National College of Art & Design
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The History and Future Prospects of the Electric Car

by

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Introduction

The thesis aims to look at the origins of the electric powered car in the 1880s in France and chart its early success and the reasons it was not further developed in the first decade of this century. The revival of interest in the possibilities of the electric battery as a power source for the car came as a result of pollution and economic factors in the 1960s and 1970s. The results of continuing research into batteries during this period did not provide a solution that could offer motorists the cheap price and high performance they expected. The features and capabilities of the concept cars of this period are examined and the reasons for their lack of success outlined. Pollution controls initiated in the 1960s and regularly updated has brought about the current situation where petrol cars are finding it increasingly difficult to meet the emission standards. Public attitudes to environmental protection have brought the possibilities and merits of the electric powered car back into public debate. Some of the most advanced electric car designs of the 1990s are examined and improvements in their designs are considered and compared to their predecessors. Their performance is also evaluated with respect to the changes in the requirements of the modern motorist and city living. Environmental legislation and protection issues which are largely responsible for bringing the renewed interest in the electric cars are studied. Finally interviews with leaders in the automotive industry and environmental protection organisations give some indication of what the current attitudes are to electric cars. The insight that these interviews give also enables some conclusions to be drawn as to the possible role of the electric car in the coming century.

The first cars were little more than motorised carriages and buggies modelled on the existing horse-drawn traps. Late 19th Century attempts at car design produced several methods of powering these carriages to speeds of little more than 10 mph. The electrically powered car was one of the most successful car designs that vied with the petrol and steam cars for dominance in the market. The final decade of the last century saw an electric powered car achieve its peak performance when it held the world land-speed for three years. None

of the electric cars at the start of this century were capable of comparable speed to their petrol competitors. The batteries that had pushed the cars to record breaking speeds refused to offer significant improvements to enable electric engines to compete with the petroleum internal combustion engines. As a result, the development of the electrically powered car declined and all research and development had ended by 1910.

It was the increasing awareness of smog pollution problems in the early 1960s in America that generated interest again in alternative fuels and modes of transport. There were several studies and reports commissioned in the United States of America and in Europe on the subject of alternative fuels and power sources. The primary aim was to change the fuels and methods for generation of electricity. The car being the second largest consumer of petroleum products was also targeted as a possible area in which reductions could be made. In the case of the car the main aims were to find fuels and power sources that would have reduced emission characteristics. It was the fuel crisis caused by an embargo by the oil producing nations in 1974-1975 that highlighted to the western world its dependency on oil and the ease of which this could be exploited. The opportunity arose to revive the electric battery as one of the solutions to demands for cars that emitted less pollutants and that could be less susceptible to fluctuations in the petroleum market. In the United States, car manufacturers such as GM and Ford along with battery companies ESB and Vanguard amongst others produced prototype electric cars. Some small car manufacturers went to small scale production on an order basis but without lasting success. The average American driver was unwilling to tolerate the discomfort, high price and poor performance of the electric cars which rendered them useless for any purpose other than short city trips.

The current interest in environmental preservation by the public has been the product of increasing awareness of the state of deterioration of our environment. This is possibly due to the studies by scientists which reveal that there is serious degeneration and depletion of essentials such as fuel resources, forests, rivers and the

very air we breathe. The scientific researchers, although conflicting over levels of deterioration, are of one voice in agreement that Global Change is occuring. Mounting evidence has shown that what were considered to be 'natural catastrophes' such as floods, droughts and famines were, in part, caused by the actions of man.

This realisation that we can, through our actions and purchases, indirectly affect the lives of thousands of others has caused many people to exercise their power as consumers and demand that changes be made to certain products. The introduction of CFC-free aerosols was directly due to the consumers demands after extensive campaigns by certain scientific and environmental lobbies. The car is also a topical source of pollution both during its life in service and when it needs to be disposed of.

Since the mid 1980s several of the bigger car manufacturers have presented a range of fuel efficient, alternative fuel and modified construction concept cars at Motor Shows such as Geneva and Tokyo. It is only in the last three years however that they have actually unveiled concept electric cars to the public.

Many of the features that these concept electric cars offer are not presently available but are based on technology still under development. Depending on public reaction at the car shows and in tests they may be put into production in the future. With the latest in super composite materials making up the body and chassis, the most advanced electronics in the car, engine and aerodynamic shape the cars are capable of giving impressive performance figures. Most of the electric cars that have been displayed would be prohibitively expensive to manufacture due to the level of innovation and technology. Instead the latest technology is replaced by more proven and cheaper processes and parts from existing petrol models to enable the easy introduction of electric cars. In the field of electric cars the major obstacle to the success of electric power has been the battery. This problem is most evident in the fact that since the first electric powered cars in the late 19th century the source of the power has remained almost completely unchanged. Lead-acid batteries are used to power the latest General

Motors concept car as they were in two person electric vehicles back in 1890s. In all that time there has been an increase in driving range of only 80 miles, from 40 to 120 on a full charge. This minimal increase however is not directly comparable as the levels of comfort, appearance and safety standards are hugely improved over the cars of a century ago.

With such poor performance it is not surprising that the electric car does not appeal as a consumer product. There is a strong demand for a pollution free car as witnessed by the numbers of vehicle emission regulations being enforced in Europe and the United States of America at the request of the public. Conversely, the consumer is not willing to make the substantial sacrifices in performance and increases in cost that present electric cars entail. The luxury, performance (in terms of speed and acceleration) and freedom of range that petrol and diesel cars can offer cannot be matched by electric cars.

The solution to the performance and popularity of the electric car does not lie solely in the improvement of the limitations of speed, range and high price. Many questions also exist as regards the the myth of reducing pollution by going electric. This argument is countered by the fact that the pollution created currently by ordinary cars is only being transferred and centralised in power stations without being tackled in real terms. It has also been shown that the energy efficiency of burning petrol in the car is better than burning it in a power station for conversion to electricity. The economics of running an electric car such as the high cost of batteries: as much as 20% of the overall price which must be replaced approximately every 40,000 miles. Although the maintenance of electric cars has shown to be lower than the initial purchase price of a car would be up to 40% more than current petrol models (21, pp. 85).

In 1991 the electric vehicle has shown itself to be viable but only for short distance fleet cars operating from a home base. The ideal examples of this already exist in the form of commercial vehicles such as electric milk vans, golf carts, fork lifts and city corporation vehicles all of which are recharged on night-rate electricity. These vehicles

have been around for many years and benefit from the strong points of the electric powered engine. Unlike cars the speed required by these vehicles is quite low, the operating range is small and they can recharge at a time when they would not be in use anyway. In the case of vehicles operating in enclosed spaces such as railway stations and airports where emissions would be hazardous to the public the electric battery is an ideal solution. The practicality of the battery for this purpose is witnessed by the large numbers of electric powered vehicles both in this country and in the United Kingdom. The number of electric vehicles in the United Kingdom was put at 50,000 in 1977 (2, p. 60) and is currently estimated to be in the region of a quarter of a million. When compared to the 17 million cars alone not counting the other vehicles the previous figure seems less significant. Advances in battery technology and research in the 1970s and 1980s, although not providing adequate for cars, have increased the capabilities and widened the possible applications of battery power for other vehicles.

As for the private electric car for personal use, the days when our roads will teem with quiet, non-emitting cars seem to be still quite a distance off. Due to the laws and directives already in existence and those due to be passed there will be without a doubt electric cars in small numbers visible on our roads within the next ten years. It is unlikely however that they will be any cheaper than petrol or diesel powered cars as governments have expressed an unwillingness to subsidise the costs and it is likely that they will cost 30-40% more. They will most likely be the reserve of the environmentally conscious rich until some major changes occur. The price must come down, the networks must exist to support the cars, the performance must improve and the electricity generation must be shown to be much less environmentally damaging than that of current cars. The big car companies of Europe and America are somewhat sceptical of the short term prospects for electric powered cars. Most are in agreement that it will not be until the middle of the next century that any form of power other than petroleum whether alternative fuels or electricity will be advanced enough to become dominant.

Chapter I

The Beginnings of Electric Car Design

The most crucial thirty years of car development began in earnest in 1880. This chapter focuses on these early years as the electric car emerged as one of the leading contenders in the race to become the dominant form of road transport. From this period of dominance at the turn of the century, its rapid demise by the end of the first decade will be examined.

The history of the electric powered car is closely linked to that of the petrol engine and the beginnings of the car itself. Electric trams were no strange sight in the major cities of Europe from the 1860s onwards running on rails through the main thoroughfares. The development of the first independent locomotives (non-rail) began in the late 1870s and early 1880s with a variety of different principles of locomotion tried and tested for viability. Amongst others the petrol engine and electric powered engine were the first to show good promise. In 1888, Daimler and Maybach, later to become the one of the prestigious German marques, displayed their modified petrol engine car capable of 10 kph (1, p. 38). Coincidentally, in 1888 in England one of the first recorded electric powered carts in use was a D.I.Y. model produced by Magnus Volk, managing director of the Brighton Electric Railway. He used six lead-acid storage batteries to power a Dog-Cart with a $^1/_2$ horsepower engine, no record is available of the top speed of the cart.

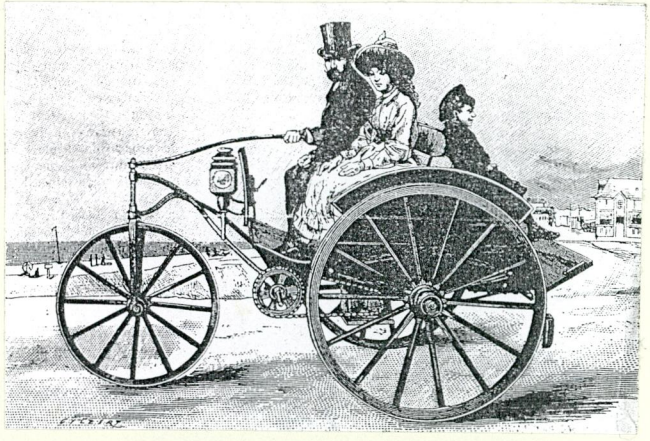


Plate 1. Magnus Volk's Electric Dog-Cart, Brighton, 1888.

The development of the electric car however was mainly due to the work of two Frenchmen, Jeantaud and Jenatzy. Jeantaud was a carriage builder and a man of considerable talents. His areas of interest were as diverse as the electric motor and basic studies on geometry (which are still accepted by engineers today). He produced his first model in 1881 and later did further research into batteries producing gradually faster and more reliable models.

The 1890s were the peak period of development for the electric cars. In Europe the more important electric car manufacturers were Dore, Bouquet, Garon, Milde, Richard and Homard, all Frenchmen. In America the first car dates from 1891 but it was the Chicago World Exhibition of 1893 which gave a boost to the industry by offering prizes for practical land vehicles with non-animal propulsion (1, p. 47). Surprisingly electric and steam powered cars made up over 50% of the 4,192 cars produced in the United States of America in 1900 out of a world total of approximately 9,000 (14, p. 897). By 1902 the petrol cars had reversed the tables and were well in the majority as Henry Ford and Oldsmobile amongst others began large scale production of their petrol powered cars.

The electric DC engine and the lead-acid battery had been in existence for many years and it was the intelligent use of the existing electric technology that permitted some of the cars to record better performances than their petrol counterparts. The electric engine achieved its final sensational feat when the electric car set and held the land speed record from when it was first recorded in 1898 up to 1902 when petrol took over. It was the rivalry of the two Frenchmen that kept the electric car to the fore. The initial record was set by Comte Gaston de Chasseloup-Labat in a Jeantaud car in 1898. He achieved the speed of 39 mph but almost immediately Jenatzy, in his own design, achieved 41 mph. The following year the record changed hands four times with Jenatzy eventually winning with the outstanding speed of 66 mph in the 'Jamais Contente', the first car to exceed 100 kph.

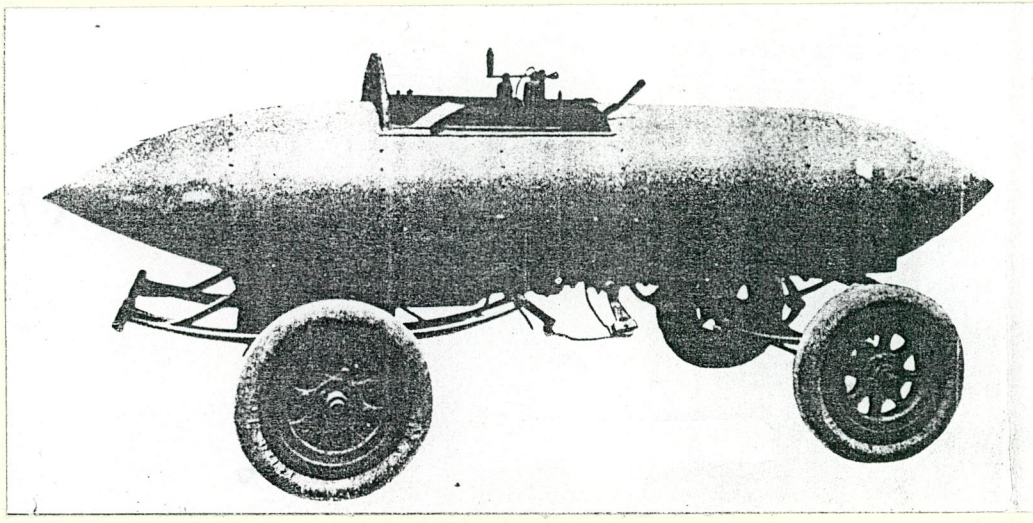


Plate 2. Jenatzy's 'Jamais Contente'.

In England however the law did not promote the development of 'locomotives' for the roads. The Red Flag Act forced anyone driving a horseless vehicle to be preceded by someone, on foot, waving a red flag. The maximum speed limit of 3 mph was excessively slow and did not encourage the development of cars as it gave the horse an advantage of speed. Repeal of the Act in 1896 and an increase in the limit to 12 mph finally saw the dawn of the 'horseless carriage' get underway. It was not until 1901 that the numbers of horses in Britain began to decline from a maximum of one for every ten of population this was a sure sign that the car had finally arrived to stay. The cars at the turn of the century were still built as the traditional carriages had been. Coachbuilders put their own bodywork on the chassis and engine of other manufacturers. This De Dion engined car (see over) from 1901 displays most of the hallmarks of the modern car, pneumatic tyres, headlamps, radiator grille and seating for four, if a little uncomfortable. The petrol engined cars enjoyed a huge level of success as the royalty and nobility were quick to develop a taste for the motor car. The electric engined car faded into the background in the face of rapid improvements in the internal combustion process. There were a number of manufacturers producing electric cars and carts at the turn of the century mainly in France where interest and commitment to electric power was strongest.

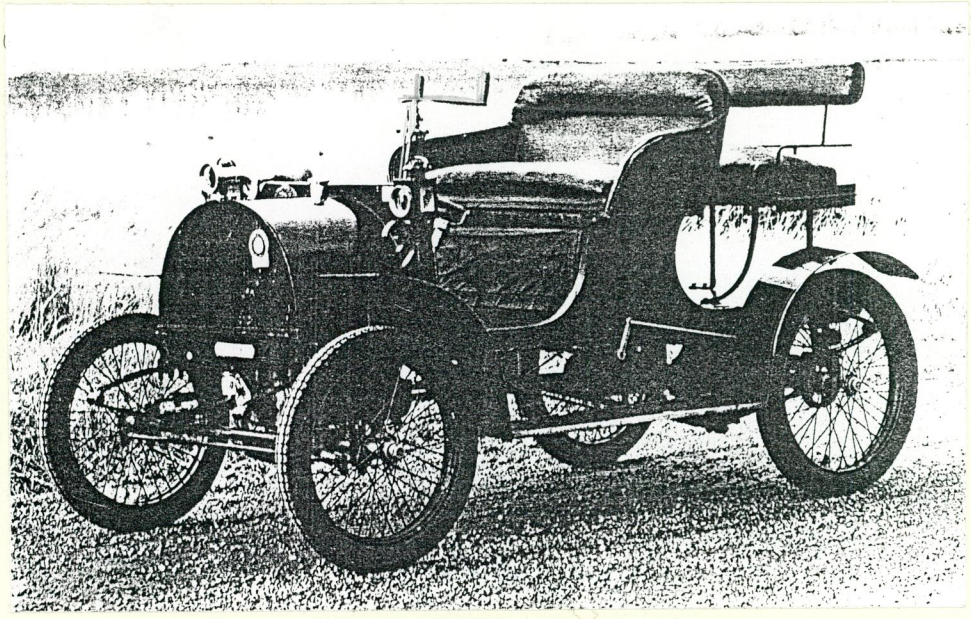


Plate 3. De Dion Engined, Petrol Car, 1901.

At the end of the last century there were several light vehicles in use in London which were battery powered mostly for the purposes of small goods transport and even a small number were used as taxis. The 'Bersey Electric Cab' operated on the streets of London for several years from 1897 until 1902 when use of the cab seems to have stopped.

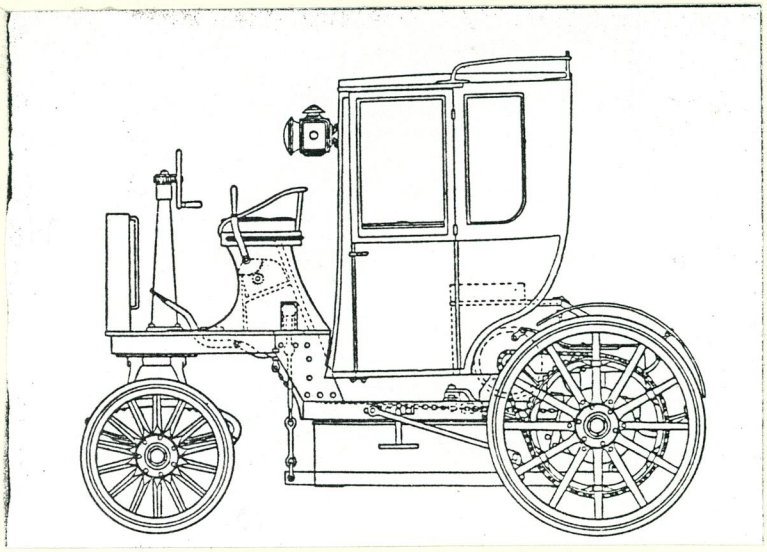


Plate 4. Bersey Electric Cab.

The failure of the cab appears to have been due to its increasing slowness and long recharge time in comparison with the competition of the newer and more economical petrol cars. The speed limit in England for public highways was further raised to 20 mph in 1903 which finally saw off the challenge of the existing electric cars and gave way to the dominance of the petrol engine.

The limited level of battery performance was the major cause for the failure of the electric car to keep pace with the developments of the petrol cars. Although capable of delivering high speeds the lead-acid battery could not sustain the effort for distances greater than a few kilometres. With the added load of passengers or cargo the speeds had to be curtailed to achieve adequate range from the battery. It was hoped that if the battery could be made with greater power output and storage capacity it could regain its place in the car race.

Thomas A. Edison had been promising that he was on the verge of developing an improved storage battery that 'would make the electric car more practical than the gasoline automobile' (14, p. 856) and turned his hand to the development of an improved battery. His solution the nickel-iron battery although offering better power output had a much shorter life and was far more expensive to produce. Edison, although taken seriously at first, was being ridiculed for his rash promises and failure to produce any viable proposals by 1908. An auto periodical Motor Age commented ' Mr. Edison's bunk has come to be somewhat of a joke -- a real joke' (14, p. 856).

Time has revealed that Mr. Edison did not succeed in his efforts to make electric more practical than gasoline and by 1910 the electric car was all but extinct in the marketplace. His success in battery design was extensive however as his nickel-iron battery was used widely in ships, railway carriages and industrial tractors.

The operating parameters of cars had proven to be very restrictive and demanding for the battery to compete with petrol. The quantity and size of lead-acid cells required to power a two person cab at walking pace was far too great when compared to the compactness of

the internal combustion engine. Petrol as a source of fuel was easier to transport and store than large quantities of lead-acid cells. As electrification standards necessary to support electric cars were far from national in most countries the ease of availability of petrol far outweighed any advantages that the electric car possessed. The steam powered engine had also been used as a petrol alternative but the sheer size and the inherent danger with high pressure cylinders meant that the steam engine only worked for large 'horseless carriages' and soon was only in use in ships and trains. Without any real alternative the petrol engine became the sole mode of powering the car.

After 1910 and particularly from 1920 to 1950 there is little or no reference to the electric car as a commercial proposition. The lead-acid battery problem of power to weight ratio (the power output of the battery with respect to unit weight) was scarcely improved. There is reference to the testing of alternative materials like iron, zinc, sodium for use in batteries but other factors such as the high cost and short lifespan negated any major improvements in power output. The electric battery itself far from disappeared from use. It found use in the engine of petrol cars for igniting the fuel-air mixture in the numerous cylinders. In industry it acted as the only form of portable power storage for use in small motors and lights.

The existing and proven electrical technologies enabled the electric car to shine in the early days of the development of the motor car. Within the space of twenty years from 1880 to 1900, the electric car had appeared, developed and achieved its maximum performance. The development of the petrol powered engine was much slower due to the new technologies but the merits and performances of petroleum were to bring it to the fore and keep it there.

Chapter II

The 1960s Revival in America

This chapter outlines the re-emergence of the electric powered car in the 1960s as a considered alternative fuel source to petrol cars, particularly in America. The reason for the return of electrical power was as a result of a change in attitudes as the effects of the rapidly increasing numbers of petrol cars became evident. The first real smog and pollution problems, increases in consumption of petroleum from other countries and road congestion gave cause for the re-evaluation of the role of the petrol car. Electric power for cars was part of the solution suggested by many research reports and the major recommendations of these reports were acted on by several car manufacturers. Some of the more significant concept models of this period are highlighted to illustrate the capabilities of the cars of this period.

Energy consumption and production in the United States began to increase rapidly in the early 1950s. The car companies were fast to capitalise on the consumer boom. Cars of the 1950s were big, chrome covered, thirsty and fastand were considered a statement of fashion as well as affluence. By the early 1960s cars had become bigger still, they gained bigger engines, bigger wheelbases and even more luxurious interiors with every possible add-on feature available. The Ford 'Thunderbird' is a classic example of a car of this type.

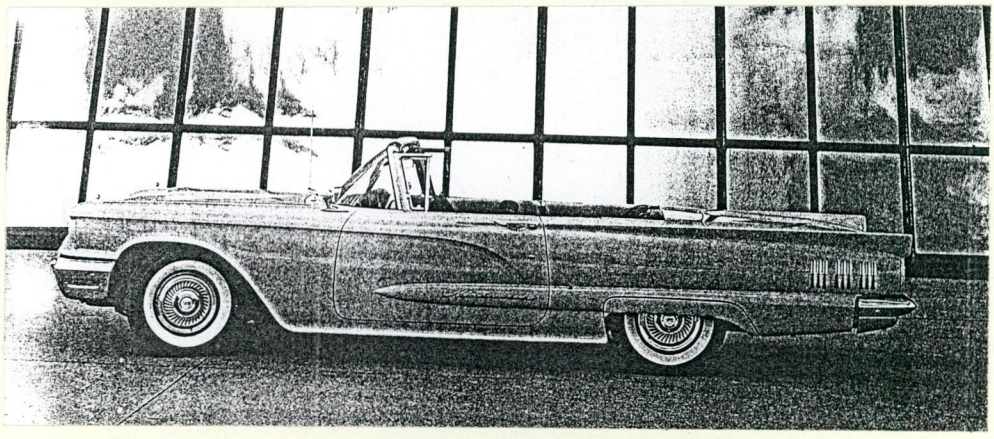


Plate 5. Ford 'Thunderbird', 1960.

Amidst all this expanding consumerism it became evident that the bigger cars created even more air pollution. The cities of Los Angeles and New York which often had fog problems in the late winter and early spring months found their problems increased with the amounts of smoke emissions from industry and cars. Smog, as this condition is commonly known, was recognised as being a health hazard to the population.

The early 1970s also saw the fuel embargo by some of the oil producing nations. The effects of this were to highlight to the government and public that the consumption of petroleum products made them over reliant on supplies from other countries. The international events aroused the Americans sense of independence and this was reflected in the urge to be as invulnerable as possible to international pressures. Several reports were commissioned on the use of alternative fuels that could be produced in the United States of America and research was intensified into the development of batteries for use in cars and other vehicles. Car manufacturers were encouraged to perform some of this research and to produce cars which could be put into production.

Models relying on petroleum substitutes such as methane, ethanol and hydrogen had varying levels of success with ethanol being the most viable solution. Since these gasses are also less polluting when compared to petrol they also satisfied the need for cleaner motoring. Brazil introduced ethanol as an alternative fuel to cut its petroleum dependence and at one point in the late 1970s was in use in 90% of cars in the country. The high cost of refinement and large tracts of land needed for cereal growing to create the ethanol were prohibitive and usage of ethanol has now dropped to less than 40% (19, p. 18).

The clean image of the electric car which was quiet, emission free and, if the electricity was generated in nuclear power stations, petroleum free seemed to offer an ideal solution. By the late 1960s both Ford and GM two of the big American car companies had produced working prototype electric cars.

In 1967 Ford presented the 'Comuta', a boxy two seater electric car, which was capable of a mere 41 km on a full charge travelling at a constant 50 kph and 38 km for ordinary urban driving. This performance was adequate for short urban trips but was definitely only just roadworthy as regards speed and could not be used on the highways. The 'Comuta' sat two people in sparse comfort with just enough room for luggage or shopping. Not to be outdone GM introduced the '512' a year later. This inauspiciously named car was capable of vastly improved performance relative to Ford's offering. The '512' claimed 91 km at 50 kph and 60 km for ordinary urban driving. The passenger space in the '512' was much smaller and luggage room was almost non existant as GM had increased the quantity of batteries to improve performance.

In 1970 an American battery manufacturer, ESB, produced a promotional concept car to illustrate the ultimate capabilities of the battery powered car. The 'Sundancer' had exceptional performance when compared to the Ford and GM models, a maximum range of 173 km and 105 km in the city with speeds capable of coping with highway travel.

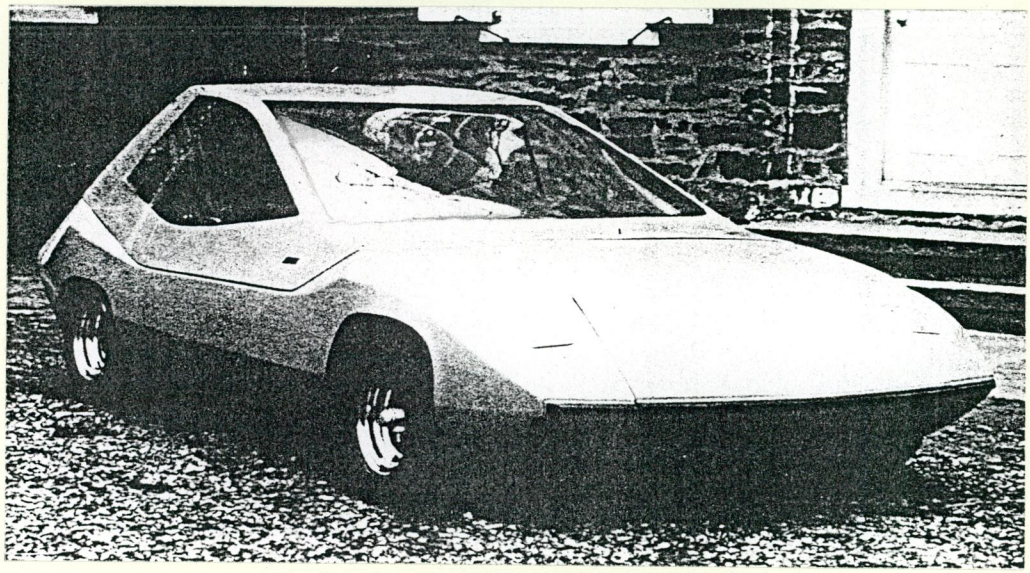
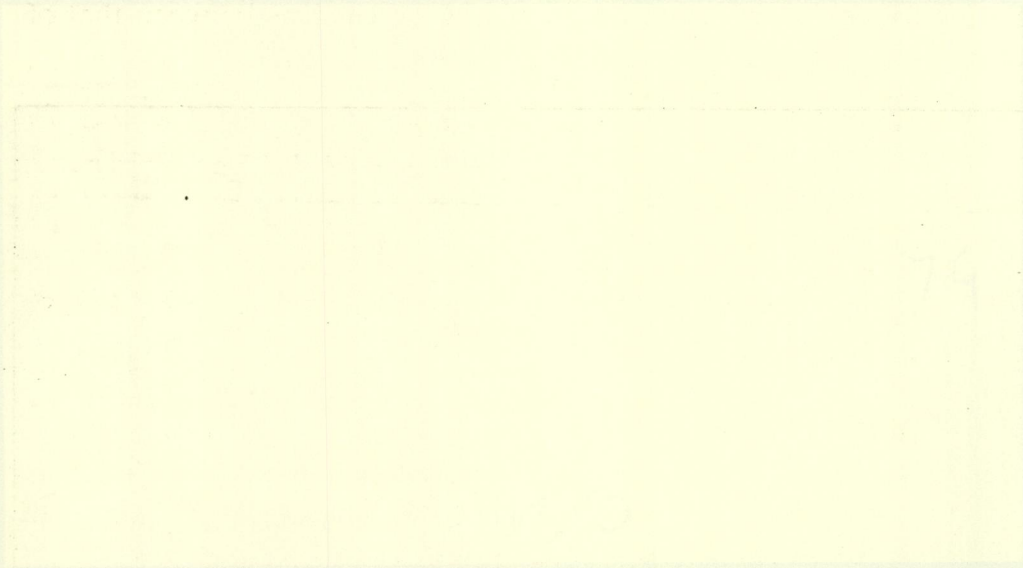


Plate 6. ESB 'Sundancer'.



The drawbacks though were also obvious, almost half the car's weight consisted of batteries and access and driving were described as 'uncomfortable' by many of the journalists from auto magazines who had the opportunity to test drive the car (8, p. 15).

For both of the big car makers the electric car was never a proposition for production. The practicalities of producing such an alternative shape and structured car would have meant phenomenal costs to the companies who did not see a large market for electric cars. What the cars did serve to do was to demonstrate that Ford and GM were actively working on more emission free concepts and this in turn acted as good publicity. Far from stopping research into electric power both Ford and GM regularly released papers on the running test results for electric cars and engines during the 1970s and 1980s. The sizes of these corporations enabled them to carry out extensive concept and research programmes while continuing with ordinary development of the petrol cars.

The only electric car to see any level of production in the early 1970s was the Vanguard 'Citicar'. This model was produced shortly after the oil embargo and shortages in 1973-74. The performance in relation to maximum speed and range of the car was between that of the Ford and GM concepts of the late 1960s.

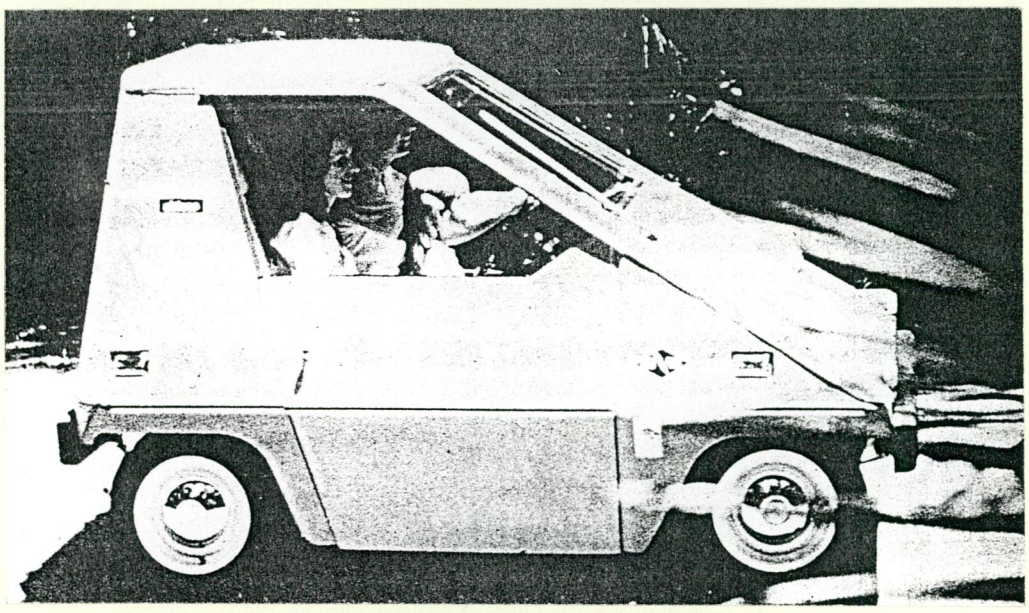


Plate 7. Sebrig-Vanguard 'Citicar'.

The car was constructed using aluminium tubing and ABS plastic panelling with the batteries located under the driver and passenger seats. Though the car was incapable of freeway or highway use its owners generally liked it. It was slated by Consumers Union of the United States of America as 'not acceptable' for lack of capability, comfort, convenience and safety as the brakes had failed in tests which seemed due to inadequate design (8, p. 10).

The 'Citicar' did not last as its manufacturer, Vanguard, did not find it economical to continue production, approximately 2,000 were produced in several model variations. Demand for the car was not high and there was no governmental price subsidisation or incentives to purchase the car.

It was the introduction of emission regulations that had been one of the major reasons for the research into alternative fuels. In 1964 the State of California introduced the first emission standards for cars which controlled the emissions of carbon monoxide and hydrocarbons. A similar law was passed in 1968 by the American Congress and by the EEC in 1970. The European emission standards were set out in UN/ECE Regulation No. 15 and EEC Directive No. 70/220 and enforced on all new cars from October 1971. The following years saw the tightening of emission levels and the inclusion of oxides of nitrogen in 1974 (EEC Directive No. 74/229) as regulated gasses (6, p. 1). Europe was around ten years behind America in its development of emission standards. The effects of tighter legislation was evident first in America in the late 1960s shortly after the levels were first set out. The surprising result was that the emission levels were well within the reach of the car manufacturers and the need for alternative fuel cars, over the following decade, never arose. The performance of the best electric cars was only just adequate and since the petrol cars could satisfy the slowly rising standards there was no incentive to trade down.

The late 1970s produced no major new concepts in the field of electrically powered cars either in Europe or America. Smaller projects such as the 'C5 personal transport vehicle' by the entrepreneur

designer Clive Sinclair in 1979 had a small level of success. He sold just over 1,000 models before production stopped. His one seater vehicle was aimed at the young and old for easy city commuting. The 'C5' was as big a failure as the 'Spectrum' mini computer was a great achievement for Sinclair. A Danish equivalent the 'Mini-El' had had a much higher level of success, this was possibly due to the environmentally conscious nature of the Danes. They have sold over 5,000 models since the early 1980s and are stepping up production to meet the increased demand in the last few years.

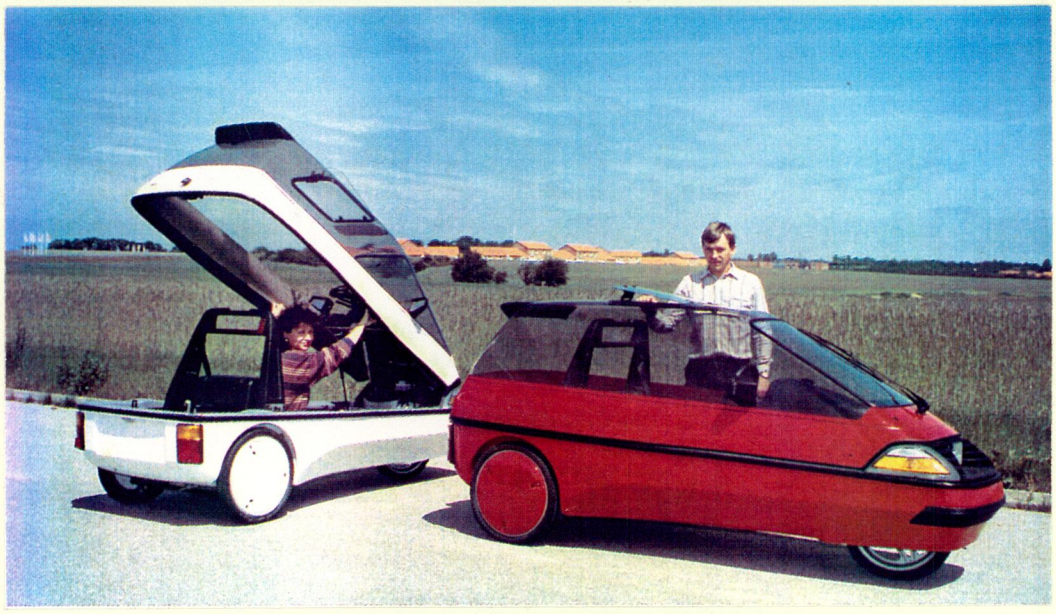


Plate 8. Danish 'Mini-El'.

The lack of success of the electric cars in the 1960s and 1970s was as much to do with the lack of genuine public interest in fuel economy and efficiency as it was with the poor performance of the cars themselves. Despite the threatened fuel shortages and the forecasts of world resources of petroleum by the year 2000 the public did not respond to the offer of electric cars. The laws restricting emissions were within the capable reach of petrol engines and so there was not a strong push towards the introduction of alternative fuels and definitely not the electric car. As at the turn of the century a report from 1975 stated:

> After enough batteries are loaded on a vehicle to provide acceptable speed and range, little power is available to move a payload of either packages or people (2, p. 60).

The batteries that had held the electric car back in the first decade of this century were still the major stumbling block for the cars of the 1970s.

Chapter III

Electric Car Design in the 1990s

This chapter looks at the current situation in the development of electric cars. The environmental and social background, which lead to the resurgence of interest, is reviewed. Several concept cars from the last two years are outlined to give an idea of the current state of performance and technology when compared to the cars of the 1970s and earlier.

Despite the shortcomings of the batteries and cars of the 1970s, research and development continued steadily into the 1980s. In both America and Europe governments allocated increasing amounts of money to alternative fuel research including battery improvement. It was clear that in the longer term the car could not hope to keep pace with tightening emission regulations. It was therefore essential to develop alternatives that could be phased into use in the longer term. Regulations have tightened further in the last six years than at any time before as environmental lobbies push for reduced emissions from industrial and motoring sources. Nowhere is legislation as restrictive as in California in the United States of America, this state has lead the field in the introduction of air pollution control legislation. This fact is not surprising as it also has the highest number of cars per head of population. The astounding figure of 610 cars per 1000 of population when compared with 533 in the United States in general and 240 in Ireland (18, p. 8). With such a high density of cars it is clearly the Californians who notice the problems and have acted first in legislation. Emission legislation introduced in California tends to be adopted by the American Congress and Europe within the space of a few years.

The CAFE (corporate average fuel economy) regulations imposed in the United States in 1975 control the average fuel economy of the complete range of cars produced by a car manufacturer. (The Energy Policy and Conservation Act, Public Law 94 - 163, 94th Congress

of the United States of America, Dec. 22, 1975). At present the limit stands at an average of 27.5 mpg. For this year 1992 several manufacturers (Saab, BMW, Porsche, Mercedes, Volvo) may not be able to meet slightly raised levels of 28.5 mpg and may be unable to sell company cars in the United States of America. Other companies such as Ford, Mazda, Honda and others have no major problems in meeting regulations as the fuel economy of their smaller cars brings up the average to over 30 mpg in many cases. Small cars are not the answer however as the American tastes at present still favour the big cars of Ford, GM and prestigious European marques. The greatest concern for the car manufacturers is the proposed further increases to 40- 50 mpg by 2000 and 75 mpg by 2025.

It is clear that the only way for many of these manufacturers to meet the regulations will be to include at least one electric car or low fuel consumption car to bring their fleet average down. Within the last three years there has been a visible flurry of activity and increased interest in electric cars as possible future models.

In Europe, the following car companies have already displayed concept working electric car prototypes Opel, BMW, Fiat, Peugeot, Citroën, VW and Mercedes. Some such as the Peugeot, VW and Opel models are merely modified versions of existing cars. Electric powertrains are fitted to slightly modified 205s, Golfs, Clios and Astras which means that existing production lines can still run at efficient levels and cut initial car cost.

Plate 9. Renault 'Clio' Electric.

The disadvantages occur in the running of a car with an already heavy body and structure loaded with batteries resulting in poor range and performance. The alternative is to start from scratch and design from the electric engine onwards, the VW Chico is one such model. This car has different structure, construction, materials and shape to existing cars. Its performance is superior to that of the modified cars but the initial cost would be much higher by nature of the huge sums of money invested in development and manufacturing setup.

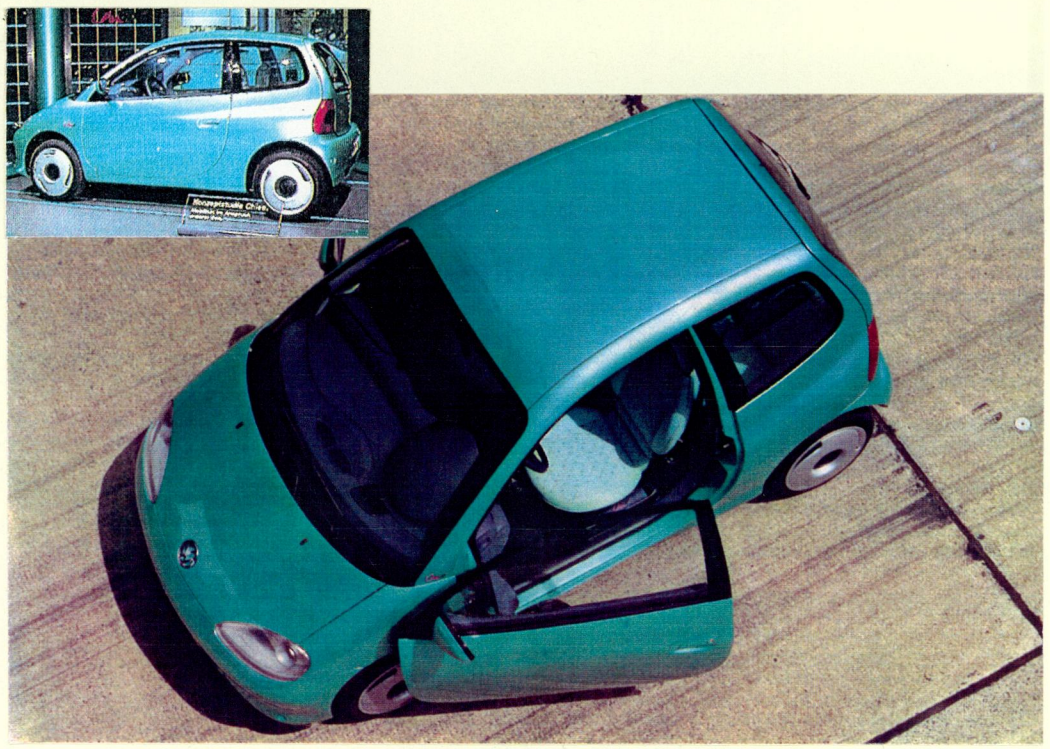


Plate 10. VW 'Chico' Electric.

In the United States where the standards and laws are already quite strict there are more advanced level electric cars due to go into production in the next two years. The reason for the seeming hurry to get these cars on the road are the recent laws passed in the state of California forcing car manufacturers to sell low emission vehicles and zero emission vehicles by the end of this decade. By the year 2003 any car manufacturer wishing to sell cars in California will have to sell a minimum of 10% ZEVs (21, p. 84). Before then the number of electric cars available to the public is to be increased with effect from 1994. Although the first models will tend to be experimental it is hoped that

they will achieve the levels of current concept models within the first three years.

To gain a better idea of the current level of development in the field of electric power two new models illustrate the range of performance that these cars will offer. Firstly, the GM 'Impact' the high profile, high performance electric car and secondly the Citroën 'Citela' the French compact city runabout.

The 'Impact' is probably the most famous all-electric car to have been unveiled in recent years. The car was designed by General Motors in their design offices in Detroit. What is special about this car is the way that it has captured the public interest and imagination. The performance of this electric car is unlike that traditionally expected from electric powered engines and a huge amount of research went into its development to achieve this purpose. The traditional image of the milk float and golf cart-type electric vehicles could never be accepted as replacements for the city runabout not to mind a family car or even a sportster yet the Impact purports to do just that. It boasts an acceleration of 0 to 60 mph faster than a Golf GTI, a top speed of 100 mph, a range of 120 miles on a full charge and a recharge to 90% full capacity in an hour. The car also offers the comforts of current cars with air-conditioning, stereo and heads-up display on the windscreen giving speed and charge remaining readouts. This impressive performance machine is housed in a most interesting and innovative form which in itself has aroused much comment both favourable and not in many circles.

Plate 11. GM 'Impact'.

The shape and arrangement of the engine and batteries in the electric car are different to that of a conventional car and so this enables the designers to utilise new forms and styling. Probably the most notable difference is that the car is the strong aerodynamic look which is necessary to get the maximum efficiency from the engine. The streamline shape is aided by the lack of exhaust and petrol cap which give the car perfect symmetry from all angles of view. The latest in composite material technology is used throughout the car in both structure and panelling to reduce the weight and counteract the extra load of the lead-acid batteries. When it was unveiled in 1990 it attracted great attention and featured in every car magazine and periodical. Such was the interest that GM have decided to take the car into production. The news is however that the car, in its finished form, will not be available until 1994 or possibly after as the cost of producing the car in its present form is prohibitive (21, pp. 8-9).

On the other side of the Atlantic in mainland Europe another car manufacturer is also pushing forward on research into Electric Power for cars. PSA the owners of Peugeot and Citroën the French car manufacturers have produced the Citroën 'Citela' a pre-production electric car. Although not offering the startling performance of the Impact the Citela is a more realistic proposal as witnessed by the fact that it will go into limited use in 1993.

Plate 12. Citroën 'Citela'.

The car is constructed on an existing AX chassis and uses many parts currently used in production cars. There are a variety of different body shells designed to fit onto the chassis to provide a range of different models which cater to different demands. Instead of lead-acid batteries the car uses nickel-cadmium batteries which have a faster recharge time, greater power to weight ratio and the life of the battery in service is longer. The disadvantages of the new battery is its greater cost, size and limited availability of materials.

PSA have committed themselves to getting a viable model on the road within the next two years. The city of La Rochelle in France has been chosen as the test bed for this car when it becomes ready for use. The city will have a full recharging network setup including public and private recharge points by the French electricity concern EDF. The purpose of this project is to study the operating requirements and problems with running new electric cars on a daily basis. PSA have already been running electric powered 205s for two years and recently completed tests in Paris. The results of this research it is hoped will give a clearer indication of the precise requirements of the car.

The incentives for the development of electric cars in the last few years is one of plain necessity. Laws will require car makers to have ZEVs on the roads by the end of this decade in America and probably by 2010 in Europe. The current concept models offer something approaching the comfort and performance of petrol cars for the first time since the demise of the electric car at the turn of the century. The performance restrictions however are still related to the limited range and long recharge times that the batteries in the cars require.

Chapter IV

Evaluation of Contemporary Electric Cars

The aims of this chapter are to outline the advantages and disadvantages of contemporary 1990s electric cars under the following headings: environmental concerns, engine performance, legislation and public attitudes.

In chapter two it was shown that the biggest drawback with the electric cars of the 1960s and 1970s was their inability to offer the range, speed or price that came close to the petroleum powered cars of the day. The performance question has changed quite considerably within the last decade. Increasing time is spent in city traffic travelling at slow speeds where the acceleration of the car is not an important factor for the motorist. With this in mind the benefits of the electric car are much more obvious.

> Electric cars offer exciting prospects for the future. Inherently efficient, reliable, silent, and pollution-free, they could provide high mobility without the environmental damage of the gasoline car (8, p. 1).

This commonly held 'green' view of the electric car as the ideal solution to the pollution problems is something of a misinterpretation of the facts. Transferral to electric cars would not suddenly eliminate the damaging effects of the car environmentally. The city air may become cleaner but only at the expense of output increases from the electricity generation stations. Research conducted in 1978 has shown that the estimated improvement in air quality with the large scale introduction of electric cars would be 'of the same order of magnitude as changes which were actually recorded in the U.S. on the early 1970s' (8, p. 319). The amounts of carbon monoxide and hydrocarbons would decrease but sulphur oxide emissions would rise giving increased acid rain. It is therefore essential that pollution be tackled as a problem instead of diverting it from one source to another. The only advantage

to a conversion to all-electric driving would be that the air pollution is now at one point source, the power station, and can be monitored and changed much easier than millions of small roaming cars. However the efficiency improvements in petrol cars themselves at the moment and in the near future should reduce further the advantages of conversion to electricity.

> The energy-conversion efficiency is higher if petroleum is refined and then burned directly in the vehicles engine than if it is consumed in the power station to generate electricity, which then has to be transmitted, transformed, refined and stored (12, p.239).

Although there is enough wasted night-rate electricity to recharge several million cars in the United Kingdom it is likely that day time recharging would be common. This would add to the burden and hence output of pollutants from these stations.

There are of course other forms of pollution such as the cars themselves seen rotting in the fields and ditches of this country. The non-recyclable nature of many of a cars components especially the engine could be improved with the electric engine as it is simpler, more reliable and wears much less. Electric cars also have a longer working life and smaller failure record due to the smaller number of moving parts and less strain on the engines components. The advantages of changing to an electric car would be small as advances in petrol engine technology already increase the amounts of recyclable parts in current cars. Several countries in Europe including the Scandinavian countries and Germany require the labelling of parts for identification and disposal or recycling. The only area of pollution reduction in which the electric car seems to excel is that of noise. While stopped in traffic the car makes practically no noise and when underway only a faint whine of the electric motor can be heard. The reduction of noise pollution from cars is welcomed but silent cars also have their problems albeit of a different type. A recent article on electric cars in use in Paris highlighted other problems. The fact that electric cars were so quiet that people found it difficult to gauge the speed and distance of a car. This problem caused several near accidents

with pedestrians walking in front of the oncoming cars. Drivers of the new electric cars found the silence of the engine diffult to accept and judge especially when pulling away from a stop (15, pp. 57-58).

Probably the most valid argument in favour of the electric car is that the actual performance of these cars is within the requirements of a second car in an average household. Research completed in the United States of America both in the 1960s and this decade shows that the operating range of a business commuter or housewife in a secondary car is under 70 miles for over 95% of the time (8, p. 136). This applies to a car capable of seating 3-4 people. Current electric cars especially custom designed models are well capable of 120 mile trips on a full charge at city and suburb driving speeds. It could therefore be argued that for the other 5% of the time public transport or the primary car could be used. The capability to produce cars of this type has existed since the 1970s so why are there not a high percentage of secondary electric cars? The reasons are also quite obvious:

> It would be the exceptional individual who would pay more for less car in order to make infinitesimal reductions in the nation's petroleum consumption and air pollution. Incentives for the individual, in short, are lacking despite the potential collective benefits for society from large-scale electrification of automobiles (8, pp. 1-2).

What the electric fails to deliver is the freedom and variety that even the smallest petrol car can give. The ability to refill in a matter of minutes and travel another full tank is a simple feature that the electric car cannot offer. Current electric batteries are very slow to recharge and a complete rundown on the batteries renders them completely useless entailing a replacement of several batteries at great cost. The 'Impact' mentioned in the previous chapter claims a 90% recharge in one hour other manufacturers claim to have reduced it further to 30 minutes or slightly less. Even if these times could be reduced to the equivalent of a petrol refill the damage of regular rapid recharges reduces the service life of a battery drastically. The top speed and range claimed for the 'Impact' are correct but they are not

achievable simultaneously, 100 mph but not for 120 miles! A possible solution would be that 'if battery exchange stations were as common as gasoline stations, the range limitations of electric cars would become inconsequential' (8, p. 173). However the study also shows that this system would prove much more expensive to the motorist than home recharging and the setup of this system would be difficult. Whatever benefits the electric car does have the cheap price of petroleum keeps the petrol car very competitive.

In America , the price of gasoline makes it cheaper to run a car on petrol than to recharge it at home, recharging in the day or away from home makes it even less economical. In Europe the higher cost of petrol gives the electric car a better chance. If the electric battery replacement cost is ignored, tests have shown that a BMW 320 is cheaper to run on electricity than on petrol (16, pp. 10-11). Unfortunately it is difficult to ignore the £7,000 that the battery costs to be replaced every 2-3 years.

The futuristic form of the cars has been suggested as a reason why the public have not reacted well to some of the concepts. The styling of the electric cars can vary widely depending on your tastes. Consumers will be offered a choice from the indistinguishable Renault and Ford vans which look exactly the same as the petrol models (until you look under the bonnet) to the more radical GM 'Impact' and Citroën models.

The advantages of the more futuristic cars is that the construction,and technology are also more advanced. These models should have a large element of success as the benefits of a more economical and recyclable car should be seen in the medium term over the more conservative models. According to some designers the electric car has 'more interesting design potential because of the fact that less frontal area is needed to house the powertrain'(18, p. 8). Shorter and more aerodynamic front bonnets are a design possibility and may become the hallmark of an electric car. In general though the configuration of the car will not undergo any major changes as the seating, lights, wheels are not affected by a conversion to electricity.

The styling of the BMW E1 due to be put into production in 1996-1997 illustrates these features of shorter frontage and higher cabin for better driver vision. Concepts for the petrol and diesel cars of the coming years also display these features as there seems to be a move towards more a open cabin area and lighter, recyclable chassis and panels in the cars.

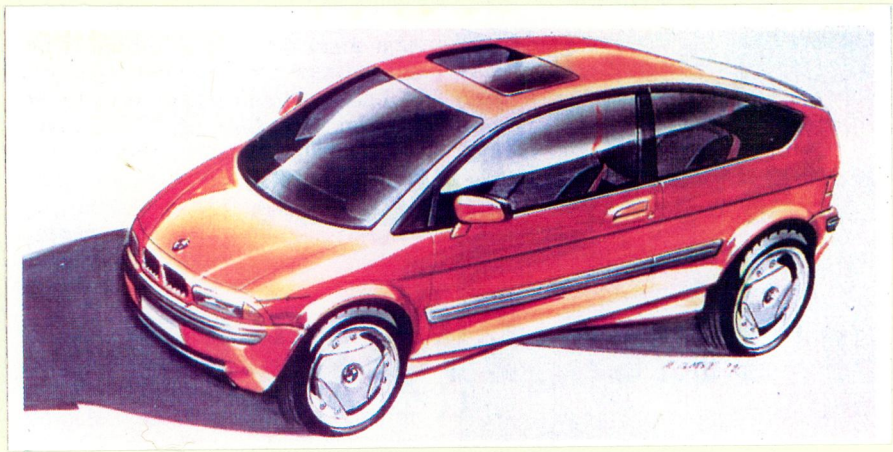


Plate 13. BMW 'E1'.

The legislative push that the car manufacturers require has only come into being in the last few years. Emissions regulations have been set at levels that suited the car makers and only tightened at a level that they can keep pace with. California state upset the situation and has accelerated car development by forcing the introduction of emission free cars by 1998 as mentioned previously. On the 12th of February, President George Bush announced that as part of his election manifesto he promised to put forward the implementation of emission standards by five years. This announcement reflects the importance attached to the pollution issues in America. Car industry sources replied by complaining that such tightening of regulations was beyond the reach of many car makers. It is unlikely that Europe will adopt the same law and in fact the reaction was quite hostile especially by Germany whose car industry has strong links with America. Even though almost any level of electric car usage could be achieved depending on the strength of action by governments few will risk the displeasure of the multi-national car empires. The steady tightening of emission standards is more to the taste of the car companies. The car

manufacturer, Volkswagen, claims that if required it could tighten its fuel economy average by 2 mpg per annum. The most likely increase as regards legislation is more in the range of 10 mpg in the next 10 years (19, p. 22). Fuel economy is only as good as the willingness of the motorist to keep the car in good working order. 'In the 1978-1988 period car fuel efficiency increased by 22%' (20, p. 33) despite the reduction and removal of lead and emission reductions. This seems to have been a good achievement but any benefits were negated by poor maintenance of cars by their owners and increased traffic congestion. In actual terms 'the amount of fuel to move one person one kilometre has increased since the 1950s' (20, p. 33).

The reaction of the car makers worldwide to the Californian directive been angry as the burden of developing electric cars and selling them has been dumped on them. The development of these electric car concepts by the car companies is more of a reflex reaction to the current and upcoming regulations than a genuine concern to reduce pollution. Due to the slow reaction from the manufacturers the government of California invited submissions for a practical electric car design. The winning design developed by IAD of England will go into production in 1994. It is hoped that the arrival of this car will give added incentive to the other car makers to also make models available.

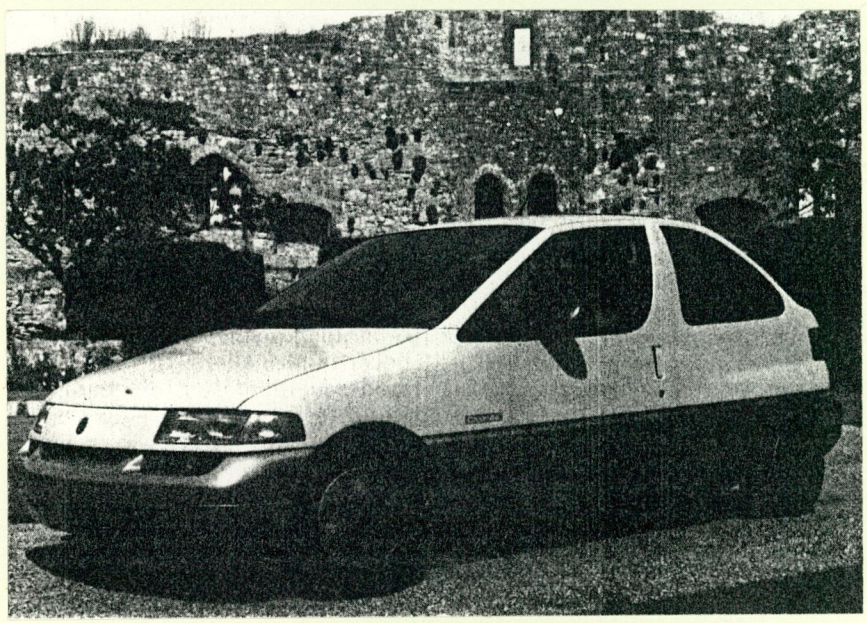


Plate 14. IAD 'LA301'.

Legislation has ensured that, whatever the outcome, electric cars will be on the roads in the next few years. The electric car brings undoubted benefits such as noise reduction and elimination of emissions. Longer life and fewer failures are also promised to improve the lifestyle of the driver. Increased costs and emissions from power stations are also a likely outcome of the introduction of numbers of cars.

Chapter V

What the Experts Say

Interviews with leaders in the motor industry are an ideal way to gain some idea of what the electric cars can be expected to achieve in the coming decades. The changes in fuel sources and car designs are already under development but the final release dates are still well in the future. In the interim there are partial solutions that will be provided to keep in line with pollution regulations and other traffic restrictions.

> Dr. Heiko Barske, the senior research engineer for the Volkswagen group, sums it up:' the electric car is a vehicle for rich people. The less well-to-do must switch to public transport' (21, p. 84).

This stark statement from Dr. Barske is common of the attitude of many people working in the automotive industry. The high cost of batteries and poor performance is cited by many as the major stumbling block in the development of electric cars. Estimates by BMW put the current purchase price of an electric car at '20 to 40 percent higher than a petrol car, depending on the type of motor and battery' (21, p. 86). Add to that replacement battery purchase every two to three years at a cost of around £5,000. Installation of the battery unit in existing cars also takes up a certain percentage of what was originally storage space. The inclusion of a battery unit in a Peugeot 405 adds considerably to the weight of the car and puts added load on the rear suspension.

Plate 15. Peugeot 405 Battery Unit.

The additional costs are incurred irrespective of breakdowns, repairs or any other incidental expenses. Yet the benefits also exist especially for companies who wish to promote a greener image and whose needs can be serviced by short range fleet cars. Citroën who are offering electrical converted Clios in their range have taken orders from several companies for small fleets of electrical cars. The French electricity company EDF have an order for 200 cars. PSA, the owners of Peugeot and Citroën, are convinced a market exists for them among local governments and co-operatives, organisations and firms that care about the protection of our urban environment (7, p. 263). Part of the solution has been the leasing of fleet cars which has proved to work well in tests in America. Ford have over 200 electric vans on lease to several companies at the moment. Leasing the cars eliminates the initial high purchase costs for the companies and allows them to reap immediate benefits from CAFE exemption. Using these electric car for personal transport for the moment is too expensive for the ordinary motorist as the lease scheme is not likely to be extended.

Few would argue that the electric cars are as capable as their petrol counterparts but it is also clear that tightening the emission laws further will eventually eliminate the petrol engine. One of the first major changes is the use of the catalytic converter. Already obligatory in the United States of America, effective from 1993 in the EC, the catalytic converter will have to be fitted to all new cars. Fitted to the exhaust pipe, the function of the converter is to remove the toxic gases emitted from the engine post combustion. The converter consists of a platinum and rhodium coated honeycomb filter which changes the

toxic gases (carbon monoxide, hydrocarbons and nitrous oxides) into carbon dioxide. Although it is commendable that the Parliament is taking strong steps to control emissions the manner in which they have done it has upset many people especially the car manufacturers.

The actual result of the directive has been to seriously stunt the development of more efficient engines and better fuel management by forcing all the car manufacturers to develop catalytic tuned engines. In order to get around the emissions requirements some serious changes will have to be made to the engine. Lindsey Halstead, Chairman of Ford Europe sees the introduction of 'flexible fuel vehicles, using conventional internal combustion engines and using a fuel source such as methane, LPG, or methanol in addition to petrol' (19, p. 18). Volkswagens head of Research and Development, Ulrich Seiffert is inclined to favour the direct-injection petrol engine 'which offers the fuel efficiency of the diesel engine but with the smoothness and cleaner-burning qualities of the petrol unit.' (19, p. 21) Further alternatives include two-stroke engines, which are smaller and more efficient than current designs, and gas-turbine engines. The gas-turbine engine is currently being researched primarily by Toyota. Shiro Sasaki, Executive vice-president of Toyota puts the development of the gas engine:

> More than 15 years away. I see it as a possible stage in between the current petrol internal combustion engine and a new engine of the future, that uses natural power and does not pollute (19, p. 22).

The 'green' lobbyists on the other hand argue that there is nothing wrong with a switch to public transport. The car is not an efficient means of transport and changing to new engines, new fuels and new materials will have no major effects. The rate of growth of car numbers means that if car efficiency was improved by 40% over the next ten years (a sizable improvement) the increasing numbers of cars would completely eliminate any environmental benefits and traffic congestion would get even worse (24, p. 33).

Car pooling, city centre taxes and outright city car bans are already in existence in cities over the world in attempts to curb pollution. Athens, Milan and many other cities impose bans on cars in the city centre over the winter months when environmental conditions are conducive to smog. In Germany it is expected that several cities may ban all petrol and diesel-engined cars from the city centres during the winter months within the next 12 to 24 months because of excessive air pollution, noise and damage to the architecture of the cities themselves. Singapore has introduced road taxes which charge the motorist the more they use their car in the city centre. The introduction of the road tax is being looked at by the Netherlands and Sweden.

The suggestion from Jonathon Porritt, spokesman for Friends of the Earth, is that the car should be left at home and public transport used for both city commuting and long distance travel. Although conceding that cars area necessity at the moment he argues that if the networks were well setup we could walk or cycle to the centres of public transport:

> No car, however efficiently it uses the cleanest of fuels, can be described as environment friendly, simply because of the energy and raw materials needed to produce it, the roads it requires, and the vast infrastructure of garages necessary to keep it on the road (24, p. 32).

The shortcomings in public transport are in part to blame for the prevalence of cars. The other factor which the environmentally aware can seem to forego is the enjoyment and independence gained from driving cars. It is this reason that many car companies believe that the future of the car is secure.

What will be the fuel of the car of the future ? In the longer term, diesel and petrol will have to be completely eliminated. No matter what is added or taken away there are still emissions of some quantities of the harmful gases. Ford put the arrival of the 'pollution free' car as 'the middle of the 21st century' (19, p. 18) Volkswagen and

Toyota are a little more optimistic with suggestions for the first models post 2010. Solar Cells and Hydrogen are seen by most as the ultimate solutions. Battery powered electric cars could exist by being charged by on-board solar cells where hydrogen functions similar to petrol. Development of storage in cars for the hydrogen is still in its infancy and is expected to be difficult as hydrogen is a potentially hazardous fuel. The arrival of hydrogen by no means discounts the usefulness of electric cars.

As the only current solution to emission free transport the electrically powered car is guaranteed a long period of usefulness. The limitations of these cars are acceptable for city driving and if they are part of a fleet system then the recharging network problems can also be overcome. Longer term the possibility of recharging the cars from solar power exists to keep the electric car going into the next century and beyond.

Conclusion

The history of the electric car stretches back to the beginnings of the car itself. Initial success was due to the rapid and clever use of established technologies, the electric dc motor and lead-acid battery had been in use for several decades. In the face of weak competition from early internal combustion engines the electric engined car offered quite acceptable performance. The electric engine could not keep up with the rapidly improving petrol engines and by 1910 there were few electric cars in the cities of Europe and America. Despite the best efforts of the scientists and researchers, batteries refused to yield greatly improved performances. The batteries of the time were heavy and when combined with the crude bodywork of the cars the speed and range were severely restricted. The versatility and portable nature of petrol gave it even advantages over the battery which required regular recharges often only possible in the big cities.

Revival of serious research into electric cars in the 1960s gave hope that improvements could be made to at least give it openings in the market. Most of the concept cars of this period did not see production. Tests showed the cars to be very slow and concessions to weight reduction resulted in loss of comfort and quality that the driver expected. Despite the oil crisis, the envisioned demand for electric cars never materialised. A small number of manufacturers made and sold electric cars but without lasting success. The achievements of research into batteries in the 1960s and 1970s were to be seen more clearly in the arrival of large numbers of specialised vehicles to which the application of battery power was more suited. Golf cars, wheelchairs, milk vans and many other vehicles which had been in existence for many years found improvements in battery technology much to their benefit. The development of batteries for various applications had continued since the 1970s but without any specific concentration on the electric car itself. The ongoing research had shown that the electric car was far from as capable as its petrol or diesel counterparts and as a result the consumer was unwilling to make the sacrifices.

The environmental concerns which prompted the research in the 1960s into electric cars by the government and car makers alike has filtered down to the public. The level of consumer concern in environmental protection was vastly underestimated by the major car companies. The damaging effects of both smog and lead emissions to people and the environment is common knowledge and of great concern. Regulations to control and limit the emissions of harmful gases have been strongly supported by the public over the last two decades. Legislation has already all but eliminated lead from petrol and emission standards are constantly tightening both in Europe and in America. The state of California advanced further the speed of the change when it introduced the low emissions and zero emissions levels in 1990. Their attempts to interest the big car companies in viable electric cars failed and so the opportunity was opened to public entries. The resulting three designs are expected to go into limited use within the next eighteen months. The interest initially is coming from industry which may wish to gain a stronger environmentally conscious image or simply to comply with tightening CAFE regulations.

The moves in Europe seem to be much less orientated to electric power as a solution. Most of the concepts are based around the hybrid car, run on electricity in the city and turning over to a petrol or diesel unit outside city limits. For city centres the solution required must be of a non-polluting nature. Although not truly pollution free, the battery powered car does eliminate pollutants, both gas and noise, from the cities. Due to this fact there has been interest in producing higher performance batteries to meet the needs of city driving.

The concept cars by Ford, GM, VW and PSA amongst others reflect the move towards private electric cars while their practical models are designed with companies in mind. In the short term the competitiveness of these cars as regards price still needs to be addressed. The renting of batteries has been suggested as a solution or even the renting of the cars themselves. This method of sale would suit the companies who could have several electric cars in their fleet. The private motorist has different demands from a car and this

performance is much more difficult for an electric car to achieve. It is expected that further advances will widen the battery's range of use and capabilities in the next ten to fifteen years. The longer term promises even greater changes with solar power and hydrogen being suggested as the ultimate solution to pollution free transport. Between now and the arrival of these clean power sources the use of the electric car is assured as it is currently the only form of transport that is emission free.

As to when we will see the first cars in the showrooms? California should be seeing the first commercial models in 1994 and Europe by 1998. If you want a model before then there are several models to choose from. Volkswagen will sell you a converted Golf costing £15,000, the same price as a GTI. It offers a range of 40 to 60 km, top speed of 60 kph and an acceleration of 0-60 in 19 seconds. If you want something a bit more radical there are custom designed cars such as the Mini-El designed for the city commuter. However according to Volkswagens head of research:

> The electric cars of the moment are still in a state of development. Don't expect the first proper electric cars that are designed specifically for the private motorist until the first decade of the 21st Century (19, p. 20).

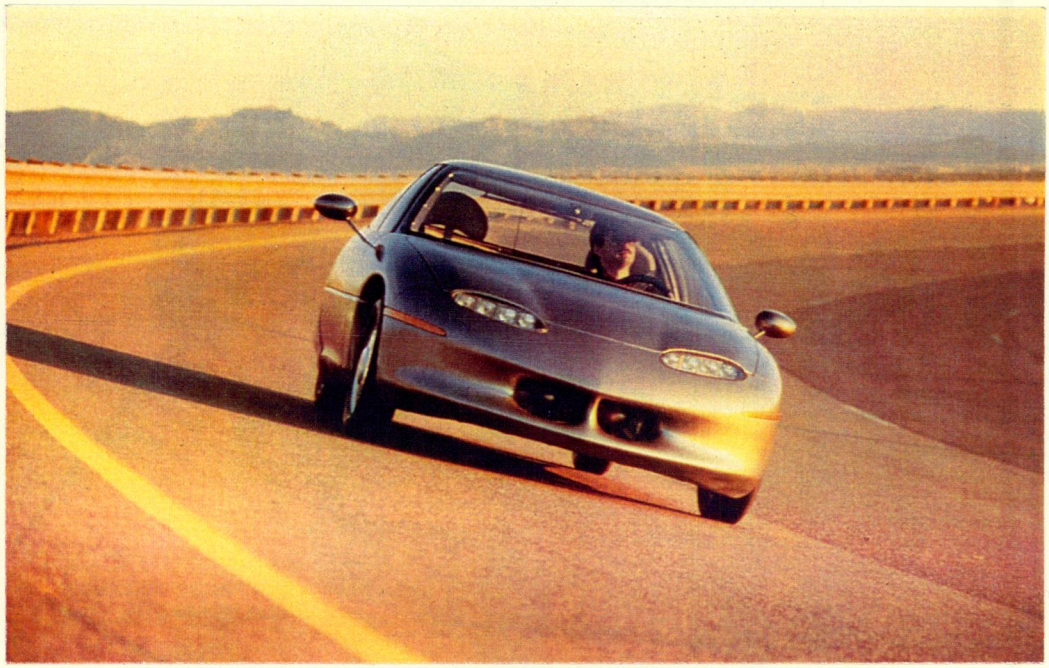


Plate 16. GM 'Impact' during performance tests.

It seems that for the next few years the best advice is to wait and see what the new cars will offer and if you wish to be a 'green' commuter then car pool or take public transport.

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