Political, socio-economic and technological environments affecting transport energy use in Europe

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Abstract

The success of advanced technologies depends on their cost, performance and reliability. This paper focuses on gaseous and alternative fuels, biofuels, electric and hybrid vehicles, and hydrogen/fuel cells. After a brief presentation of their technical development status, their market potential, market barriers for introduction, critical success factors, and the applicability in various market segments are discussed. Some market barriers are common to many new technologies. Generally, a combination of policies is required, and a number of supporting measures increases their effectiveness. The following policies affecting energy use in transport are discussed: market incentives, policies targeting technology and vehicle efficiency, and overall system improvement.

Keywords:

Market incentives, barriers to implementation, alternative fuels

Introduction

Demand forecasts are expected to have a substantial impact on international fossil fuel prices. This trend could be reduced by international and national efforts to promote renewable energy and energy efficiency. Most new technologies are developed to achieve the reduction both in dependence from oil and in the emissions derived from energy use, e.g. the development of “cleaner” energy services and technologies.

The transport sector is one of the main responsible for global energy consumption and related emissions. Recent decades have witnessed the development of transportation energy conservation strategies; although still today the assessment of their effects on final energy consumption constitutes an underdeveloped field for researchers (Litman 2005). In recent years, the rate of increase in transport volumes is outstripping the rate of improvement in environmental technology for transport, resulting in increasing environmental problems in the transport sector (Stead 2001). Consequently, there is an increasingly strong environmental argument to enhance the utilisation of cleaner and energy effective technologies. It is necessary to improve the efficiency of the market so that energy-efficient solutions become financially attractive both for enterprises and consumers.

There are many economic, technological and institutional barriers for the implementation of energy efficient solutions in the transport sector. These include entrepreneurial and household traditions, insufficient capital availability, market imperfections such as the external costs of energy use and subsidies, traditional legislation and rules, shortcomings in technical education and training. In this direction, several studies have analysed key factors and barriers for market penetration of new technologies, for example Reddy and Painuly (2004), and Tseng and others (2005).

A wide list of available energy efficient policy measures is applied in most OECD countries to overcome these barriers (Saidel and Alves 2003). It is difficult to find empirical evidence of their effectiveness. In this context, this paper investigates existing market barriers for the implementation of transport-related technology developments, and existing policy measures to overcome these barriers. The following policies affecting energy use in transport are discussed: market incentives, policies targeting technology and vehicle efficiency, and overall system improvements.

1. Framework for analysis of political, socio-economic and technological environments affecting the use of energy in the transport sector

Figure 1 shows the relationships between the different elements of the complex Transport-Energy System and its main driving forces.

Figure 1: Conceptual approach and relationships between the different drivers affecting energy use

Primary drivers of the system are presented at the left side of the diagram:

- *Energy supply*, defined as the world- level existence of energy resources in varied forms, in sufficient quantities, and at reasonable prices;
- The “*PEST* environment” or Political, Socio-Economic and Technological Environment.

These primary drivers affect final energy use in transport through three interrelations:

- Complex interactions between Spatial development and Transport activity;
- Impact on energy availability
- Impact on transport activity

A certain PEST environment will affect both the energy availability and the final volume of transport activity, measured in terms of passenger-km and tonnes-km for each mode of transport. We refer to *energy availability* not as the existence of primary energy resources, but as the possibilities for use in different transport segments.

Once the transport activity is fixed, taking into account the two-way relationship between transport and spatial development shown in figure 1, it is possible to determine energy efficiency -defined as the unit consumption per unit of activity (Stead 2001)- which determines the final energy use (or energy consumption) of the transport sector.

The investigation of existing and future possibilities to change PEST driving factors as a means to ensure energy availability and improve energy efficiency, focuses on technological developments and available policy measures; given a transport activity.

2. Leading technological improvements

Improvements in ordinary combustion engines (petrol and diesel) are being constantly introduced in new models and enhanced versions of current models. Although these developments have a significant influence on energy use, the potential of non-oil resources will be discussed in more detail.

3.1. Natural gas and LPG

3.1.1. Current status

Natural gas. Natural gas basically consists of methane, and it therefore provides a genuine energy alternative. Natural gas can be used in engines in a liquefied form or as compressed gas. Gas has a calorific value similar to that of diesel but due to its lower energy density it needs to be stored in pressured tanks. In order to give the vehicles a running autonomy similar to that of conventional vehicles the storage capacity must be enlarged. The gas tanks are also heavier. The body of the vehicle has to be reinforced since the tanks are usually located on the roof.

Liquified petroleum gas (LPG). LPG engines have developed alongside petrol engines on which they are based. In future years there is a technological potential for developing new LPG injection equipment which will make the use of LPG more attractive.

3.1.2. Market position and future potential

Natural gas. Widespread use of natural gas as a transport fuel will require easy access to the fuel from a large number of suitable filling stations of a similar nature to the current network that would allow rapid refuelling. Currently, certified gas compression units, storage and filling systems are available to meet the necessary criteria for safe and emission-free vehicle refuelling. Suitable gas storage facilities are also available.

A range of existing conventional engines can be converted to run on natural gas. Compared with conventional vehicles, vehicles running on natural gas are characterised by the engine settings and the presence of larger volume storage tanks. Engines designed specifically for natural gas are available as prototypes. Programmes to demonstrate the reliability of these systems are currently in progress. Until this process is complete and the demand for dedicated natural gas vehicles increases, the costs of such vehicles will remain high.

There are two important markets for the use of natural gas and the acquisition of refuelling stations: fleets of vehicles with either a central base that contains its own gas filling station or that has negotiated access to a local commercially run gas filling station (transport companies, postal services, urban goods distribution firms, taxis and communal business services, etc), and conventional fuel supply stations open to the public, which add gas to their supply.

LPG: The potential for LPG use is limited by the availability of LPG in refineries (only 5% of crude oil input).

Pilot demonstration projects are being implemented in several cities throughout Europe. Leading LPG engine companies are continuously carrying out R&D activities concerning LPG engines.

At a European level there is a need for the formulation of LPG to be standardised so that vehicle manufacturers can optimize vehicle performance for the standard fuel in use. Lower road tax and excise duty and more demonstration projects will also help the deployment of LPG as an alternative fuel.

3.1.3. Barriers to implementation

The development of a gas powered engine from a new fundamental concept is risky, as there is no guarantee that the support or demand will be present at the end of the development phase for the end product. *Financial barriers* are a problem to deployment, especially in those countries at the very start in terms of infrastructure development. The capital cost of the gas powered vehicles will tend to be higher than the alternatives, and prospective users of gas powered vehicles will only use such vehicles if the overall lifetime cost is less than the alternatives.

Likewise, the *cost of implementing* a widespread infrastructure of filling stations would be significant, and would need to be reflected in the price of the gas supplied. Companies are reluctant to invest on a large scale unless they are forced to, either by government legislation or by consumer pressures. Depending on the different countries, this means: subsidies for domestic programmes, gas utilities being responsible for refuelling stations and providing competitive gas prices, vehicle makers providing facilities for purchasing gas vehicles.

In order to overcome the current barriers, it will be necessary to create a legislative framework and to define responsibilities in each country covering the use of gas as a transport fuel. This framework will only be developed by the progressive introduction of the technology. Also, probably an aggressive national policy could resolve this problem. For instance: financing compressor stations, allowing only "green" cars in the cities, taxing more the classic fuels, requiring companies to buy a percentage of "green" vehicles.

The costs of operating a gas bus compared with a conventional bus are higher, although there are many aspects, which are not defined and are pending resolution. Once these aspects are defined and the existing distortion in prices is eliminated, gas could become competitive. The main aspects referred to are:

- The absence of a tax on the use of natural gas as a transport fuel - this should be small or non-existent, taking into account the environmental benefit which it provides compared with other fuels and energy diversification. Currently there is no coherent European Union tax policy related to alternative fuels, although individual country governments are beginning to provide tax concessions for Natural Gas Vehicle and alternative fuels.
- The price of the gas - in some countries there is still no commercial price for the use of gas as a transport fuel. Also, the prospect of large fluctuations in the cost of gas as a result of changing government policy or restrictions of future supply, are seen as a potential disincentive by users.
- The additional cost of the vehicle compared to a conventional vehicle - this cost would be eliminated if vehicles were mass-produced.
- The additional cost of the refuelling station.

One feature of the market, which has a considerable effect on the implementation of gas as a transport fuel, is the fact that gas companies throughout Europe are *not unanimous over how gas supply should be organised* in terms of supplying it in compressed or uncompressed form.

The *fuel availability* must be assured before a market can be established. Refuelling infrastructure is currently the main barrier to the introduction of gas in transport fleets, requiring considerable time and resources.

The *lack of specific legislation* and safety certification provides nowadays a major barrier to the introduction of gas and LPG as commonly used automotive fuels. There is no legislation to regulate the use of natural gas in vehicles. As a function of the degree of introduction of gas as a transport fuel, each country has prepared guides and standards for use. Also the lack of common standards for LPG is an important inter-operability barrier, as vehicles would need to be readjusted for each different formulation of the fuel.

The *tax* applicable to gas used as a fuel in transport is a decisive factor in deciding on the financial viability of this technology. Incentives of a fiscal nature should be based on the environmental improvement brought about by gas compared with the use of other fuels. The European Commission has proposed that the tax applicable to alternative energies should not exceed 10% of the amount of the tax applicable to fossil fuels. Given the loss of income that this would involve, governments have treated this proposal with caution.

Additional market barriers for the introduction of Liquefied Petroleum Gas vehicles.

In many European countries, there is a *lack of technical information* on LPG. The LPG wholesalers do not dare to have a strong marketing policy: they fear that this will attract government attention on this marginal fuel and that a LPG fuel tax will then materialise. The present infrastructure is also too old to support a sudden strong increase in demand. Therefore, a first step would be to have a government declaration certifying the prices of LPG and of the tax on LPG cars as fixed for the next years. This would give security to LPG wholesalers to start investing when the market begins to expand.

Since LPG is heavier than air, its *use is subject to certain restrictions in various countries*. Workshops must be adapted for these vehicles and equipped with a fireproof electrical system, drainage U-traps and special gas detectors and ventilation systems, all adapted to the number of vehicles used by the workshop. The right safety installations should be made compulsory in vehicles and refilling stations. The indoor parking should be adapted with specific ventilation.

The main problem is the *accessibility of fuel* (which is not an issue for fleet operators refuelling from their own garage, but is for private users), lack of governmental measures for stimulating uptake and the future of pricing/taxation levels.

Financial barriers are quite similar to those for the deployment of natural gas engines. The LPG car is still a gasoline car retrofitted for LPG. This creates a supplementary cost. However, this should not be a fundamental barrier considering the lifetime of the car and the fact that the LPG system can be taken from one car to the next one. Due to the extra cost of LPG equipment there is a need for an adequate financial regime for road taxation and for excise duty. Otherwise the turning point for the decision to use LPG will be too high. The supplementary tax for LPG cars compensates the advantage coming from the price of LPG itself for cars running less than about 15.000 km/year, when compared to a gasoline car.

The *supply and distribution systems* that are required for this alternative fuel could provide a significant barrier to its deployment. However this barrier is tempered by the fact that the existing players in the market - notably the major oil companies - would also be significant players in the LPG market (as it has similar origins to more traditional fuels). An LPG station is hardly any different from a petrol station. The actual distribution network could not cope with a mass increase of LPG vehicles. The rise of the market must be progressive in order to avoid bottlenecks but strong enough to give the signal of needed investment to distribution companies.

It is unlikely that gas powered vehicles will take a significant proportion of the private vehicle market, due to the low number of public gas filling stations. However the market for fleet vehicles, especially those based in urban areas with a regular base is likely to be a suitable target, since vehicle autonomy is limited. The types of vehicle that are most likely to be converted to gas power (buses and urban delivery vehicles) tend to have a relatively long service life. Therefore long term uncertainty over gas prices and supply is likely to discourage the use of the technology. Additionally, the *long vehicle life* means that even if all vehicles due for replacement were replaced with gas powered vehicles, it would take a significant time before the fleet became 100% gas-powered.

It is unlikely that LPG vehicles will take a significant proportion of the private vehicle market, due both to the low number of public gas filling stations and the overall limitation on LPG availability in the longer term. However the market for fleet vehicles, especially those based in urban areas with a regular base is likely to be a suitable target.

The fact that a car buyer must first choose between gasoline and diesel and then decide to install LPG (and pay a supplement for installation and for tax) is a clear barrier for private vehicles.

3.2. Hydrogen

3.2.1. Current status

A fuel cell consists of an electrolyte sandwiched between two electrodes. Fuel is oxidised at the anode, liberating electrons which flow via an external circuit to the cathode. The circuit is completed by a flow of ions across the electrolyte that separates the fuel and oxidant streams. Practical cells typically generate a voltage of around 0.7-0.8V and power outputs of a few tens or hundreds of watts. Cells are therefore assembled in modules known as stacks and connected electrically to provide a larger voltage and output. The other major components of a fuel cell system are a fuel processor and a power conditioner. For vehicle applications, the fuel cell stack and fuel processor are together described as the fuel cell engine.

Fuel cells are a surface related technology, while Internal Combustion Engines are volume related. This means that fuel cell size and costs scale linearly with power (size and costs per kW of power are constant independent of rated power), while the power related specific size and costs of Internal Combustion Engines decrease with increasing power. The efficiency of fuel cells is ideally independent of rated power, while the efficiency of Internal Combustion Engines increases with rated power.

Although the fuel cell technique has been known for more than 150 years now, the application to transport is still in a developing stage. Of all the fuel cell types it is the Polymer Electrolyte Membrane Fuell Cell technique which has the biggest potential for cost reduction. So far test applications in cars proved good acceleration performance up to 90 km/h and a maximum speed of 110 km/h. The range is 250 km. As a long-term option, possibilities for cost reduction are considered in the reduction of catalysts load, reduction of CO sensitivity, simpler systems, which do not require pressurised operation. System development has also to consider environmental issues, such as performance during vibration, or operation and parking at outdoor temperatures between -30°C and +40°C.

Another big research field is the development of direct Methanol Fuel Cells. This concept uses methanol as a fuel and does not need a pre-reformer. The stacks can be cheaply mass-produced and the use of methanol assures simple storage and distribution of the fuel. Major technical problems still exist. The necessary research and development will postpone a possible introduction for a longer period than for the other fuel cell types.

3.2.2. Market position and future potential

Fuel cells are usually classified by their electrolyte. The main types and their potential applications are shown in Table 1.

Table 1: Main types of fuel cell and their applications

3.2.3. Barriers to implementation

The main barrier to the deployment of all fuel cell types is cost; the costs have to be brought down enormously, before a market introduction can take place.

The lack of an existing fuel infrastructure is a barrier to the introduction of fuel cell vehicles fuelled by hydrogen, methanol or natural gas. Development work is now under way on gasoline fuel processing for polymer electrolyte membrane fuel cell systems but this represents a major technical challenge.

Other barriers include a lack of operating experience and a lack of awareness of the technology among potential users and fuel suppliers. Safety risks in the use of hydrogen are mainly attributed to the hydrogen storage and supply to the engine, not to the engine itself.

The deployment of fuel cells will depend on the gas price, since hydrogen as well as methanol will be produced from natural gas in the near future. Hydrogen generation from water via electrolysis or production from coal and biomass is currently not economically feasible, therefore the investment risks are very high.

The automobile market is not only characterised by technical requirements - emotional and irrational aspects play an important role in the decision process of buying a car. Different requirements for different uses are likely. They differ for a car used to travel to work from a car used for leisure or holiday and for one needed for shopping. The widely-differing customer desires cannot be fulfilled by any of the known propulsion technologies. A summary of the requirements is an economic operation with low or zero emission.

To make fuel cell technology competitive, a broad introduction into the market is necessary. This is only possible after changes to the existing infrastructure. Hydrogen production and supply routes to the consumer can have very different infrastructure requirements. Decentralized onsite hydrogen production at the point of consumption makes maximum use of existing energy infrastructures, especially those for electricity and natural gas (or in the case of biomass of the road infrastructure). Large-scale centralized hydrogen production requires hydrogen transport and distribution infrastructures existing to a very limited extent at present. Existing infrastructures for natural gas distribution may be used for hydrogen in the future with limited modifications. The build-up of a basic hydrogen refuelling infrastructure is an essential challenge for the short to mid-term as it has to be in place at the beginning of the commercial introduction of hydrogen fuel cell vehicles. Economically, this challenge is not as big as it might appear. In the European Union, approximately 100,000 refuelling stations supply fuels to road transport. About 20% of these, or 20,000 stations, should be equipped with hydrogen dispensers before fuel cell vehicles are brought to the mass market. Assuming investment costs of 1.3 million Euro per station sums up to 26 billion Euro for a basic refuelling infrastructure.

There are 5 main issues that are critical for the introduction of hydrogen in transport (EC, DG JRC, 2004):

- The cost of fuel cell vehicles and the cost of hydrogen as a fuel are expected to continue to fall in the future as a result of the constant improvement of technologies. A crucial condition for the reduction of costs is the realization of economies of scale in both vehicle and fuel production. The relative cost of hydrogen compared to conventional or other fuels is the main factor from the economic point of view. The boundary conditions for which hydrogen would have an advantage correspond to the case of high oil prices combined with either low natural gas prices or low electricity prices.
- The performance of fuel cell or hydrogen-based vehicles can potentially match that of conventional technologies. Fuel cells even offer some advantages in auxiliary power units and some niche markets. But -everything else being equal-hydrogen based technologies do not still offer enough advantages to shift user choices. It is obvious that in order to be competitive, they have to provide comparable performance at comparable cost, with accessible and reliable infrastructure. Otherwise, only a strong shift in user choices towards clean technologies would justify the substitution of the proven conventional technologies.
- Distribution and storage raise important challenges. The development of a wide network of refuelling stations is a major requisite, but would need a critical mass

of demand before it takes off. In this context, it is indispensable that the cost of hydrogen distribution is kept low and that its introduction is massive, so that the investment costs are justified.

- Significant environmental benefits may occur, depending on the primary energy used for hydrogen production. Electrolysis-based solutions would only be beneficial for the environment as long as the electricity used for the electrolysis is produced from carbon-free fuels. Solutions based on reformation of fossil fuels would be neutral from the environmental point of view. The introduction of hydrogen in transport would therefore be feasible only in the case of low cost of renewables in electricity generation or in the case of high-performance fuel cells with low prices of natural gas or biofuels. Only stringent environmental legislation world-wide would increase the options for fuel cells, local restrictions will not open the market.
- The commitment of the industry could be influenced by policy. The key industrial stakeholders (car manufacturers, refineries and fuel providers, infrastructure providers, fleet managers) will invest in a new technology only if the future market prospects are clear. The role of policy makers should therefore be that of decreasing uncertainty through suitable and timely policy measures, legislation and standards. Legislation could also influence user choices, by promoting the use of hydrogen, penalising CO_2 emissions, or by limiting the use of conventional technologies in certain areas.
- The year 2020 seems to be too early for a wide scale introduction of hydrogen or fuel cells; it is questionable whether even year 2030 is a feasible time horizon.

But it is also clear that even if the goal is the shift to hydrogen after year 2030, the preparation needs to start already.

3.3. Biofuels

3.2.1. Current status

Biofuels are liquid fuels produced from biomass feedstock via a number of chemical processes. The two biofuels that have advanced the most are biodiesel (produced from vegetable oil) and bioethanol and its derivative ethyl tertiary butyl ether, (ETBE) (produced from plant sugars). Other liquid biofuels have been researched but have not gained the commercial potential and market share.

Biodiesel can be operated in any diesel engine with little or no modification to the engine or the fuel system. The technologies for the production of these liquid biofuels are well understood chemical processes using proven techniques. Typical feedstock for these fuels are mainstream agricultural crops. The conversion technology in itself is low risk because it is well proven. The development of the liquid biofuel industry was quite quick because of this, but major reductions in the cost of biofuel production have not occurred because of the relatively high feedstock costs.

Most countries have tailored standard practices to their own situation. This has largely depended on the different feedstock and the final application of the biofuel (mainly transport). Research into the production processes have focused on the efficiency of the conversion, and hence reducing the costs of production. Investigations in Europe into using lignocellulosic material are underway. There are however some constraints to this, including the high cost of the enzymes and the strength of the agricultural sector which continues to campaign for the profitable industrial use of food crops grown on set-aside land. The main scope for innovation is the use of waste cooking oil or lignocellulosic material as cheaper feedstock. These will help to reduce the costs of fuel production quite considerably and help to make it more competitive with fossil fuels.

3.3.2. Market position and future potential

The main factors which have been instrumental in the production of biofuels in Europe, are very similar for the rest of the world: (1) the need to develop an indigenous transport fuel supply because of the dependence on imported fossil fuels, and (2) storage of over produced agricultural produce is extremely expensive. These are traditional and 'practical' reasons for examining the prospect for liquid biofuel use. More recently, the environmental damage caused by burning fossil fuels with the resulting global warming, have had a positive impact on the consideration of liquid biofuels as a serious fuel option.

Once these generic issues have been taken into account, the commercial availability of the fuel will depend on another the scale of industrialisation and access to a suitable conversion technology, a suitable infrastructure to get the product to the consumer and public support for the use of liquid biofuels, particularly when food crops have been used in their production.

The market status of bio-ethanol and ETBE technology has a similar history.

Europe has taken the lead position in the production of biodiesel across the world, with a current production of over 500,000 tons, and an installed capacity of 1 million tons in over 20 production sites, capturing 1% of the diesel market. There are a number of key interacting factors which have led to the commercial availability of liquid biofuels in some European countries and not in others. The reasons are usually political, but the source of the 'political will' may vary. For example, the widespread introduction of set-aside agricultural land. Production of non-food crops; oilseed rape or sunflowers for methyl ester production would appear to be an ideal alternative. Coupled with the actual or perceived environmental benefits of biofuels, there is a very strong agricultural lobby for their development and use. In addition, some governments have chosen to implement the outstanding EC 'Scrivener' Directive, which recommends a certain level of tax relief for pilot biofuel production plants. Clearly, where countries have implemented this scheme, there is considerably greater incentive to produce the biofuel; without this tax relief, it is very difficult to compete.

The more sophisticated conversion technologies (enzymatically catalysed options) are likely to benefit from further R&D to reduce costs.

There is a very attractive technology potential for both biodiesel and bio-ethanol of 12% of market share by the year 2020, which equates to 45 million toe.

3.3.3. Barriers to implementation

The *availability of information* to potential investors is mixed across Europe. This is largely due to the conflicts surrounding the environmental benefits of the fuel. Farmer co-operatives and trade associations have tried to promote the exchange of information. More co-ordinated information availability is likely to facilitate future investments in biofuel technologies.

The main risk barrier to the deployment of liquid biofuel technology across Europe is the *uncertainty surrounding feedstock availability*. The set-aside scheme was hailed as a suitable mechanism to promote non-food crop production. If farmers were restricted from growing food crops, then the land could be suitably used for other applications. However, the great success of the set-aside scheme in reducing cereal crop surpluses, has lead to decreasing percentages of land to take out of food production, and has destabilised the non-food crop industry, rather than enhanced it. The variable set-aside rate, has lead to uncertainty in the agricultural sector. Other mainstream food crops in many cases provide better returns than oilseed rape for industrial purposes on non-set-aside land. This competition for land use will continue to be a problem, and as such, farmers will be reluctant to enter into long term supply contracts for crops whose return may fall in comparison to other crops.

The main restriction across the EU on the further development of the biodiesel industry is the 1993 *Blair House agreement* which is part of GATT. This agreement imposes a limit on the amount of rape meal that could be produced as a by-product from industrial oilseed crops grown on set-aside land across the EU to the equivalent of 1 million tons of soy meal per year. This equates to approximately 900,000 ha of oilseed production across the EU.

Another key legislative barrier to fuel use is the *lack of a common European standard*. These standards are a pre-requisite for the approval of liquid biofuels by engine manufacturers and the public, whose confidence in the fuel will be undermined without a stamp of quality (NTB-Nett Phase I Interim and Final Reports, 1995; NTB-Nett Phase II Final Report and Annex, 1997; Alternative Fuels For Transport, Kerr Walker, 1996).

The *price distortion* for liquid biofuels normally works in its favour - ie. the tax relief which enables it to compete with fossil fuels. However, the complex nature of the calculation for crude oil inevitably means that the final price is distorted. As well as price distortions in the market place for the fuel, there are price distortions in the feedstock market. This is particularly the case for oilseed rape which has a noticeable price difference depending upon whether it is sold for the food market or for the non-food market.

3.4. Electric and hybrid vehicles

3.4.1. Current status

There are two types of electric in-source vehicles, pure electric and hybrid. In the pure electric vehicle, the drive power required is solely obtained from a set of batteries. This restricts the range of the vehicle because the batteries need to be recharged from the grid. In the parallel hybrid, electricity is obtained from a small diesel generator set with an optimised constant turning system and power which allows the vehicle to travel at low speed. Additional power needed for acceleration and start-off is provided by a set of batteries which are recharged while braking and when the vehicle is stationary. In the series hybrid concept, there are two drive systems, electric and mechanical heat, which can be separated or coupled in a single kinematic chain. When the electric drive is used, energy is obtained from a set of batteries which is partly recharged when travelling under mechanical drive and by using braking energy.

Electric vehicle technology has developed to the point where it can be immediately introduced into the market although present purchasing cost and performance prevents its distribution. The pure electric vehicle can already be built and used for urban applications but is not yet totally mature. Most of the electric vehicles were not specifically designed from the start as such and they also have the added problems associated with the batteries.

The hybrid vehicle is less mature. Many options exist and more development is needed to determine the most appropriate solutions. An existing promising hybrid technology is the diesel-electric drive in serial configuration.

Increasing battery energy density and cycle lifetime are crucial factors, to which the industry is directing major effort. Current technology developments focus on the incorporation of new developments into the electronic components and more energy efficient driving equipment. Attention is also focused on the reduction in weight of the electric drive train, including the motor and the battery.

3.4.2. Market position and future potential

The world electric fleet can be estimated at some 10,000 vehicles, with a European share of about 60%. Most of these vehicles are first-generation, low performance, modified conventional small cars.

The supply of infrastructure, both at home and in car parks etc, for recharging batteries will be crucial to the take up of electric vehicles. Without a reliable system in place, people are very unlikely to purchase private cars powered by batteries. This consideration is less important for fleets of delivery vehicles with limited range, for example, which could be charged at the garage.

3.4.3. Barriers to implementation

There is a considerable amount of *information* available on the progress of electric vehicle design, and there has been very rapid development in many battery technologies which is likely to continue. Thus, decision makers are now faced with a profusion of technologies, none of which has yet accumulated enough experience to answer all the questions associated with it.

The development of a completely new propulsion system for automotive vehicles involves huge *investment*, without any certainty of return. There is no real market for these vehicles in their present form, and there is no infrastructure to support them in operation. Much of the battery technology is very new, and not proven in the context of powering vehicles. The investment needed to tool up a car manufacturing plant for mass production of a completely new type of car has been estimated at 1 billion USD. Such an enormous investment is beyond the reach of any but the largest manufacturers, and the risks attached to a totally new type of vehicle preclude such investment at this time. Financial support for companies developing battery technologies is difficult to find.

The *price of electric vehicles* will depend on the degree of industrialisation involved. Without taking into account the cost of the batteries, the cost of producing electric vehicles will be similar to conventional vehicles for lines of 100,000 vehicles/year. If anything the current *prices of electricity* should favour the electric vehicle. Electricity is not presently subject to the same levels of duty as petrol and diesel.

The present market for cars in the EU remains dominated by the multi-purpose family car, which can be used to both run local errands around the urban area, and tour the country on holiday carrying the entire family and luggage. Despite the increase in two-car households there is still little differentiation of function between the different cars. Electric vehicles at the moment are suited to only limited functions. This *limited functionality* will prevent those buyers seeking multi-functions from their car from considering an electric vehicle. In addition to the limited functionality, the question of infrastructure remains to be solved. Without co-operation between all the players - vehicle manufacturers, electricity suppliers and policy makers - the introduction of electric vehicles will not be feasible. Also, the image perceived by car-buyers of the performance of electric vehicles may harm their sales potential.

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 are not expected to be very serious.

3. Policy options to overcome barriers to implementation

At country level, a wide variety of policy measures affect the use of energy in transport. Generally, a combination of policies is required, and a number of supporting measures such as public education, increases the effectiveness of many political measures. Policies affecting energy use in transport are further classified as: market incentives, policies targeting technology and vehicle efficiency, and overall system improvement.

4.1. Market incentives

4.1.1. Fuel pricing measures

Fuel pricing measures consist of fiscal incentives to encourage the use of certain energy sources and their end-use applications. Energy products generate most of the tax revenue in the EU Member States. Although energy products are heavily taxed, the tax itself varies from product to product and from Member State to Member State, as well as the share of total tax revenues stemming from the transport and energy sectors. Despite major disparities, taxation, particularly in terms of ‘excise duty’, can be an effective tool in energy policy. A more harmonized Community framework on taxation of energy products is needed to prevent competition between member states.

4.1.2. Tax incentives and credits for efficient technologies

Performance-based tax incentives and credits for advanced technology such as fuel-efficient vehicles are intended to help jumpstart the introduction and purchase of advanced vehicles. Once the new technologies become widely available and produced on a significant scale, costs should decline and the tax credits could be phased out. There is a wide variety of possible instruments to encourage the development of new efficient technologies. For example, the US Department of Energy recommends tax incentives for hybrid and fuel cell vehicles. These credits would save energy directly due to purchases of equipment eligible for the credits, but even more importantly, if the credits helped to establish these innovative products in the marketplace and reduced the first cost premium so that the products would be viable after the credits were phased out, the indirect impacts would be many times greater than the direct impacts.

A variety of “incremental” technologies can be applied over the next 5-10 years to conventional vehicles at very low or even negative cost (taking into account fuel savings). The International Energy Agency estimates that these technologies could reduce average new light-duty vehicle fuel consumption by up to 25% by 2010, if aggressive policies such as fuel-economy-based fees and rebates are implemented very soon (IEA, 2003).

4.2. Technology and vehicle efficiency

4.2.1. Fuel standards

Regulatory standards set either technology standards or performance standards, enforceable through fines and other penalties (IPPC, 2001). There is no general agreement on terms by which regulatory standards are classified. They may apply to a product, a line of products, or the provision of a service. Although all regulatory standards have consequences on economic decision-making, they differ from market-based instruments, which operate by directly changing relative prices rather than by specifying technology or performance outcomes.

Regulatory standards can be effective policies to address market failures and barriers associated with information, organization, and other transaction costs. If continually modified to account for technical progress, they can provide dynamic innovation incentives. Regulatory standards can yield net benefits to society if the costs associated with the regulation are less than the losses due to informational barriers.

Energy efficiency standards in general are widely used in over 50 nations and the number of standards is still growing. Energy efficiency standards are most effective in countries with high and growing consumption and in countries in which consumers' energy awareness is low because of historically low energy prices.

The development of an effective regulatory standard requires national and, potentially, international, leadership to balance the interests of manufacturers, consumers, environmental non-government organizations (NGOs), and other interest groups, while creating sufficient societal support and incentives for successful implementation. While decisions to introduce regulatory standards are commonly made by legislatures, the development and implementation of standards over time is often left to a less transparent public administration. The enforcement and monitoring of all policy instruments is costly and subject to failures.

4.2.2. Voluntary agreements

"Voluntary agreement" is used here to mean an agreement between a government authority and one or more private parties, as well as a unilateral commitment that is recognized by the public authority, to achieve objectives or to improve performance beyond compliance. The tool is gaining popularity to cope with environmental issues. This type of policy measure is administratively and politically feasible, especially if it is used in a policy mix or in new policy areas (OECD, 1998). Most industries seem to prefer voluntary agreements instead of other tools. There is a suspicion that if the goals are too ambitious, they will not be attained. Voluntary agreements may precede more formal arrangements. For example, the vast majority of greenhouse gas emissions reductions called for in the US Climate Change Action Plan come from voluntary initiatives to increase energy efficiency. Voluntary agreements are not a substitute for mandatory efficiency standards, they are complementary.

From a methodological perspective, it is rather complex to assess the effectiveness of voluntary agreements because it is difficult to establish a counterfactual and no empirical evidence is available on their cost-effectiveness (OECD, 1998).

4.2.3. Measures to improve in-use fuel economy

Under this category we can find measures such as vehicle inspection and maintenance programs, on-board driving technologies and driver training, speed limits and enforcement, or vehicle scrappage programs.

4.3. Overall system improvement

Policy instruments to improve information are applied to raise awareness, to stimulate research, and to help implement measures. Poor information is widely recognized as a barrier to improved energy efficiency (IPPC, 2001). Information gaps result in uncertainties, risks, and missed opportunities. Social marketing is becoming a crucial instrument to create an appropriate social environment for policy measures. Governments communicate their targets and policy measures to the public and influence the preferences.

There is a need for expansion of R&D efforts, e.g. with industry to further develop key technologies, such as vehicle on-board hydrogen and electricity storage (IEA, 2003). While many research programmes are already underway, greater co-ordination and co-operation across countries and regions, especially in terms of demonstration programmes, could help speed learning and commercialisation of key technologies. Such efforts should focus on developing both cleaner and more efficient vehicles by adopting aggressive emissions goals to complement fuel economy goals.

4. Conclusions

Regardless of the type of renewable source of energy, there are obstacles of a structural nature to its development. In many areas there already exist energy-efficient products and solutions that could lead to significant energy savings. In many cases these products and solutions seem to be financially very attractive for consumers. Despite this, enterprises and consumers often do not choose the energy-efficient solutions when buying new products. End users need better information. Also, the life time of a car is increasing and this slows down the replacement of the car park. The development of national economies may influence the replacement of the car park.

Market imperfections include the external costs of energy use as well as subsidies, traditional legislation and rules, and traditions, motivations, and decision-making in households, companies, and administrations.

Most important innovations are developments of reliable technology. One *risk* involved is that the vehicles implementing new technologies may have problems causing rejection amongst users of the vehicles which incorporate them. The *investment risks* in new technology are also high. Manufacturers are unlikely to take such risks unless the regulatory framework both enforces and supports the development of new engine technologies. The role of policy makers should therefore be that of decreasing uncertainty through suitable and timely policy measures, legislation and standards.

New technologies require an *infrastructure* capable of guaranteeing that faults are resolved in all parts of the countries where vehicles incorporate them. This will entail serious problems for a widespread use of some new energy sources due to difficult handling and storage. This problem may be limited for specific market segments.

The additional cost involved in applying new technologies will gradually go down as their use becomes more widespread over the entire range of engines on the market and production costs gradually also drop. But it must be taken into consideration that differential duty on different types of fuel or yearly taxes based on the power of the engine could have a large impact on the future development of engine technologies.

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Figure 1: Conceptual approach and relationships between the different drivers affecting energy use

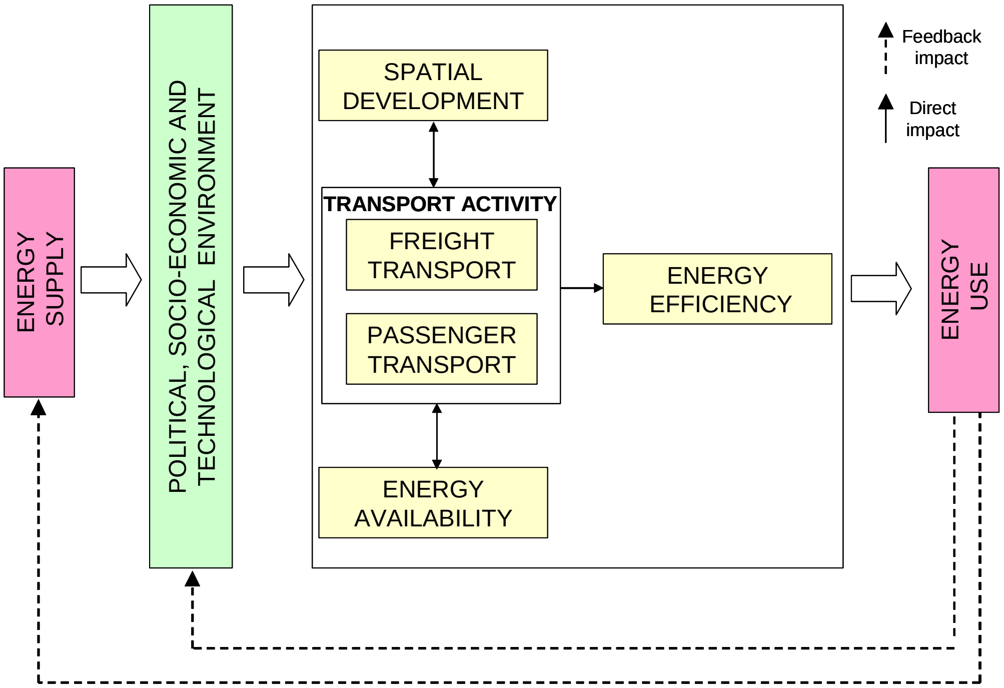

Table 1: Main types of fuel cells and their applications

Fuel cell	Applications
Solid Oxide Fuel Cell	Combined heat and power, Power generation
Polymer electrolyte membrane fuel cell or Solid polymer fuel cell	Transport, Combined heat and power, Distributed power generation
Alkaline fuel cell	Space, Transport
Molten carbonate fuel cell	Power generation, Combined heat and power
Phosphoric acid fuel cell	Combined heat and power, power generation