EDS

"Advanced electric drive systems for buses, vans and passenger cars to reduce pollution"

SYNTHESIS REPORT

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Supported by the European Community

INTRODUCTION

Vehicle emissions account for a substantial fraction of all atmospheric pollution: for example in P-017, a Dutch study, it is reported that road traffic contributes 65% of the CO, 55% of the NO_x and 45% of the hydrocarbons emitted. From standpoints ranging from international problems of global warming to local issues of air quality, this situation must not be allowed to continue forever.

The widespread introduction of electric and partly electric (hybrid) vehicles will doubtless reduce air pollution significantly, and is one important answer to this problem.

The first of this new generation of cars will arrive within the next 2-3 years, and more are surely to follow. Together they herald the next major change to our transport system. However it is not yet clear what the overall result will be, for the number of possible technologies are numerous - there are many versions of electric vehicle currently being touted as 'the world's future in electric transport'.

Car manufacturing has always been an important industry. If electric vehicles are this industry's future, then an important segment of the world's manufacturing is obviously going to change drastically. So it is not a matter of whether electric vehicles are going to appear - it is a matter of how many of them are going to be produced in Europe.

This report synthesises the results of 18 studies that have examined possible electric vehicle technologies. It is divided into the following sections:

- The Environmental Perspective
- Development Trends and Obstacles: An Evaluation
- User Acceptance of Electric Vehicles
- Traffic Management Actions and Infrastructure Design
- The European Position in Electric Vehicle Development
- Europe-Japan-USA Comparison
- Overall Summary and Action Priorities

THE ENVIRONMENTAL PERSPECTIVE

How much will electric and hybrid vehicle technology reduce the emission of atmospheric pollutants?

In report P-018, the following figures on emission levels from internal combustion vehicles and electric vehicles were quoted from the U.S. Electric Power Research Institute. Electric vehicle emissions, of course, account for the pollution emitted by power plants.

	NO_X	Hydrocarbons	CO
Gasoline Cars	1.10 g/mile	0.70 g/mile	9.00 g/mile
Electric Cars	0.08 g/mile	0.01 g/mile	0.01 g/mile

These figures have now been calculated for the Belgian situation, using standard European cars following the ECE-R15 cycle (a standard European driving profile).
The following cars were considered, with their energy consumption:

diesel:	6.5 L/100 km	=	234 Mjth/100 km
petrol:	8.5 L/100 km	=	306 Mjth/100 km
electric:	28 kWh/100 km	=	100 Mje/100 km, provided by mains supply

After considering factors such as primary energy consumption, electricity production, fuel transportation, the distribution of electricity sources in Belgium (62 % nuclear, 24 % coal, 8 % natural gas, 2 % blast-furnace gas, 1 % each for heavy fuel, waste burning and hydraulic) and more, the following results were obtained (in kg/100 km)

	Gasoline	Diesel	Electric
CO_2	25.8	19.8	10
SO_2	0.005	0.027	0.04
NO_X + HC	0.098	0.098	0.026
dust	negligible	0.019	0.0043
CO	0.27	0.27	0.0025

Obviously, the electric vehicle emissions depend on the power sources used. In this case electric vehicles are significantly lower in all areas except for SO_2, caused by the large percentage of non-desulphurised coal used in Belgium. This can be reduced in a number of ways at the power generating level. Only electric vehicle technology gives policymakers that ability.
A final point to consider is that, although the fuel consumption and emission levels of the internal combustion engine vehicle are still dropping, after a hundred years of development it is already a highly matured technology. On the contrary, electric and hybrid vehicles, particularly their propulsion system and energy source, represent new technology. The early designs considered in these studies are not optimised, so a healthy market will doubtless bring even more improvements.

Conclusion

Electric and hybrid vehicle technology will reduce the production of atmospheric pollution by significant amounts compared to today's levels. They will also enable policymakers to reduce pollution further through improving the cleanliness of the central electricity supply.

DEVELOPMENT TRENDS AND OBSTACLES: AN EVALUATION

This chapter introduces the basic vehicle types and their major components, summarises the results of studies of their feasibility and recommends future actions.

The Electric Vehicle

Electric vehicles use electric motors for propulsion, and store this energy in batteries. They are short-range vehicles for urban applications. The ability of battery technology to accommodate their demands is crucial to the feasibility of electric vehicles.

The 'newness' of this technology makes defining the different electric vehicle categories rather speculative. The following tentative classifications and mission characteristics for electric cars are considered:

city cars: shopping and leisure trips in urban areas.
medium-sized passenger cars: local traffic or commuter functions.
vans: parcel and commodities distribution in the same area.
minibuses: public transportation with relatively high frequency and mileage in protected urban areas.
buses: high frequency and mileage public transportation in all urban areas.

Report P-017 defined the first three car varieties above based on the distribution of 'classical' (non-electric) vehicles in the city of Amsterdam and four existing vehicles[1] all able to pass the ECE-15 cycle, the standard European simulation test of urban driving conditions. The range of all of these cars, described below, is 130 km.

type	total weight (kg)	payload (kg)	battery weight (kg)	required battery specific energy (Wh/kg)
city car	750	150	150	100
medium sized car	1275	150	275	100
van	3650	1000	650	100

The battery considered for these vehicles is of an hypothetical type. It corresponds to the medium- and long-term goals (MT - LT) of a recently created American consortium comprising the three main American manufacturers: Ford, GM, and Chrysler. These goals are in the next table, which also summarises the batteries that are currently or will be soon available on the market. All have a recharging time of 6 hours.

[1] The four existing electric cars used to define these vehicle types are the Swiss Pinguin 7, the Cityströmer (VW Golf), the Renault Express and the Renault Master, respectively

type	specific energy(Wh/kg)	specific power(W/kg)
MT requirements	80-100	150-200
LT requirements	200	400
lead-acid	26-36	80-120
Nickel-Cadmium	50	200-400
Sodium-Sulphur	100-126	136-180
Sodium-Nickel	80-100	120
Zinc-Bromine	40-60	120

Hence battery technology is not an obstacle for these or the other, larger electric vehicles defined earlier. In addition, the American programme's medium-term goals have almost been achieved for certain types of batteries.

Note that the final choice of battery must take account of the battery's cost. Despite their low performance, the lead-acid variety currently used for electric vehicles are viable power sources, due to their low cost. Report P-044 defined the application field for which different types of batteries are the most economic solution. Further developments of other types will further reduce costs and improve performances.

Conclusion

The electric vehicle can already be built and used for urban applications. A development methodology to optimise the technology is necessary for the industrialization of a reliable product for these applications. This process has hardly been started. Consequently, considerable efforts in development are necessary, and they should be based on developing experimental, pre-industrialized fleets of satisfactory size.

Despite the current technological position, coordinated development is still vital for standardization. The evaluation of different solutions and designs could be usefully performed using a simulation tool. This tool would need sufficient flexibility to be usable in different R&D centres and would have to easily accept the introduction of new elements.

As in every field, fundamental research remains an important element in the long-term development of electric vehicles. In this case it is particularly important because the technology is still in the initial stages of development. The fundamental research should focus on structures, electric motors, electronic components, static converters and batteries.

An important effort in standardization is indispensable for the electric vehicles components, particularly batteries.

The Hybrid Vehicle

Hybrid vehicles combine electric and other drive systems, such as internal combustion engines, gas turbines and fuel cells. In general they have a longer range than purely electric vehicles, and still have the option of running on electricity alone in urban environments.

The analysis of road vehicle use in Europe shows that hybrid vehicles must fulfil different missions, and must satisfy acceleration, maximum speed, high range, gross weight and payload criteria.

Being a new technology, the hybrid vehicle concepts examined featured traditional components corresponding to current technology. These designs are therefore limited by their performance in electric mode. Technological development, through optimisation alone if not through further breakthroughs, will bring better performances.

The reports P-027, P-030, P-036 defined the various components (batteries, traction motors, static converters, flywheels), and assessed their price evolution based on current applications.

The various morphologies (parallel hybrid, series hybrid and combined hybrid) were compared. All are fitted with an internal combustion engine, an electric traction motor and a battery. In certain cases flywheels, which store energy when braking for use in subsequent acceleration, were added.

The reports concluded that all hybrid solutions will be more expensive than the reference conventional solution, so their lower fuel consumption (18-25%) will not be enough to make the further investment worthwhile alone. This additional cost depends on the complexity of the solution and the component design. Costs are assessed based on producing several tens of thousands of vehicles per year.

Of course, lower fuel consumption is not the main benefit: the reduction of CO_2 emissions may range from 30-50%. The range of values reflects the uncertainty in design due to the fact that no concept has been optimized. For the same reason, it does not yet seem appropriate to examine the differences between purchase price and environmental benefits.

The reports also develop a methodology for such a vehicle's market penetration - its major point is that vehicles able to at least partially function without polluting emissions are allowed in urban areas totally or partially closed to conventional vehicles.

Conclusion

It is clear that the hybrid solution is a serious alternative to the entire current vehicle fleet for both energy and environmental reasons. It is also obvious that a considerable development effort is necessary to determine the most appropriate solutions.

The Hybrid Electric Bus

The P-039 and P-033 reports show the technological feasibility of the series-type hybrid bus, which uses a diesel powered generator set at constant power to supply an electric motor.

In the series solution, the constant power of the diesel engine reduces emissions significantly, as the following table demonstrates:

emission	reduction compared to a diesel bus
hydrocarbons	88%
CO	83%
NO_x	67%
particles	90%
CO_2	25%
fuel consumption	25%

Immediate development is possible due to the availability of all required technologies, In addition, note that in the future the diesel engine can be replaced with fuel cells, which emit no pollutants.

Conclusion

The technology for the hybrid bus is near to hand. The next step should be to develop an experimental fleet of about twenty vehicles, exploited in an urban area. In this way, the lessons typical of a pre-production and initial commercialisation phase could be learnt.

At the same time, research efforts should focus on implementing other types of generating units, such as fuel cells, Stirling motor, gas turbine and more.

The Technological State of Electric and Hybrid Vehicle Components

Batteries

Apart from issues of power and energy, the cost and recyclability of the different battery technologies are important. The studies show that recycling is definitely feasible, and costs can be lowered.

Europe should continue this process and consolidate its position in the industrial design and the development of both batteries (Pb, Na-S, Ni-Cd, Zn-Br, Na-NiCl) and fuel cells. This requires support to compete with American and Japanese efforts. The now existing pre-industrial phase has to be consolidated to allow moves towards full industrialization. Note that in the USA, 30 million dollars are planned to be invested in battery development in 1992, with an equivalent sum coming from industry.

Fuel Cells

Fuel cells produce electrical current from the chemical reaction between hydrogen and oxygen. The only byproduct of this reaction is pure water. As such they are possible future sources of energy for electric vehicles.

The P-001 report presents very comprehensive analyses of fuel cells fit for electric traction and reformers. The latter produce hydrogen from methanol on-board, and add substantially to weight and volume.

Fuel cells are high in volume, so their greatest potential lies in heavy vehicles like buses or medium-sized vans. As they are current sources, they are combined with a buffer battery that will be useful to provide energy peaks at moving off and vehicle acceleration.

Three types of fuel cells are investigated: the alkaline fuel cell (AFC), the phosphoric acid fuel cell (PAFC) and the proton exchange membrane fuel cell (PEMFC). As the PAFC cell has the least interesting characteristics for electric vehicle application, the AFC and PEMFC cells will probably be the subject of future developments and applications.

The PEMFC cell is currently more complex than the AFC. Nevertheless, though the performances of the cells seem to be different, they have to be compared to both the whole system and to the different applications in vehicle use (starting period, stop time, idle time etc).

Motion sensitivity and the origin of the hydrogen are also relevant issues. If the hydrogen is not obtained from fossil fuels, alkaline cells will be favoured, whereas a production of methanol from coal will favour the other, acid solutions (PAFC or PEMFC).

The report also provides design data regarding the weight and volume of different fuel cells for both current technology and future projections.

Conclusion

At their present stage of development it is impossible to choose between the different fuel cell systems. However it is clear that the development of fuel cells for road vehicle applications could give concrete results in the medium term.

At the present stage of fuel cell development a demonstration on a certain number of vehicles is very important. This demonstration should be followed by a pre-industrialization phase on a sufficient fleet of vehicles.

Electric Motors

The electric motor determines the drive train design of an electric or series hybrid vehicle. Its role is slightly different in parallel or combined hybrid vehicles, where both electric motor and an internal combustion engine provide traction.

The electric motor is chosen according to considerations of:
- weight
- volume
- reliability
- efficiency
- cooling
- noise
- integration of drive train
- maintenance
- cost

Three ranges of power may be distinguished:

Power range (kW)	Application
1-10	small goods carrying vehicles, golf caddies, lift trucks
10-50	electric city vehicles, average hybrid vehicles, vans, minibuses - the most important range
50-200	public transport vehicles

Currently, few motors have been designed for close integration in a road vehicle drive train. One notable exception is the induction motor of the hybrid VW-Golf vehicle, which is now being tested on twenty vehicles in Zürich.

Theoretically, the choice still can be made between five motors:

- the direct current motor
- the induction motor, AC current
- the synchronous motor, AC current
- the reluctance motor, AC current
- the permanent magnet motor

At the moment, the most widely used is the direct current motor. It shows several disadvantages, but its capacity to adapt easily to the battery and the simplicity of the intermediate electronic power controller considerably compensate for them.

All the other motors present advantages and drawbacks at different degrees. A clear choice will depend on future efforts in development as well as on the development of electric and hybrid vehicles themselves.

Conclusion

Electric motor technology is well developed in Europe, but mainly in standard industrial applications, not electric vehicles.

Associating electric motors with power electronics has led to a fundamental evolution in technology, and has allowed the most recent developments in electric transportation (train, tram, trolleybus, and automatic systems).

The technology required for electric vehicles is theoretically the same, but it differs considerably in application. Important developments, adapted specifically to road vehicles, are necessary.

Consequently, a significant technological effort must be made. This effort would fit perfectly into the framework of European R&D, and is indispensable to maintaining the essential role of Europe in this field.

Electric And Hybrid Vehicle Electronics

Power electronics will be a vital element to a successful electric and hybrid vehicle industry.

The traditional car already has components associated with "intelligent" control and protection functions. In electric vehicles, however, power electronic systems control the vehicles movement, so additional concepts like efficiency, reliability and safety become relevant.

Power electronics already constitutes a key element in European technology, as the following points demonstrate:

- the European Power Electronic conference is the most important congress in the world in this field. It outmatches its American and Japanese equivalents;

- in the most industrialized European countries, more than 50% of electric energy is transformed by a power converter before being used;

- the increasing sophistication of many industrial process is driven by improvements in power electronic converters.

However this technology is not sufficiently supported, and Europe risks losing its preeminent position. The P-003, P-021, P-004, P-033, and P-039 reports highlight the need for developing both electronic control systems for optimal management of all electric or hybrid vehicle components, and the power converters themselves.

Not only is it necessary to develop power components and their intelligent functions, but the structural integration has to be carried out in order to obtain a compact and reliable whole which will easily lend itself to the functions that have been defined.

This field is quickly evolving, with new components appearing regularly on the market. Japanese industry constitutes the most direct danger to European industry.

Conclusion

Power electronic components are responsible for transforming energy on the vehicles. They must have a high efficiency, and specialized components for electric and hybrid vehicles should be developed.

The control and command functions are essential, and will be partially or totally integrated to power functions. Since they have a central role, they will require considerable development efforts.

Europe must recognize the role of power electronics in its whole industry and agree to make the R&D efforts needed for maintaining its current position in this field. This will lead to rational management and reduced consumption of electric energy.

These efforts will benefit the motor car as well as the electric and hybrid vehicle industries.

Internal Combustion Engines for Hybrid Vehicles

The internal combustion engines solely concern hybrid vehicles. They are not the same as standard engines, but obviously development efforts will come from the traditional motor car sector. The usable solutions could be provided by work carried out towards "clean" car technology.

"Parallel" hybrid vehicles use internal combustion engines to provide part of their traction. In this case, the technological transfer is obvious.

In "series" hybrid vehicles, the electricity is generated on the vehicle by an internal combustion engine supplying an electric generator, and the traction is exclusively supplied by the electric motor. Because the engine works at constant power, polluting emissions are largely reduced. The development of engines designed for such constant work (Stirling motors, gas turbines, gas motors, lean burn motors) should be supported, given their contribution to reducing pollution.

Conclusion

On the basis of both hybrid solutions, different combinations, each having its own characteristics, can be defined. The P-030 report describes about twenty solutions. It appears that further research must be carried out in order to determine the most interesting solutions.

Electric and Hybrid Solutions: A Summing Up

Both electric and hybrid solutions will have to be the subject of thorough investigation in order to define the best solutions. Comparison and evaluation could be carried out with a simulation software tool, with sufficient universality and modularity to make an easy comparison of the different structures.

From this preliminary stage, a demonstration phase on several vehicles will make it possible to compare experimentally the different solutions. Eventually, the pre-industrialized fleets will be implemented in a preparation phase aiming at elaborating proposals for the market.

Infrastructure and Electric Energy Distribution Problems

Electric and hybrid vehicle technology will have a significant impact on the electricity distribution network. These problems are mainly dealt with in reports P-002, P-018 and P-017.

If we consider a group of batteries with an energy density of 200 Wh/kg (the long-term objective in the USA), we reach an energy content of 60 kWh for a 300 kg battery. Recharging such a battery in one hour requires a network capable of providing 60 kW - no individual user normally has such available power.

Introducing great numbers of electric vehicles into a big city (Amsterdam, Berlin, Brussels, etc.) will require solutions to the following problems:

- the current distribution network's capacity for the private consumers and firms which would use electric vehicles cannot handle the additional load;

- the load capacity of the low-voltage cabling currently supplying typical groups of houses and/or firms is insufficient for the additional load;

- the total capacity of the distribution network is not sufficient to deal with the total load represented by all electric vehicles;

- the impact on the network of day and night loading.

To plan for the future load caused by electric vehicles on the network, we should account for penetration scenarios for electric vehicles and their distribution between different categories of power. For instance, we can make a distinction between the following classes:

- 5 kW for a small city car;
- 9 kW for a medium-sized passenger car;
- 20 kW for a medium-sized van.

A possible scenario for a city like Amsterdam in 2015 could be 140,000 passenger cars, 7,500 vans, 384 buses and 3000 trucks. If we refer to the respective daily mileage of 50, 90, 200 and 50 km, we reach, including distribution factors, a 329 MW power load.

If this load was supplied during the day ('day loading'), additional power plants would have to be installed. In night loading, however, only exceptional circumstances would warrant any additional supply.

Conclusion

Forecasts:

- in the short term (5 years), no problems are expected for the electricity distribution infrastructure;

- in the medium term (5-10 years), local overloads are possible but should not be very serious;

Necessary Developments:

- in the case of massive introduction of electric vehicles (long term), cost-effectiveness would probably require the introduction of centralized or decentralized management systems;

- electric charging facilities in public areas will have to be analyzed for standardization at a European level;

- the whole parking infrastructure should be studied again in order to be accessible for electric vehicles;

- studies on the impact on the distribution network will be necessary in every city;

- at the level of electricity generation no dramatic problems are foreseen;

- rent-a-car systems can be introduced using the distribution network to support both management and data transmission;

To explore and investigate these developments, the following actions could be progressively adopted:

- organizing demonstration fleets in several cities; these fleets would be concentrated in limited areas in order to analyse the infrastructural impacts and avoid mitigating effects;

- introduce a significant population (10-20%) of electric vehicles into a number of carefully chosen areas to further investigate their impact;

- study the impact of increasing percentages of electric vehicles from city to city.

ELECTRIC VEHICLE ACCEPTANCE BY USERS

What we know about electric vehicles is not sufficient to determine their future performance or popularity. Opinions of value, as well as experience, must be taken into account.

There are many beliefs (and misconceptions) regarding electric vehicles, for example the opinion that electric vehicles are environmentally harmful because the electricity is generated by fossil fuels.

The P-017 report has carried out a survey of likely customer attitudes and the important factors liable to influence it.

These factors are:
- normal car usage;
- car characteristics;
- parking and traffic problems;
- reaction to restrictive measures on cars;
- attitude to electric vehicles;
- preference given to another type of transportation.

As far as Amsterdam is concerned, the following results were reported:

- the inhabitants prefer small vehicles (Fiat, Citroën, Austin, Renault, etc.) more than the rest of the country;

- 48% of the fuel used is lead free, 35% is normal, 9% is diesel and 8% LPG (which is not widely distributed in Amsterdam);

- 19% of the vehicles are firm vehicles and 80% private vehicles;

- 26% of the vehicles have an engine displacement lower than 1200cc, 32% range from 1200 to 1500cc, 33% from 1500cc to 2000cc, and 9% exceed 2000cc;

- 85% of the users covered less than 100 km/day in the week preceding the survey, and their mobility would not be limited by using an electric vehicle; these 85% may be considered the upper limit for electric vehicle penetration;

- 53% of the users estimate that they do not travel more than a 100 km in a typical week; these 53% therefore represent the lower limit of the penetration potential of electric vehicles;

- 70% of the urban population favours restricted access to cities, but most (56%) consider that such measures should not affect them;

- 61% of the population consider that electric vehicles with their present-day characteristics (100 km/h - 100 km range) are a good choice for cities; nevertheless, this opinion does not necessarily imply an equivalent purchase intention.

Note that when considering the penetration potential, the holiday use of vehicles was not taken into account.

Conclusion

The penetration potential of electric vehicles is high, but measures will have to be taken in order to convince and stimulate people to purchase electric vehicles.

A thorough effort will be necessary, as well as an increased number of examples initiated by the authorities, who should consider promoting electric and hybrid vehicle penetration by way of:

- tax measures
- regulations
- creating preferential access areas
- lowering gas emission limits
- lowering noise emission limits

TRAFFIC MANAGEMENT ACTIONS AND INFRASTRUCTURE DESIGN

The introduction of electric and hybrid vehicles could radically improve the local city environment. There are many opportunities which can be grasped at this point, so forward planning is essential.

There are many ways of changing access to motorized vehicles downtown, and each solution has a different impact on the electric vehicle's prospects.

Evaluating the economic consequences of each decision is essential, and difficult. The simplest method consists of replacing all traditional vehicles by electric vehicles in urban areas. The resulting outcome is simple and limited in terms of economic implications, control needs, and the creation of parking lots outside cities. All the advantages resulting from relieving city congestion are lost, except, of course, for the widespread introduction of clean air.

Other actions that could be taken, are, for example:

- speed limiting control measures;
- efficient energy consumption and vehicle fleet management;
- further reduction and enhanced control of emission levels;
- intelligent traffic control;
- reduced number of parking lots in cities;
- increasing the supply and attractiveness of public transport;
- rail transportation development;
- more, higher priority cycle tracks.

Conclusion

The role of electric vehicles in urban areas depends mainly on a range of specific measures in these areas: the availability of such vehicles will not be enough alone.

The same goes for the role of hybrid vehicles on the road transportation network as a whole.

There are several means to initiate the penetration of electric and hybrid vehicles:

- **implementing bus and minibus fleets**
- **use by public services, including the fleet used by the Commission**
- **testing out rent-a-car systems in several cities**
- **implementing electric and hybrid taxis.**

EUROPEAN POSITION IN ELECTRIC VEHICLE DEVELOPMENT

All the reports show important development potential for electric and hybrid vehicles in Europe, whether in scientific or industrial circles. All necessary technologies exist already, but they have not yet been adapted to the stage of pre-industrial or industrial implementation.

Currently, many 'realizations' are only a 'stylistic composition': they lead to the construction of a single prototype, but are not really intended for full development.
To go from this stage to production requires experimental phases with a sufficient number of vehicles and a subsequent industrial phase. The latter is expensive in both time and investment, and therefore needs and deserves support.

Conclusion

Electric and hybrid vehicles can decisively improve the environment, so incentives must be created to allow or prompt their development. Among these incentives, a concerted intention on the part of the cities towards this goal would be fundamentally useful.

A European action is necessary because it will help to initiate this process. Inside the Commission, a close coordination among the different services is necessary in order to improve the efficiency of Community actions.

EUROPE-USA-JAPAN COMPARISON

European industry is currently at a satisfactory position in comparison with American and Japanese positions. However, recent innovations by these competitors may leave Europe behind in the near future.

The American Department of Energy (DOE) has launched a new and significant financing program aiming at developing batteries ($30m from the DOE and $30m from industry). The American car industry have united their efforts in the Ford-GM-Chrysler consortium to face the challenge of the recent legislation in California, which forces manufacturers to ensure that 10% of all cars sold by 2003 are electric, and a further 15% are hybrid vehicles. Note that Los Angeles and Southern California alone contain about 30 million vehicles, so a large market is without doubt on the way.

As far as Japan is concerned, the perceptible development efforts show a similar position to that of other industrial sectors, but secret and much more important developments may well be under way.

Conclusion

Unless Europe makes a concerted, political effort to match these competitors, its current position shall be lost.

OVERALL SUMMARY AND ACTION PRIORITIES

Electric vehicles, due to their typical urban usage, prove to be an important way to reduce pollution.

Hybrid vehicles combine the advantage of electric vehicles in the cities with an extended range. In most demonstrated cases they offer an interesting substitution possibility in the field of energy saving.

Electric and hybrid vehicles and their components are still in pre-production and initial commercialisation phases.

An analysis of the situation in the USA and Japan shows the existence of a very similar situation, as well as the development of important governmental support actions to accelerate industrialization.

European competitiveness has to be supported to rapidly meet emissions and energy goals and to match overseas developments.

Furthermore, users and public authorities must be convinced of the usefulness and effectiveness of electric and hybrid vehicles.

Development Factors

The reports clearly show the appearance of new factors affecting the development of electric and hybrid vehicle transport.

These new factors are:

- **battery manufacturers:** must deal with the transition from producing for a developed car sector to creating a new sector;

- **the electrotechnical industry:** will conceive the electric drive system and control system; the urgency and importance of recognizing the quality of fundamental technology in the power electronics field, and defining R&D programs for it in order to reinforce competitiveness, must be underlined;

- **electric energy distributors:** a prepared distribution network is obviously vital to the successful introduction and development of electric and hybrid vehicles;

- **the authorities and cities:** have a considerable influence through regulation and legislation;

- **standardization efforts:** a considerable amount of work must be performed for the standardisation of components (batteries, motors, etc.), safety, and infrastructures. Vital to achieving the development of electric and hybrid vehicles.

Action Priorities in the Technical Field:

Europe has a good position in the development of the different component technologies for electric and hybrid vehicles. Accordingly, the following action priorities in the following fields are suggested:

- The development of pre-industrialized and pre-marketed fleets based on existing technologies. This must be undertaken on a large enough scale to create useful feedback for future developments. The development of pilot fleets allows similar development of the corresponding components: motors, electronic converters, control electronics and energy sources.

- The short-term and medium-term existing energy sources (Pb-acid, Ni-Cd, Na-S, Na-NiCl, Zn-Br) should be further developed. A pilot plant should be developed in parallel with the pre-marketing of the fleet. Note that the preparations towards full industrialization will have a strong impact on the economics of electric and hybrid vehicles.

- The electric systems (electric and hybrid vehicles) and thermal systems (hybrid vehicles only) have to evolve technically for use on board vehicles. This is the responsibility of the corresponding industries, in strong collaboration with the automotive industry.

- University and research centres should intensify their role in preparing the way for new components. In addition, the development of simulation software to evaluate the merit of different solutions would be a very useful tool if sufficiently general, modular, interactive and widespread.

Action Priorities in the Legal and Educational Field

- Standardization will have the advantage of promoting coordination between development efforts. To begin with they should not be too restrictive.

- Actions demonstrating the advantages and characteristics of electric and hybrid vehicles to users and public authorities should be developed. A good knowledge of these new technologies will both:

- help the public authorities take measures allowing them to meet pollution, energy and traffic regulation goals, and
- prepare users for the new market and regulations.

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October 1992

LIST OF EDS SUBCONTRACTORS

Nr.	Participant	Title
P-001	ELENCO, Dessel, Belgium	Piles à combustible (Fuel Cells)
P-002	Technische Universität, Berlin, Germany	Concepts and models for the introduction of battery charging stations for electric vehicles in centres of big cities
P-003	Univ. Kaiserslautern, Germany	Decentralizing of electric vehicle components by a communication network
P-004	Université Libre de Bruxelles, Brussels, Belgium	Elaboration de stratégies de commande adaptées aux véhicules électriques mus par moteurs à courant alternatif
P-005	Studiengesellschaft für Nahverkehr, Hamburg, Germany	Evaluation of advanced electric drive systems for buses, vans and passenger cars concerning their environmental benefits
P-016	Hydrogen Systems, St. Truiden, Belgium	Technical and economical comparison between a conventional trolleybus system and a bus system based on electrolytic hydrogen
P-017	Energiestudiecentrum Nederland, Petten, The Netherlands	Urban electric transportation systems. Social Acceptance and impacts on environment and electricity production
P-018	Vrije Universiteit Brussel, Brussels, Belgium	Analysis of distribution, training and information infrastructures required for the use of electric and hybrid vehicles in town traffic
P-021	ABB Hochenergiebatterie, Heidelberg Germany	Application of "The Smart Battery Drive System" for electric road vehicles
P-022	ABB Hochenergiebatterie, Heidelberg, Germany	Application of NaS high energy batteries for road vehicles
P-027	PSA, Paris, France	Voiture Particulière Electrique Hybride
P-028	Electric Vehicle Development Group, Richmond, Surrey, England	The environmental impact of electric vehicles, covering materials supply, air pollution, electromagnetic interference, noise and safety factors, related to cost benefits for Europe as a whole
P-030	Institut für Kraftfahrwesen, Rheinisch-Westfälische Technische Hochschule, Aachen, Germany	Analysis of hybrid-drive systems with new electric components and optimization of one concept morphology evaluation and optimization
P-033	Genova Ricerche, Genova, Italy	Low emission urban hybrid vehicle

P-036	The University of Birmingham, Automotive Engineering Centre, Birmingham, England	Analysis of design and operation of environmentally friendly battery and hybrid powered cars, vans and small general purpose vehicles
P-039	PTI Albatech, Trofarello, Italy	Hybrid bus with wheel hub motor
P-043	Daimler-Benz, Stuttgart, Germany	Elektrofahrzeuge mit Batterien und ihr Einfluß auf die Umwelt
P-044	Institut für Stromrichtertechnik, Rheinisch-Westfälische Technische Hochschule, Aachen, Germany	Comparison and evaluation of nickel-cadmium, zinc-bromine, sodium-sulphur and lead-acid batteries