Sprague](#) invents a high torque DC traction motor. It is capable of consistent speed under varying loads and does not create sparks.

1887 - Sprague uses his DC motor in the first commercial electric streetcar systems in North America, beginning with Richmond Virginia.

1890 – **William Morrison builds the first four-wheel electric road vehicle** in America to demonstrate his battery.

1893 – The World's Columbian Exposition is held in Chicago IL, ushering in the electrical age for most Americans. There are several motor vehicles on stationary display including an electric taxicab designed by Walter Bersey and a few of German petrol vehicles. The Morrison car, now owned by the American Battery Co, is the only one moving about. It becomes well known as it is used to drive important visitors - including many future automobile manufacturers - around the grounds.

1894 - Henry G. Morris and Pedro G. Salom in Philadelphia were designers of battery streetcars and saw potential in electrifying smaller road vehicles. They design and commission a heavy four-wheel electric wagon similar to the Morrison car. It runs at 15 mph.

1895 - Morris & Salom come up with an elegant new design, which they call the Electrobat II. It is lighter weight and has front wheel drive with coil spring suspension at the rear wheels. Along with the Morrison electric it is entered in America's first automobile race, which is held in Chicago. Neither car has the battery capacity to go the distance in the freezing weather, and the race is won by the Duryea brothers, followed by some German Benz based cars.

1896 – The same Electrobat II, and a new electric built by Andrew Riker, soundly defeat five next generation Duryeas in a series of five mile sprints on a dirt horse-track in fair weather. The short range allows for a light, hot battery. Because of the high initial cost and vicissitudes of lead battery management Morris and Salom felt the vehicles are more appropriate for fleet service than individual ownership, and design an electric version of the popular horse drawn Hansom cabs for the streets of major American cities.

Major commercial implementation:

1897 – Cabs in New York based on the Electrobat II are the first in commercial operation. The event is announced in January - with only two cabs ready - but due to licensing delays operation actually begins in March. They soon had a small fleet of 12 Hansom cabs and one Brougham (Coupé). Venture capital for the Electrobat projects came from owners of the Electric Storage Battery Company of Philadelphia under the leadership of Isaac L. Rice. ESB is founded to provide battery sets for streetcars where a trolley line is not practical, to extend service past the reach of electrical lines, and where overhead wires are restricted by ordinance. They are also used for power station backup, railway lighting, and such. May 13th A Columbia Mark III, the first electric car for sale to the general public, is demonstrated to the press and public. Made by a subsidiary of Albert A. Pope's bicycle empire the company has a significant advantage over the Morris & Salom New York cab startup as they had a factory for manufacturing the chassis and running gear, the bodies are farmed out to the New Haven Carriage Co. Although a Bersey cab prototype has been around since 1893 it takes several years to find the capital and change laws to put them on the streets of London. On August 19th, 1897 Walter Bersey's cab is finally put into service. The Bersey cabs use a 3 ½ HP Lundell motor, ran at 9 miles per hour for about 20-30 miles on a charge, and feature quick-change battery boxes. The enterprise failed in August of 1899. Painted yellow and black they were popularly called "hummingbirds" due to the bright color and whirl of the straight cut gears.

September: Isaac Rice takes over the New York cab company as the Electric Vehicle Company.

1899-1905 - Ferdinand Porsche designs electric and Hybrid cars for Austrian coachbuilder Jacob Lohner & Co. The vehicles from 1900 on use hub motors.



1899 - Walter C. Baker founded the [Baker Motor Vehicle Company](#). Thomas Alva Edison, who does not drive, buys the second one made.

1900 – Because of the brief lead cab bubble, many US automobiles are powered by electricity. By 1915 electric cars dropped to 5% of marketshare. Electric automobiles were most popular in Chicago, Cleveland and Buffalo.

The Electric Vehicle Company has a lot of flash equity, mostly as stock shares, to spread around in support of anticipated growth. The Electric Carriage and Wagon, Columbia Motor-Carriage, New Haven Carriage, Riker Electric Vehicle, and Siemens-Halske (North America) companies, are folded into the Electric Vehicle Company, now controlled by a New York/Philadelphia transit holding company known as the "lead cab trust". EVC provides vehicles for the New York City and other taxi companies; the closely tied Electric Storage Battery Company (later ESB Exide) supplied the batteries. In many cases these buyouts are stock swaps where a majority owner of the original company became a minority owner of the briefly inflated conglomerate. The game of the holding company is industry sector monopolies based on patent consolidation and exclusive franchises.

1902 - Things are already falling apart for the lead cabs. The men running the holding and operating companies are far more successful at selling the companies than their products, and sold more equity stakes than the wildest success might have justified. Although the New York cab company and vehicle manufacturing companies are profitable, and of more value operating than liquidated, the taxi enterprise failed in most other cities. After 1899 the Electrical Vehicle Company does not pay their preferred stock dividend obligations, much less return a dividend on common stock. Several of the original partners, such as Pope, Rice, and Riker, sold out early - were pushed out to a degree - and left the later investors holding a somewhat empty bag. This apparently

fraudulent scheme gives quite a blow to the whole concept of electric vehicles in the minds of investors and customers.

The Baker Motor Vehicle Co. produces a fully streamlined electric racing car called the Torpedo, with a top speed said to be 120 mph. When it crashed and killed two spectators during its first speed trial, press toward both speed contests and electric vehicles took a negative turn.

1903 – For Walter C. Baker it is not about top speed, it is about efficiency. The following year He Built the Baker Torpedo Kid; it is a one-person vehicle, smaller and far lighter than the 12 HP tandem-seat Torpedo. Most racecar designers increase the power and speed of their cars with each new iteration. Baker has different priorities. The motor in the Kid has a nominal rating of 1½ HP. The Torpedo has no recorded time registered at over 80 MPH; The Kid is clocked on Ormond Beach at 103.

1905 - Rauch & Lang, a well-established maker of luxury coaches in Cleveland, sees the success of nearby Baker and the fading of the horse. They decide to make their coaches electric.

All makers combined produce approximately 1,200 electric motorcars in America.

1907 - Bank panic and recession of 1907: Several of the individuals and their business practices in the lead cab holding Company were involved in causing major bank panic with the collapse of many large banks and a freeze of liquidity, ending many businesses. Although the Electric Vehicle Company had earnings of ~\$200,000 a year from explosion car makers paying a royalty on the Seldon patent, and decent earnings from vehicle sales, they were not able to refinance \$2,500,000 in mortgage backed securities, and went into receivership. At its peak there were 616 cabs and busses in the New York fleet. Gasoline cabs were introduced around 1908 and by 1910 the electrics were out of service. This recession was a factor in Henry Ford's decision to make only one model at a low price.

The Anderson Carriage Company starts production of the Detroit Electric.

1908 - A few months before he sold the first model T, Henry Ford bought Clara her first Detroit Electric. It had a special child seat for Edsel. The Ford family bought a new Detroit Electric every other year thru 1914.

1910 – Shaft drive electric cars are made the standard by Baker.

1915 - The Baker Motor Vehicle Company merges with Rauch & Lang. Only two versions of the Baker Electric are sold through the following year and the Baker brand is only used for industrial trucks thru the rest of the Twentieth Century.

The Milburn Wagon Company is the last important maker of electric pleasure cars to enter the market.

1916 – Venerable Chicago electric vehicle maker Woods introduces a hybrid car called the Woods Dual Power in an attempt to revive the company. This is the most serious attempt at a true hybrid automobile for the general public.

1919 – Only Detroit Electric, Milburn, and Rauch & Lang survive World War II, the Influenza pandemic, and the postwar recession. Production slowed to a trickle. Electric starting and lighting systems, combined with much more reliable gasoline engines, and better sliding gear transmissions, made the advantages of electric cars less significant.

A few serious attempts were made to revive the electric, notably by Charles Proteus Steinmetz, but none had any market impact.

Modern History:

1970s - After the price of gasoline hits record highs the interest in electric cars is rekindled. The US Department of Energy funds efforts to try to make a cost effective electric car.

1982 - The first [modern hybrid car is made at GE Research Lab](#). It is computer controlled and is the ancestor of current commercial hybrid cars.

1989 - Audi creates a hybrid called the "Duo" with NiCad batteries and a 5 cylinder gas engine. The vehicle never sees mainstream production

1995 - Toyota debuted a hybrid concept car at the Tokyo Motor Show

1997 - The first Prius went on sale in the Japanese market.

1997 - Audi creates the Duo III and it makes it to series production

1998 - Nissan produces 200 of the Altra EV from 1998-2002

2008 - Tesla Motors sells the Tesla Roadster with a 200+ mile range

2009 - Ford Fusion hybrid is released

2010 - Nissan Leaf all electric car sold. Synchronous electric motor used on front axle.

2010 - Mercedes-Benz collaborates with Tesla Motor Company to produce the A-Class E-Cell

2011 - Chevy Volt, hybrid car, sold in US market 25-50 mile range

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2.) How Electric Cars Work

There are many ways to produce an electric car. The subject of how electric cars work is a large enough subject for a major series of web pages, so we'll keep it short here. Here are some major points to understand:

Direct Drive - electric motor directly drives wheels without a gearbox, this can be a smooth and efficient way to run an electric car.

[Learn more >](#)

Generally there are three kinds of electric motors used in electric cars:

3-phase AC induction motor - [See our video here on the Tesla's use](#) of this kind of motor

Permanent magnet DC motors - this type of motor uses brushes and is noisy, you'll find them used in smaller electric vehicles like bikes and carts.

DC Series wound electric motors - this is the most common motor used in electric cars, they have great torque and are quiet.

Learn about the individual components of an electric car:

[Electric Motor Batteries](#)

[Iron/Steel](#)

[Electric Light](#)

[Control Engineering](#)

3.) Electric Cars in History

This is not a complete list of electric vehicles but it covers some of the great icons of electrical vehicle history.

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The Baker Electric Car

The Baker Motor Vehicle Company was based in Cleveland Ohio, a center of early automobile manufacturing second only to Detroit. Baker produced some of the best electric cars from 1900-1916. The Baker family was joined at the hip with the White family, generations of whom built sewing machine and motor vehicle empires. Walter C. Baker started the American Ball Bearing Company with his father-in-law Rollin Charles White and brother-in-law Fred White. The Baker motor vehicle company was a spin-off of the ball bearing and axle company, with similar management, and an original purpose of demonstrating the efficiency of their ball bearing axles. By 1910 the companies were of similar size and occupied twin factories with a shared power plant. Baker was one of the more innovative electric car companies and American Ball Bearing was a pioneer in Vanadium steel axles.

Cleveland's electrical history began in the 1870's with local pioneer [Charles F. Brush](#) who created the first city lighting systems and the first central power stations in North America for his [arc lights](#). More important for electric car development, and co-incident with Faure in Europe, he invented the pasted plate lead-acid battery, which had three times the capacity of an improved Planté cell, and made a full size battery vehicle practicable. The Electric Storage Battery Company purchased his battery patents. General Electric got the others (thru Thomson-Houston) such as dynamo, motor, distribution equipment, arc light, and the American license for the Swan incandescent light bulb.

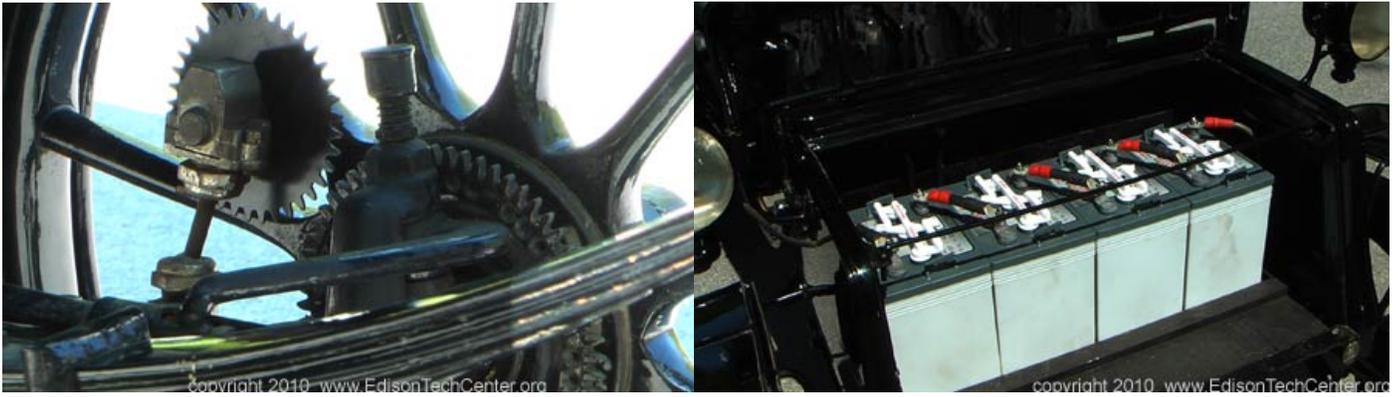
These photos are of what is probably a 1907 Baker Electric. Originally we thought it was a 1901 Baker Electric due to documents registering such a car to [E. W. Rice](#) of General Electric, but under the seat there is a GE motor with a last patent date of May 1903, so unless the motor is a replacement the car is later. The serial number suggests it is an early 1907 motor. This car might well have been the second Baker that Rice owned, as six years is a reasonable interval between new cars.



Above: The motor under the seat, this is not a direct drive obviously. Electric cars with a direct drive require the motor to be low, down by the wheels.

Below. This Baker Electric uses a center axle single chain drive.



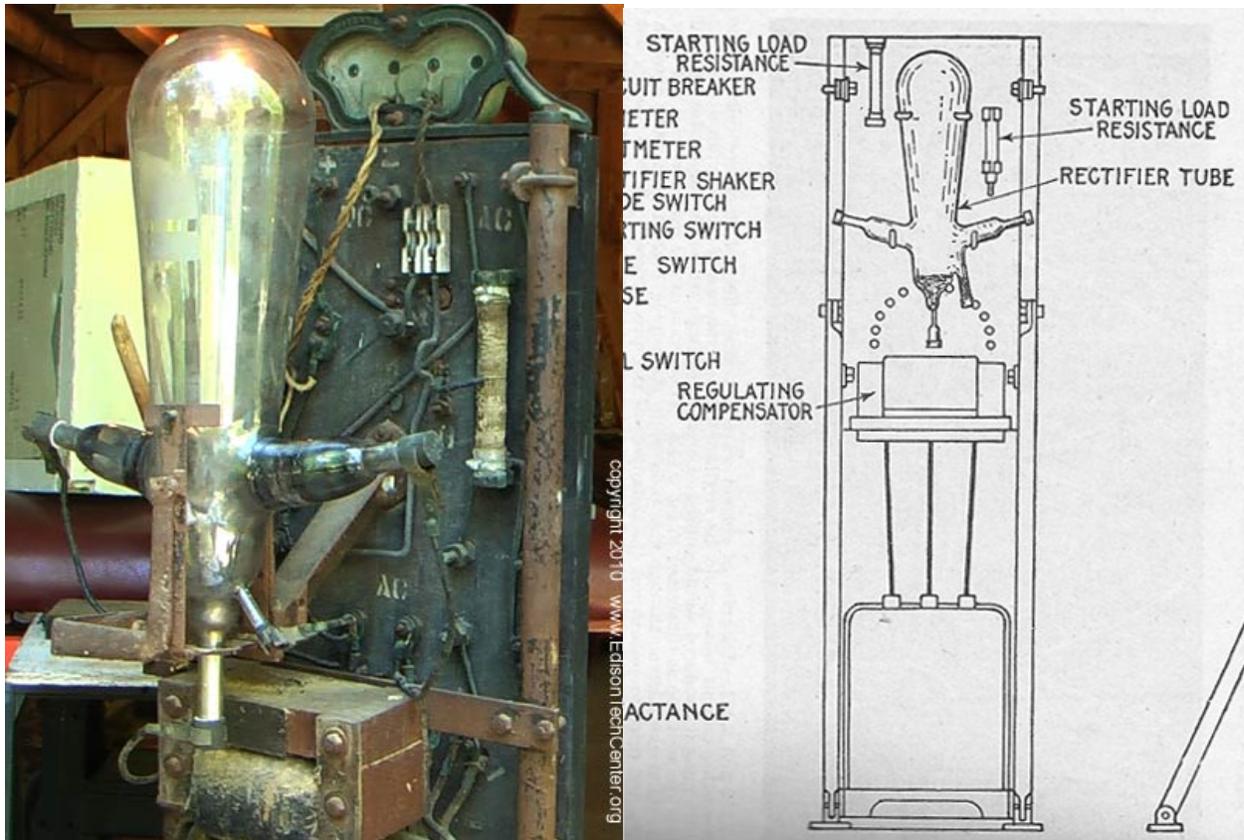


The battery is in the front and rear of the car. This battery is not original. The original battery was composed of individual lead-acid cells set in wood crates and wired in series.



Automobile Motor Number 116324 - Classification GE1020 E2W6 – 26 Amperes - 48 Volts - Speed 1980 RPM - Patented July 9, '89, March 25, '90, July 8, '90, Nov 10, 91, April 25, '92, Oct 22, '95, May 5, '96, Dec 14, '97, Jan 31, '99, May 12, 1903. General Electric Co. Schenectady, N.Y., U.S.A. This gives the motor a nominal rating of 1.25 kW or 1.7 HP

Below video of this car in action:



This is a General Electric [Mercury Arc Rectifier](#) battery charger made for home and small garage use. It could charge the battery of nearly any electric car or truck at rates up to 50 Amperes. Edison was the first (1880) to notice that a vacuum tube with a hot filament and an additional cold element functioned as a rectifier, only allowing current to flow in one direction. As the current capacity was very low it had little practical use other than as a radio detector. Before a practical version of the mercury arc tube was made, most battery charging required large expensive rotary converters, which were essentially a motor coupled to a dynamo. The components are mounted on a slate circuit board for fireproof insulation.

VIDEO: Electric Car charger used for the Baker Electric and Detroit Electric:



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Porsche Electric Cars

Professor Ferdinand Porsche, had an early interest in electric vehicles. He was an electrical engineer at the Béla Egger Electric Co and was given the task of designing an electric car for the coachbuilder Jacob Lohner & Co. They built a few prototypes that were similar in design to other first attempts of the time, with a pair of motors using spur gears on the armature shafts to drive large ring gears fixed to the rear wheels. The Egger motors kept burning out, so Ludwig Lohner hired Porsche away from Egger, and he came up with a radically different approach using hub motors. This was not a unique idea, as an American hub motor patent was granted in 1899 to Fred J. Newman and Joseph Ledwinka. They build a four-wheel drive prototype in New Jersey.

A small number of Lohner-Porsche front-wheel drive, and one four-wheel drive version, were produced in 1900. The next few years' production included hybrid cars, some of which could reach top speeds of 35 mph. The design was sold to Austro-Daimler in 1906 and they made a number of hub motor commercial vehicles including all wheel drive busses and trucks. Also based on this design Stoll makes twenty-six electric trolley busses 1907-1909.

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The Detroit Electric Car

One of Our Nine Best Creations
For 1912

WHEN you buy a Detroit Electric you anticipate the future, because of this car's many new, exclusive and patented features.

Remember, the Detroit Electric has the *exclusive* right to use in electric pleasure cars, Thomas A. Edison's greatest invention—the Edison nickel and steel battery.

The simple operation of the Detroit Electric makes it the motor car most easily controlled for modern use. You hold up the controller only at all speeds, but in addition you can simply reverse back to the stop with your thumb.

backward pull on this lever, without even touching the foot pedal.

This controller lever practically *stops* the car. It is impossible for it to make any further movement in retrograde. It has no other operation. It is horizontal and doesn't rise or fall.

Aluminum body panels add to the strength of the body, being as strong and life of the car. They do not rust, warp or crack.

For those who do not care to make the expenditure necessary for the Edison battery at first, we furnish the Detroit Electric Company's Lead Battery with one year's warranty and full guarantee, by and guaranteed by the manufacturer for one or two months in advance.

Beautiful illustrated catalog sent upon request. It tells you about the most up-to-date, modern and largest factory in the world, devoted exclusively to the manufacture of cars.

Anderson Electric Car Co.
Detroit, U. S. A.
402 Clay Ave.

Chicago —
St. Paul
Duluth

Buffalo
Brooklyn
Cleveland

St. Louis
New York, Brooklyn and 80th Street
Chicago, 715 Michigan Avenue
(Also Branch at Evanston, Ill.)

Kansas City
Minneapolis
St. Louis

Sell your representatives in all leading cities.

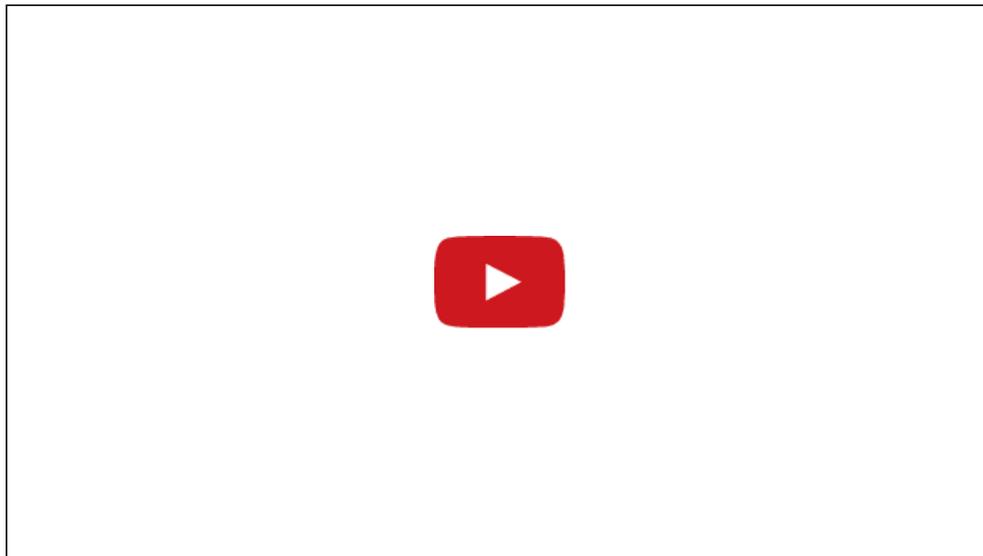
William C. Anderson establishes a Detroit carriage manufacturing company in 1895. The company is successful, but automobile

companies are starting up all around them, so when George Bacon proposed he design an electric car for the company, Anderson gave him the space and materials. At the end of 1907 three models similar to the cars he previously designed for Columbus Buggy Co. were rolling out of the factory. They were well received, and the Anderson Carriage Co became the Anderson Electric Car Co in 1911, with a new factory for chassis manufacturing, and the old factories refitted for luxury coach building with aluminum panels and castings.

The sporty Roadsters thought to be more appealing to men did not sell well and the signature model, perfected in 1912, was a roomy Brougham with curved glass at the corners that is favored by wealthy women of independent spirit (including several suffragettes) who wished to drive themselves. They are like a sitting room on wheels. Most of these cars are made to be driven from the back seat by the owner, but they also offer front-seat-drive cars meant for a chauffeur, and dual-drive cars for flexibility. A pair of horizontal tillers, one for steering and one for speed and braking, controlled them.

They make their last completely new car in 1924, but a fragment of the company remanufactured old cars, some with contemporary bodies, until 1939. Anderson/Detroit Electric make more personal electric cars than any other manufacturer in the Twentieth Century. They are popular with the wives of gasoline carmakers such as Ford, Marmon, Olds, Stutz, and the makers of Packard.

The video below shows a 1914 model 48 Duplex-Drive Detroit Electric owned by electrical pioneer [Charles Proteus Steinmetz](#). It is pulling out of the Edison Tech Center, notice the jerkiness of the controls and quiet of the motor. He was quite short and chose the Duplex-Drive model as he could see the road better from the front seat driving position.



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Hybrid Electric Cars

From the dawn of motor vehicles the hybrid concept made sense as it took advantage of the low speed torque and easy control of electric traction motors, along with the compact energy storage of petroleum. In a lightweight motorcar a clutch and several different gear ratios made a gasoline engine workable. With a heavy truck or a locomotive, clutches are a problem, they have to be large and require a lot of pressure to keep from burning out. Because of this, early trucks and busses were often electric or series hybrid vehicles.

In a pure series hybrid the engine could turn at the speed of optimum efficiency as it is directly coupled to a dynamo, which is connected through a controller to one or more drive motors. A battery is used for starting and lighting, as with most gasoline cars after 1912, or a larger battery can store energy to make the most of a smaller engine by adding power where useful.

A parallel hybrid can drive the wheels from two or more energy sources at the same time, typically through the same drive train. The goal with parallel systems is fuel economy and performance, the balance between the two depending on design priorities. In practice, the engine or a regenerative braking mode can recharge the battery for convenience and efficiency. A separate dynamo, a second field winding, or switching the motor to behave as a generator, can provide regenerative braking. Where mains power is available and cost effective, a plug-in charging option can save a lot of money. With an engine-dominated system the electric component serves the purpose of a supercharger - it gives additional peak power allowing for a smaller more efficient engine. An electric-dominated system uses the electric motor as the main drive unit; with a relatively small engine that fires up for full power, extended range, or to charge the battery.

A hundred years ago two cars are put on the market that make use of these technologies.

Woods Dual Power

Woods is one of the premier American electric car companies, along with Columbia, Baker, and Waverley; they have electric cars for sale in 1898. Other than a prototype series-hybrid truck in 1899 they are not known for innovation, being one of the last to give up solid rubber tires and chain drive. Shortly after Columbia, Electrobat, and Riker are swept up into the lead car bubble on the East Coast, a large group of wealthy investors tried the same gambit with Woods in Chicago. The car bubble burst in short order and Woods became an electric car company again, under a series of new owners.

The Woods Company's final act is a hybrid designed by Roland S. Fend in 1914-15, and manufactured from 1916 until late 1918. This is the most successful parallel-hybrid of the twentieth century, having the advantage of no significant competition. The initial version is called the model 44 Dual Power Coupé. It is a 4-Passenger car with a 14 HP 4-cylinder le Roi engine coupled through an electro-magnetic clutch to a 48 Volt 20 HP motor connected to a 24-cell battery about half the size and weight of a typical electric car battery. The car could run on both motors separately or together. When running at speed on the gasoline motor alone, the field windings were shunted and the electric motor became a dynamo, recharging the battery. There is no plug-in option but regenerative braking is employed when the brake pedal is partially depressed. The first iteration has a 110" wheelbase and is rated at 20 MPH electric only and 35 MPH on both. They claim the car can get 48 mpg, the base price is \$2,650; wire wheels add \$25, available in blue or green, custom colors add \$100. In June of 1917 an updated version is introduced called the model 54. It gets a larger body, a more powerful Continental engine, and a 124-inch wheelbase. New amenities include an adjustable rain-shield (this is before the windshield wiper), better lighting, and a rearview mirror that runs across the top of the windshield. All control is by two small levers on the steering hub and a single foot pedal. Now priced at \$2,950 with wood wheels. The January 23, 1919 issue of Motor Age lists "Woods Dual Power" as one of the companies that is "definitely and permanently out of business".

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The Owen Magnetic:



The Owen Magnetic is a gasoline car with an electric transmission. This is an enormous advantage before automatic transmissions are introduced in the late 1930s.

Justus B. Entz patented the design, and the Pope Manufacturing Co in Hartford Connecticut built a prototype in 1898 as the Columbia Mk IX. In 1907 Entz was a Vice President of the Electric Vehicle Co, which then owned Columbia, and Columbia briefly makes a production model called the Mk MXLVI, sold in 1908. EVC/Columbia is sold to new owners and stopped production of electric vehicles in 1909. Entz wants royalty payments, so he shops the patent around and in 1912 Walter Baker buys the rights. Baker and Entz both get patents for improvements over the Columbia version.

In 1914 Entz, still seeing no royalties, talked Raymond Owen into licensing the rights, and he made the cars in New York for a couple of years. In December 1915 the recently merged Baker Rauch & Lang Company buys out Owen and makes him a VP of sales. General Electric is interested in the concept and invests two million dollars in the company. GE manufactures the electrical components at their Fort Wayne Indiana factory. The cars are built in Cleveland at the Edgewater Park Baker factory, most with Rauch & Lang Bodies. Owen takes the company back in January 1919. He makes the later cars in Wilkes-Barre Pennsylvania, until bankruptcy in 1921. In 1930 three more Entz type cars are made for a wealthy disabled client by the last iteration of the Rauch & Lang Co, by this time owned by the Owen brothers. Fewer than a thousand of these cars are made over the years.

In all but the top speed position, the car functions as a series-hybrid. As it is never propelled from the small 24-volt starting/lighting

battery, or any other secondary energy source, it is not a strictly defined hybrid as all motive power is from the gasoline engine. These same components, with a larger battery, could have worked as a series-parallel-hybrid, but that would involve a lot more weight and complications for a bit of fuel economy.

Rather than using a clutch and various gear ratios, the crankshaft is bolted directly to the spinning field coil frame of a dynamo with the armature connected to the driveshaft. By switching circuit wiring the rpm of the two components could slip, or lock up: transferring 93% of the engine's power to the driveshaft. Any slippage between the field and armature causes the unit to behave as a dynamo and generate current, which is delivered to an electric motor in the same case just behind the dynamo. When the car is static, torque is delivered to the drive wheels from the electric motor. Between the first speed and the sixth the system varied energy transmission from that of a (nearly) pure series hybrid to a pure gasoline car with a magnetic clutch. The car features dynamic braking, but it dumped the current as heat and is not regenerative.

The dynamo field always spins at the speed of the engine, the armatures of the dynamo and motor always at the speed of the driveshaft. The motor field is fixed to the case shared with the dynamo. Behind the electric transmission case is a small gear cluster for reverse and a 50% reduction low gear for emergency use.

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Electric Cars at GE in the 1970's:

An article about Bob King's research at General Electric, published in the Monogram 1975



Plans for a test electric car are reviewed by VP Art Bueche (1) and the R&D Center's James M. Lafferty.

Electric cars: switching on new research

It is perfectly natural to assume General Electric's continuing fascination with electric cars. After all, founding father Thomas Edison not only drove one, but courageously ordered production of the first battery-powered vehicle back in 1889.

So one should not be surprised to learn that the R&D Center—to help meet the long-term challenges inherent in producing such vehicles economically—recently signed a \$5.98 million contract with the U.S. Department of Energy to develop and build a pair of four-passenger experimental electric automobiles over the next two years. Hopefully, such research will contribute to ideas which already have proved workable (see story at right).

The test vehicles will be subcompact-size and will be designed jointly by GE and Chrysler Corporation. A team of GE people will concentrate on various electrical and mechanical innovations plus the electrical drive system and controls. Working with the R&D Center will be the Direct Current Motor and Generator Department (DCM&G), Erie; Industrial Control

Department, Salem; Ordnance Systems Products Department, Pittsfield; and Semiconductor Products Department, Syracuse. Lead-acid batteries will be supplied by Globe-Union Inc., Milwaukee.

According to Eugene A. Rowland, Manager-Electric Vehicle Program at the R&D Center, the car will be similar to a subcompact station wagon, although the contract doesn't specify how it should look. "It will be designed along aerodynamic lines with no chrome strips or other extraneous ornaments," he explains. Chrysler will construct the body and chassis using conventional materials, but emphasizing aluminum and fiberglass for possible weight reduction. GE's Plastics Business Division will be called upon to recommend innovations in this area.

As for performance specifications, the four-passenger experimental electric has a challenging list, as ticked off by Rowland:

"The car must have a range of 75 miles, a minimum cruising speed of 55 mph, go from 0-30 mph in nine seconds, be able to climb a 5% grade at 50 mph for one mile, sell for \$5,000

in 1975 dollars, cost 15 cents per mile to run and re-charge in six hours.”

GE isn't starting from zero in its development work. The Company has been selling motors and controls for use in electric lift trucks and golf carts for several years, and even designed an experimental car called the "Delta" in 1967 and the "Q-T Van" (for quiet truck) in 1970-72. An experimental electric car called the "Lead Wedge" set a speed record in 1968 of 138.86 mph using a special motor purchased from GE that was built from the parts of a torpedo motor.

"Our car will include a DC motor from DCM&G that will be a modified, low-weight, 20-horsepower type," says Rowland. "The flow of battery current will be regulated by a new, lighter, more efficient solid-state controller using power transistors from GE-Auburn, and an on-board battery charger will be integrated with the drive system electronics. The R&D Center is designing all of the electronic systems for the car, and these will be packaged with the help of Ordnance in Pittsfield."

A new wrinkle being introduced in this model is the use of a microprocessor in a "regenerative braking" system. The technique allows the car's motor to become a generator during braking to recharge its batteries and thus recover some energy. The net result, according to Rowland, is to extend the range of the vehicle.

Those who struggle to make the electric car a reality agree that the biggest challenge is improving batteries. "Presently, the only reasonably-priced battery is the lead-acid type, but it's limited in energy density, is heavy and limited



Left: Erie electric vehicle motor is checked by DCM&G's Mendel W. Kitzmiller and Frank T. DeWolf. Right: Salem's Charles E. "Bud" Konrad holds an electric car control.



to short-cycle urban driving," Rowland says. "In fact, the main weight of our car will come from 18 six-volt batteries weighing 1100 pounds." While GE currently sells rechargeable nickel-cadmium batteries for use in cordless tools or calculators, none is designed for use in electric cars. Research at the R&D Center on sodium-sulfur batteries is designed to meet utility load leveling demands at the substation.

Another challenge is improving the motors to be used in electric cars. Mendel Kitzmiller, Manager of the Small Motor Product Engineering sub-section of DCM&G, emphasizes the need to boost their efficiency. "We know how to do this, but it's costly," he points out. "Designers have to consider the type of driving that will be done—start-stop frequency, city vs. suburban trips—to predict what the motor will be called upon to do and what will improve the overall efficiency." AS

Bob's battery-powered auto



Syracuse's Robert D. King, an advanced development engineer at Heavy Military Equipment Department, built his own electric car on a 1969 Volkswagen chassis with a Bradley GT fiberglass body. The car averages three-fourths of a mile on a penny's worth of electricity. Notes Bob: "Translated into the cost efficiency of gasoline, that's like getting 45 miles per gallon. The car cruises at 45-50 mph with a range of 50 miles between charges. With dwindling gas supplies, I think electric cars will eventually become an around-town family vehicle."

The Failure of Electric Cars in the 1970s and 1980s:

In the early 20th century cities were dense, built around trolley lines or walking distance to work places and downtown. The early electric cars functioned well for these short distances. By the late 20th century cities had exploded in size with 30+ mile commutes being commonplace, especially in North America. This energy intensive lifestyle proved very difficult for making electric cars feasible on a mass scale.

Electric motors are very efficient, they have been more efficient than gasoline motors since the 1890s, however batteries proved to

be a limiting factor. Until higher energy density batteries were developed in the 1990s, cars had to use [NiCad or other types of batteries](#). These batteries had a bad weight to energy ratio. The large weight and cost of batteries made electric cars impractical for the majority of North American users.

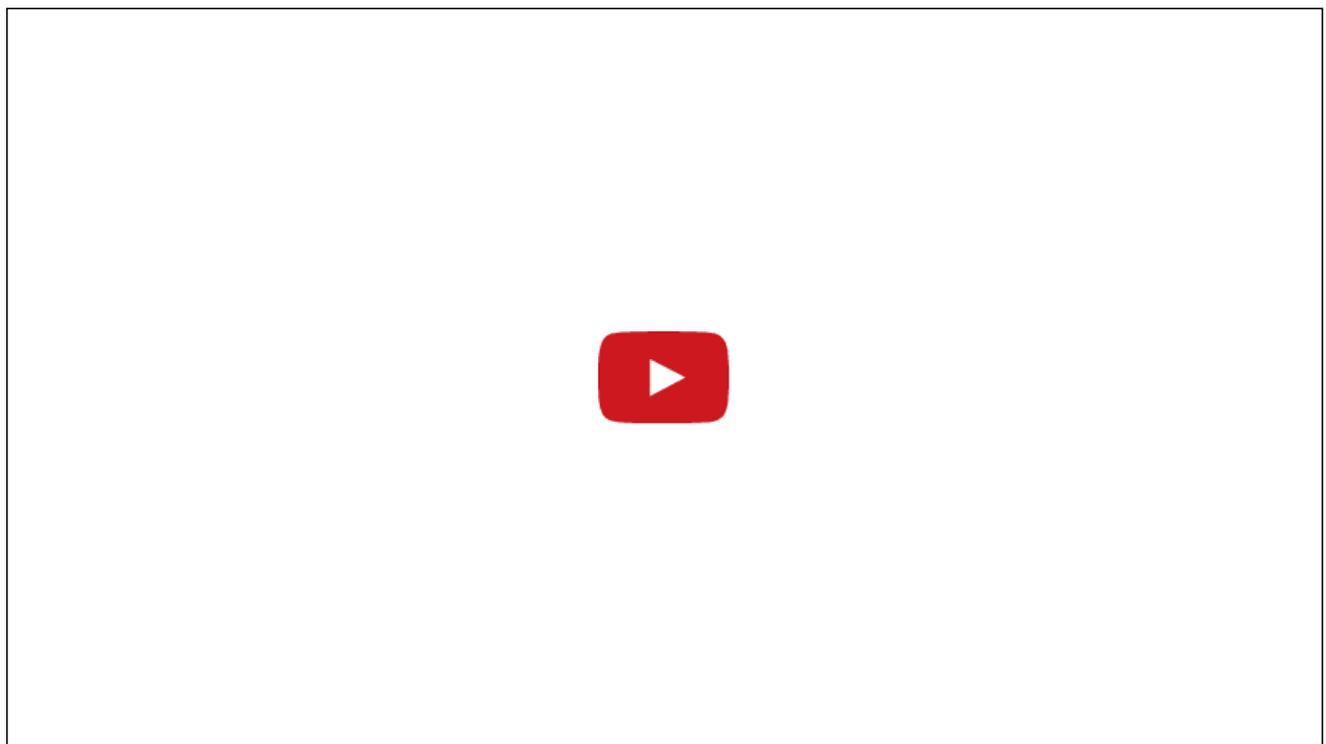
There was not necessarily a conspiracy stopping the electric car, if you speak to people who worked on them in the 70s it is apparent that technological limitations were behind the failure of electric cars in a commercial sense. If one looks deeper it is the reckless sprawl period of US urban development (1950 - 2000) that really killed the electric car. In the 2000s development trends have shifted more towards high density as the younger populations have a cultural difference from the boomer generations.

The First 'Modern' Hybrid Electric Car:

Dr. Andrew Burke developed the first computer controlled hybrid-electric vehicle in 1982 as part of the "Joint Feasibility Study of the Hybrid Vehicle" funded by the US government and GE. When GE couldn't sell the car to the big 3 US automakers, they sold the technology. Toyota later makes it into a profitable technology.

The 1982 vehicle used a computer to control the engine and power system, this enabled great cost savings. Also the braking system helped recharge the batteries. This was all possible due to the computer finally becoming compact enough and powerful enough to work in a vehicle.

VIDEO: The first computerized hybrid car 1982:



If video fails to load correctly [go here](#)

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The Toyota Prius

Toyota acquired patents for the modern hybrid electric car in the 1980s after General Electric failed to find adequate interest in the American car market. Toyota built upon the design and develop the Toyota Prius which became the first profitable hybrid car in history. The car allowed for modern users to drive long distances using gasoline while using electric around town. This was necessary since urban design changed greatly from the early part of the century.

Tesla Motor Company: Tesla Roadster and Model S

[Tesla Motor Company](#) emerged in the late 2000s with high performance and high cost electric cars. The Roadster was based on the Lotus with an attractive sporty design. It was not cost effective however but Tesla Motors achieved success with the Model S. The Model S appealed to the masses with its standard 4 door sedan design and ease of use. The Model S is so far the best performing electric car ever, and it out performs internal combustion engines in the same class. The single gear high torque Tesla beat out powerful Mercedes and BMWs in acceleration and stability.

Below we talk about the 3 phase, 4 pole electric motor and drive train in the Tesla Model S:



In the next half we discuss batteries, range, charging rate, body construction and components of the Tesla Motors Model S:



The New Rise of Electric Vehicles:

History repeats itself, and once again we see the rise of electric vehicles in the mainstream market. The Nissan Leaf, Honda Insight, and Chevy Volt are all targeted at middle class markets and have proven to be successful. With fuel prices rising many customers are seeing clear cost savings.

Some of the downsides of electric vehicles are the high cost of replacement batteries and what to do with the highly

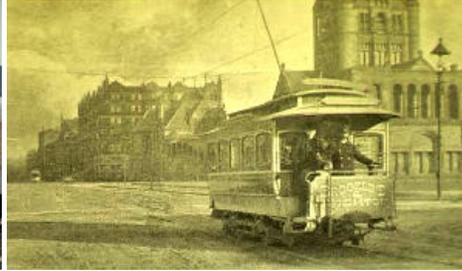
toxic waste. The long term solution to this is providing power to the EV by way of the grid. Providing grid power to vehicles would be by far the most energy efficient method. As is proven by existing overhead tram / bus lines in Europe, the cost of operating and energy consumption is worth it. Google's projects with self-driving cars may help the development of grid powered personal vehicles. By allowing cars to be controlled and spaced on a road evenly, it would make it possible highways that act like train lines between cities. Cars could connect to a "third rail" and travel most of the miles without using batteries or fuel. Batteries are getting smaller with time, and super/ultracapacitors may become an alternative to batteries all together. Andy Burke, one of the inventors of the modern hybrid car is testing ultra capacitors from many manufacturers, [see more about it here](#).

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Galen Handy grew up with electric cars and is an expert in the field of historical American electric cars.

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