Economics of Global Warming

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Economics of Alternative Fuels

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Preface

There may have been not many other inventions during the last 150 years, which have influenced and changed our lives in such an intense way as the gasoline powered has done. But even if no one would seriously deny the great benefits this technology has generated for our societies, there are worldwide growing concerns about the future of the underlying technology.

The two main problem of our mobility is that the used resource is a scarce fossil one, which the western states have first experienced during the oil crisis in the 70ies. Furthermore we change the very sensible balance in the world wide climate by burning these non-renewable resources in power plants or combusting engines.

The huge amount of carbon being embedded in Biomass or oil for million years has been blown in the atmosphere in such a wasting way, that the concentration of carbon dioxide (CO_2) has reached a level in the last 100 years never seen before in the history of our planet.

The consequences for our planet are not only rising temperatures. The expected rise of the sea level could erase whole countries like the Netherlands from the globe. The higher temperature and the correlating enhanced energy level in the atmosphere will generate a more extreme weather than before. This means more rain in shorter times, stronger hurricanes, and longer periods of drought and unpredictable consequences for the ecosystem.

The expected changes in climate will also affect the economies. The financial consequences, first estimated and summarized in the Stern report, may become a serious thread to the world wide growth of the economies.

The started process of global warming, caused by the higher CO_2 level in the atmosphere, can not be stopped on short notice. We will have to finds ways to handle the changes in climate and dealing with the consequences. But we do have opportunities to stop this process on a certain level. The climate targets formulated in the Kyoto Protocol are a first step towards a sustainable handling with the resources of our planet. But how can the ambitious targets, for instance the lowering of the CO_2 Emissions, be realized? While alternatives to burning fossil fuels in power generation are mainly consists in nuclear power plants, as long as we will generate an amount of power sufficient for an industrial country, there are some fuel alternatives existing in the transport sector. These may have the potential to prevail a balanced CO_2 emission level, as long as they are based on biomass or consists H_2 produced with solar, water or wind energy.

However, as fuel alternatives like bio ethanol are technically and economically usable, they simply are not available on the existing network of filling stations in most industrial countries. Other fuels, like natural gas or H_2 need a new distribution network, which makes huge investment necessary. But not only this network must be build, the potential consumers also have to be argued into the break through of the underlying technology. No one will produce or buy a car powered by natural gas, if there is no opportunity to buy the needed fuel on an adequate network of filling stations.

We will present a review on the existing literature dealing with these network effects and on the alternative fuels, distributable by this network today or in the near future.

The paper is organised as follows:

The first chapter presents an insight to network effects in general and in the transport sector. We will highlight some reason for the difficulty in overcoming the lock-in-effect of using fossil fuels for our mobility. Furthermore we will show that a worldwide growing awareness for environmental problems may be not sufficient to generate a switch to more environmental friendly technologies.

Second, we will give an insight to the lock-in-effects of technologies. Therefore we will highlight some reasons, why the technology of burning fossil fuels has become locked-in and which may have been the key factors which mend the end of the competing technologies.

The table in Chapter 3 summarizes all alternatives to fossil fuels under economical, environmental and technical aspects. As you will see, there are some existing alternatives to the common gasoline cars. Like ethanol used mainly in Brazil or the Hybrid Technology which has been pushed by the Japanese automobile manufactures during the last years.

In the following Chapter 4, two case studies are presented. One features Sweden, which has the target of being independent from Oil Imports by the year 2020. As Sweden has no major oil resources by its own, this is the reason why they want to abandon burning fossil fuels from power generation as well as in the transport sector. The Swedish government is working with the carmakers Saab and Volvo to develop cars and Lorries which burn ethanol and other bio fuels. Last year the Swedish energy agency announced that they planned to get the public transportation sector to move out of oil dependence.
Even if the Swedish plan, switching the whole transport sector to bio fuels, is more a response to rising prices of oil than to environmental problems, it will provides a nearly balanced CO_2 emission for this sector.

The last Chapter will give some implication recommendations for Germany. The German transport sector is responsible for about 20% of the total CO_2 emissions. So far, Germany is not expected to reach it's in the Kyoto Protocol agreed targets. We will try to give a statement if this target could be realized in the transport sector by using the existing network and technologies, which have proved there reliability and cost effectiveness.

1 Network Economic Analysis of Filling Stations

1.1 Introduction to Network effects

Although a lot of research has been done on network effects in the telecommunication market, the software industry or the consumer electronic industry, we find less research concerning the network effects generated through the filling stations for the transport sector. This may be grounded on the fact, that filling stations are quite an old technology compared to the ones mentioned above. The network has been built over the last 100 years and a competition between different standards never occurred. It is obviously, that without a dense mashed network of filling station most of the automobile users were not able to gain any benefit from their cars. The costs for a private filling station in the garage would exceed the costs for the car and are only common on farms, car dealerships or huge garages. Another explanation for the missing interest might be the fact, that no changes in the technology occurred during the last decades and the filling station network only was seen as supportive for our mobility. But with the need of changing the fuels for our cars, the focus has to be set on the network. It has become obvious, that a technical change in our mobility also requires some more or less significant changes in the distribution network. Consumers on the one hand will only accept a new fuel type if they are convinced that many other consumers also joins the technology and they will not lack of the distribution network for the fuels (the direct network effect). The vendors on the other hand will only invest in new filling stations, if the customer basis is large enough (the indirect network effect). This situation seems to be kind of the hen or egg problem. Conrad (2006) showed in his working paper, that this problem under certain circumstances might only be solved through governmental intervention. Market mechanism would fail to introduce the new and better technology, if consumers environmental concerns and therefore their willingness to pay is weak, and the new technology is too expensive or could not profit from economies of scale in the beginning. The government then has to raise consumers willingness to pay, for instance with advertisement campaigns or subsidies. But Shy (2002, page 6) noticed that governmental intervention does not necessarily leads to the first best standard solution. He mentioned two cases in the television market, where governmentally promoted standards (the high definition standard in Japan and the CBS colour TV standard in the US) missed consumers. As governmental parties are partly financed by industries, they might support the second best standard, instead of moving forward the efficient first best standard.

1.2 Network externalities

Consider an email or telephone service, you can join, but no one else does. What use could anyone have from this service, if there is no one to answer him? The utility of these services depends on the number of other clients using similar or compatible products. Such externalities are called adoption or network externalities (Shy, 2002, page 3). In our case of the filling station network, a certain number of clients have to be expected to adopt the technology; else no investor would be willing to pay for the required infrastructure. On consumer's side, the density of the network is important for the mobility of the users. The expectations over the size of the network are a crucial fact which influences the decision to join or reject the new technology. As Conrad (2004, page 15) shows, the expectations of the consumers could generates multiple equilibria in market outcome, where in one no consumer joins the new network and in one all does. Therefore, environmental concerns about the incumbent technology have to be very high, as otherwise the willingness to pay for the new technology would be too weak. A new technology, in his paper the hydrogen powered car, may lack of economies of scale in the beginning. Economies of scale in production mainly results from learning processes and in decreasing fix costs for one unit produced. The economies of scale of filling station primarily results from a larger consumer basis which uses the offered fuel. Because of the strict ecological and safety restrictions, the investment cost for a filling station are quite high, and to offer competitive prices makes it necessary that these fixed sunk costs are carried by a large consumer basis. So in addition to the higher costs of the H_2 engine system and the weak direct externalities of the dens network comes the higher price for the fuel distribution. In case of bio fuels, the environmental restrictions are missing, which leads to very low investment costs and a competitive advantage.

1.3 Complementarity, Compatibility and standards

Goods are called complements, if they mutually increase consumer's utility when used together. Complementarity in a certain market means, that consumers are shopping for a system (Shy 2002, page 2), cars and fuels, rather then for a single good. As most modern cars, because of the high complexity of the engine system, are only workable with one kind of fuel, the relationship between these two goods is called "perfect complements". In this case, the consumption of both goods together is not only necessary to derive the maximum – but any utility at all.

Most of the networks are characterized by a certain standard or compatibility between technologies. For instance, the mobile telecommunication sector in Europe is departed into three frequency standards which can be used by the phones. The frequency used is determined by the phone provider. But as the provider's network is restricted on a certain locality, users have to be roamed to a partner network when leaving this area. The mobile phone has to be compatible to all three frequencies to provide the maximum utility for the consumer. Furthermore Mobile phone producers try to reach the greatest costumer basis, and thus try to provide the maximum compatibility. The filling station network has standardized nozzles for gasoline, diesel and lorry diesel. Additionally, the storage and pumping technology is standardized due to environmental restriction and of course to the physical condition of the fuels. This standard on the one hand ensures that customers in a large area, for instance the European Union, can use every station in the network. On the other hand, this standard may restrict some kind of fuels, the gaseous one, from being distributed over the existing network without substantial remodelling costs. Another interpretation would argue that the network is protected against competing technologies and has created a solid entry barrier.

Conrad (2004, page 7) showed that a company has incentives to protect its network against competitive products or services, as the new product would increase price competition, primarily if the goods are nearly perfect substitutes for each other. Based on the Hoteling model of horizontal or vertical product differentiation, two producers maximizes their individual profits by choosing qualities which are on each side of the [0, 1] interval. By choosing qualities which would lead to a less differentiation, the firms would have to compete more for customers and therefore would have to lower prices. On consumer's side, the enforced price competition could lead to massive welfare gains. For Germany in 2004, the total amount of fossil fuels in the transportation sector sold was about 62.610.000 TOE (Eurostat). This equals a consumption of 83.848.000.000 litres[1]. A marginal market price decrease of 1 cent then would lead to 838.480.000 € of additional consumer surplus in Industry and Households respectively to a loss in gross revenue of the oil companies.

So, if a firm owns a Network in which it provides one kind of goods, protecting the network against substitutes is the profit maximising strategy. By selling bio fuels, which are up to a certain degree substitutes for fossil fuels (especially bio diesel), and thereby providing the initial network needed by the new technology, the incumbent firms would enforce price competition between the fuels on the long run. Furthermore, most of the large filling station owners are the major oil exploration and refinery companies. These companies are vertically integrated and have the potential to realize high rents along the value chain. Bio fuels, on the other side have to be purchased by local producers and would thus lead to lower earnings. We may find empirical evidence for this assumption by analysing the type of filling stations selling alternative fuels in Germany. We are expecting the main part of the filling stations to be run on private ownership and not be leased from the oil companies. As these stations have to pay higher wholesale prices for petrol compared to the vertical integrated ones, they have a higher incentive to switch to the distribution of other fuels, for instance bio diesel. This may lead to higher profits for the vendor. In case of bio diesel or vegetable oil, most of the fuel is sold by oil mills (1400 of 1900 stations) or private filling stations. The British Petrol Group (BP, ARAL,) offers over 42 of 2560 filling stations in Germany Liquified Petrol GAS (LPG) and over 148 Compressed Natural Gas (CNG). Based on the information in the sustainability report, no pure bio fuels are distributed over the German network. Shell, in the US market the largest producer of ethanol, also don't seem to offer bio fuels over the German network of 2200 filling stations. The ethanol is mixed with the fossil fuel because of governmental restrictions, but not sold directly to the customers.

As compatibility is the key to the network on consumer side, and a car is considered as a huge investment, no one would take the risk of buying a car from which he is not convinced to have access to the network. One way to overcome the network problem is to offer bi-fuel powered cars, e.g. CNG/LPG and gasoline, which allows using both networks. But this technical solution reduces the

[1] Density of gasoline 0,75kg/litre

space for the passengers and the luggage because of the two tanks and also increases the price of the car.

1.4 Switching- and lock-in costs

1.4.1 The technical Lock-in-effect of the gasoline car

The lock-in-effect of a certain technology describes a situation, in which customers are so dependent on a vendor for products or services that they cannot change to another technology without substantial switching costs. Even if other goods or services possibly would be able to generate utility on a higher level, consumers remain in the old technology. In the case of the gasoline car, the vendor is the network of filling stations, who supplies the customer in most parts of the world with only one main kind of fuel, gasoline and diesel, derived from oil. As the filling stations are often owned or rented by one of the major oil companies, the vendors finally are the producers of oil and fossil fuels. By switching to another technology, e.g. a fuel cell powered car, users will lack of possibilities to purchase hydrogen at the filling stations and therefore would not be able to use the good at acceptable prices or at all.

Cowan and Hulten (1996) showed, that some key factors in the development process of gasoline cars, for instance the bigger amount of energy stored in one kilogramme of fossil fuel[2] compared to the still very low storage capacity of a battery[3], have created a very strong, technical lock-in-effect.
In the case of the automobile, 120 years ago a strong competition was ongoing between 3 different engine systems for the first automobiles. Beside the more common steam car, used as locomotive, the first cars with combustion engines and the first electric cars competed for costumers.
In 1899, 1575 electric, 1681 steam and 936 gasoline vehicles were sold (Cowan, Hulton, 1996, page 7). The steam cars were primarily used for the transportation of goods as they had some disadvantages which made them less suitable for private costumers. The problems of the steam cars were the heating up phase and the huge amount of water consumption. Furthermore, the steam generator and the drive mechanism needed lots of space and had heavy weight, which results in huge, unhandy cars. The gasoline cars lacked of high range and speeds also consumed a lot of water and were extremely noisy. They also needed a strong person which started the engine by a crank handle.
The electric car on the other hand seemed to be in a good position to win the race. Besides a general enthusiasm for the up coming electrification of households and industry, the electric car could also profit from the huge electric cable cars by using the same technology, only in a smaller version. The major problems, the short range, the top speed and the lacking ability to climb steep hills were

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[2] 43 MJ/kg for gasoline and Diesel
[3] Altaire Nanosafe under test conditions 14,3 MJ/kg, common lithium Polymer 0,55MJ/kg

supposed to be solved soon. All these three problems resulted of the storage technology for electricity. The storage capacity of batteries was anticipated to double from 10 Watt hours per kilogram (Wh/kg) in 1980 every 10 years. While this estimation seems to be accurate during the first years, an invention for the gasoline car suddenly stopped the development process. With the starting lightning ignition was not only the need for a crank start eliminated. It also directed the development process of the battery storage technology to another direction. From there on, batteries had to be produced for a mass market, as the gasoline car rapidly gained market shares. The batteries for the gasoline car did not need to have a high capacity, but a long lifetime, cheap production costs and reliability.

While the electric car from there on was stuck on a certain development level, the gasoline car became more and more popular. The early manufacturer increased range and speed and rapidly decreased the prices for their cars. Finally, with the production of the Ford T-Model by Henry Ford, the gasoline car had become the leading technology. Henry Ford at first designed his cars to run on pure ethanol (the Ford-T from 1903-1926), gained from the alcoholic fermentation of sugar, but switched later to gasoline because of the lower price.

First concerns about the world wide leading technology for transportation occurred during the oil crisis in the 70ies. The scarcity of the resource oil became clearly visible as the OPEC restricted their exports due to political reasons. As the development process of motorisation has followed a significant path for decades, no alternative technology was ready to fill the opening gap. Cars had become faster, safer, more comfortable and more efficient, but they all needed fossil fuels for running. But the concerns disappeared with the normalisation of the political situation and beside some nice markets, no demand for alternative technologies really established. The answer of the car manufacturers to the visible scarcity of oil and the rising prices was the proposal to develop more efficient engine systems which would lower the demand for oil. We here need to distinguish between the worldwide automobile markets. While there only has been less progress in the US market, the European and Japanese manufacturer noticeable lowered the demand of their cars for gasoline. Especially in some European markets, drastic taxes on fuels raised the prices 2 or 3 times above the wholesale price and consumers demand for gas guzzling cars decreased strongly.

As during the last decade the environmental consequences of the ongoing motorisation became more and more visible, public opinion particularly in Europe accepted the need for a change in technologies. The problem here is not the technology, as you will see in chapter 3, alternatives exists even for a wide part of the mass market, but the lock in effect of the old technology. Fuel needs to be distributed over a strait mashed network of filling stations. These have over the last 100 years only sold gasoline and diesel and are not able to sell natural gas or hydrogen on short notice without substantial remodelling of the stations. So in addition to the switching costs of the consumers come the switching costs of the network. Even if consumers are willing to pay for new technologies, they may lack of the network needed to obtain utility from their cars. Because of this anticipation, consumers may put aside their environmental concerns and still buy the old technology. The suppliers on the other side, might because of profit maximizing considerations, not be willing to invest into a new network only because of the environmental consumer concerns. The scarcity of fossil fuels during the next decades primarily is a matter of the price. The price path of gasoline hence plays a crucial rule in overcoming the lock in effect. As due to scarcity, fossil fuels are experiencing raising prices over the last decades, this improves the chances of a successful market entry by alternative products. The price path of gasoline would, under assumption of successful market entries, force the incumbent to lower his prices and lead to decreasing price cost margins. At the same time, it would allow the entrants to raise prices and help the initial network to become profitable. But as long as there is no environmentally neutral backstop technology available for the mass market to restrict prices to a level on which competition for consumers might be possible and desirable, the existing network provides the highest profits for the oil companies and strengthens the dominance of the incumbent companies.

1.4.2 Economic Lock-in-effects

Shapiro and Varian 1999 (see Shy, 2002, page 4) classified some kinds of various economic lock-in-effects. These are

- **Contracts**

Consumers often are lock into contracts for goods or services, like for their mobile phone. Switching to another contractor is possible, but they still have to pay the contract fee over the agreed period for the old one. So the savings from a new mobile phone contract often are exceeded by the costs for the old contract. Switching costs results out of the fee or compensation that has to be paid by the party who breaks the contract (2002). For the carriers of the filling station which are leased from the oil companies, this might indicate that they are contractually bounded only to sell the fuels which are produced by the oil companies which does not include bio fuels.

- **Search costs**

People often try to avoid the costs and time for searching and shopping for new products. In case of the alternative fuels, the thin network of filling stations seems to be expected to cause serious search costs.

Consider a German consumer, who buys a new car every 5 years and drives about 30.000 km a year. If he buys a usual gasoline powered car, for instance the Opel Zafira (this car was chosen as there is a natural gas powered version offered by the manufacturer and no remodelling by the customer has to be done), he will have fuel cost of 2990 € per year[4]. The same consumer, driving a natural gas powered Zafira, will have fuel costs of 1270 € per year[5]. So his savings over the five year period will be 8600 € - 4.000 € (the higher investment costs compared to the gasoline powered) = 4600 € or 55%. Although

[4] Opel Zafira gasoline 1.6: 8,3l/100 km; fuel price 1,2€/ litre, list price: 21.000€
[5] Opel Zafira natural gas powered, 5,0 kg/100km, 0,85 cent/kg, list price 25.000€

the net savings are more then 4.500 €, most consumers must asses the lack of filling stations and the costs of being locked-in to this ecological more efficient engine system at least on this level. Because of its seven seats, the CNG Zafira so far is mainly used by taxi drivers. But this example could be generalized as the costs of converting an engine from gasoline to CNG are less than 4.000 € for most of the mass market cars. At least for Germany, the consumer's expectations about the search costs might be falsified by the extremely dense network of conventional filling stations. In 2006 more then 14.600 conventional filling stations provided the customers in Germany with fuels, a number much greater than needed. The strong competition is one of the reasons for decreasing price-cost margins over the last years. But the closure of the inefficient part of the network would cause costs on a very high level, as environmental requirements are very strict. As a result many of the stations are kept open because of cost avoiding - rather then to economic calculation. Compared to the over-invested network for gasoline, the existing network of filling stations for CNG (700 stations)[6]/ LPG (2200 stations)[7] or bio fuel (1900 stations)[8] may seem to be missing the required density. This impression might be enforced as most of these stations are free ones, and do not have the budget for advertisement and commercials.

- **Training and Learning, Data Conversion**

These costs mainly appear if people have to be trained to use a product or software. People working with a certain type of software every day, might react very sensitive to changes in the user interface or functions, which leads to a lower productivity. Switching costs here mainly occurs in form of training and learning costs or in the conversion of the data to the new software standard.

- **Loyalty cost**

Switching to another vendor for products might result in loosing benefits like customer programs or price discounts. Most of the larger oil companies offer some kind of allowance programs, but as alternative fuels often are cheaper as conventional fuels, consumer may not do any worse by switching.

Switching cost in general may affect the prices for goods or services in two ways. First, in case consumers are already locked-in to a certain technology, firms may raise the price up to a level where the estimated price including switching costs equal the price cost margin of the producers. This may give an explanation, why Exxon Mobil earns a net profit of 39,5 billions in 2006 (see Financial Times Deutschland), the highest profit ever earned by a company.

Second, if consumers are not locked-in, or a new technology competes for the initial basis of costumers, firms may have to offer large sales discounts. This lowers the profits of the entrant and

[6] See LPG/CNG Tankstellen Verzeichnis
[7] See LPG/CNG Tankstellen Verzeichnis
[8] See Union zur Förderung von Öl- und Proteinpflanzen e.V.

could hinder the new network from becoming profitable at all. And by lowering his to high prices, the incumbent has an effective weapon to protect his goods or services against competitors without earning losses.

2 Overcoming the lock-in-effect of technologies.

We will show some theoretical solutions for overcoming the lock-in-effects and will successional analyse them for practical use. Cowan/ Hulten (1996, page 6) identified 6 key factors, which could help to overcome the lock-in-effect of an old fashioned, but still leading technology, in our case the fossil fuel powered automobile. These factors are:

2.1 A crisis in the existing technology occurs

From a pure technical view, there is no crisis. The combustion engine has been improved over the last 100 years and still has not reached its top level. The crisis therefore results from the fuels used. But even there are technical solutions ready to defend against new fuels. Especially the diesel powered cars have the potential to reduce consumption and emissions to a level, on which they can compete with bio fuels which combust CO_2 neutral. But if you consider the well to wheel emission, the CO_2 neutrality of some bio fuels seriously has to be questioned. The amount of energy needed for the extraction of some fuels out of biomass are high enough to disqualify them in the CO_2 balance, compared to modern diesel powered cars (see chapter 3 for a more detailed comparison)

2.2 Regulations and Subsidiaries

Regulation has the ability to banish a technology out of the markets. Germany 1994 was one of the first countries which totally banned CFCs after it had become clear that this gases damage the ozone layer. This was possible, because of the existence of alternatives for these substances in industrial and private use. In the US, the California Energy Tax Act of the year 1978 enabled the deliverance of the excise tax for bio fuels. The problem with regulation is that it often has to be a compromise between different, sometimes misleading targets. The loss in taxes due to the California Energy Tax Act are estimated about 1.4 Billion US$ per year. And an emission cap for Lorries could cause disadvantages for the local transport sector. The regulator also may strongly be influenced by different lobbies. The failure of the emission limit of 120g CO_2/km in the EU was strongly promoted by the German car manufactures.

2.3 Technological or cost break through of competing industries/ technologies

As shown in Chapter 3, there are some alternatives to the use of fossil fuels. Particularly ethanol or other bio fuels have proven there practical usability. But Ethanol is mainly produce in Brazil, due to the huge sugar cane plantations. In Europe on the other hand, ethanol has to be produced out of cellulose, an energetically and cost intensive proceeding. H2 is far away from serial use, but we suppose it to be one of the leading alternatives used for mobility in some decades. The huge amount of 120 MJ stored per kilogram excels gasoline by the factor of 3. Momentary, the low efficiency rating in the production of H_2 and the problems of the storage and transport technologies have to be solved. Also, huge investment in the distribution network is necessary, as gaseous fuels can not be delivered by conventional filling stations. Another alternative, the electric car is not seen to become a serious competitor on short notice. The main problem, the less storage capacity of the battery and the long waiting time for recovering the accumulator still remain unsolved for the mass market, although there is some technical progress.

2.4 Changes in Consumers taste

Changes in consumers taste should to be the driving force behind the development process for environmental friendly cars. But it is typical for environmental topics, that consumers are well aware of the damage they are causing. The problem is that the uttered willingness to pay for an environment friendly solution often differs from the real one. In times where the mass market for automobiles is characterised by huge sales discounts and firms strongly compete in prices, environmental friendly, but cost intense products may lack of demand even in the so called rich counties. So, a switched to alternative technologies seems to be more achievable by governmental restrictions rather than market demand.

2.5 Sufficiently active nice markets

Beside the nice markets for electric cars identified by Coltan/Huton (golf and milk cars), we identify the public transport sector as one, which may help to kick off alternative fuels. As most of the larger cities have a local natural gas supplier, it suggests itself to remodel the public transportation vehicles to natural gas combustion. As this fuel often is subsidised, a lower CO_2 emission also is associated with lower transportation costs. In addition, the demand for natural gas powered cars in the private sector could be increased. People will notice the environmental friendly cars, and by opening the public owned filling stations to private consumers, an initial network for the fuel supply could be provided, which then will be enlarged and completed by private investors.

2.6 Scientific results

As shown in Chapter 3, the lack of scientific results for alternatives is not the problem. But new technologies often are more expensive than the dominating technology, so scientific results should primarily lead to decreasing cost in production then in new alternatives. Decreasing costs are mainly the results of economies of scale in the production, and in the case of network effects, in the consumption, so this point seems to be subordinately to the other 5 criterions.

- **Conclusion**

There currently exists no other technology which seriously would be able to substitute the combustion engine on the short run and to exactable prices. Alternative fuels like hydrogen or electric cars may lack of the required network or technical solutions for the mass market. Therefore, the only way of reducing CO_2 emission in the transport sector on the short run is the step by step substitution of fossil fuels by bio fuels in combination with reducing the fuel consumption of the common technology, for instance by installing hybrid engines or more efficient combustion. This could be achieved by mixing fossil and bio fuels in the first time, as modern engines are very sensitive to changes in the fuels towards others then they were built for. The next step then would be to equip the cars with engines built for the sole consumption of bio or gaseous fuels. Furthermore, the network for gaseous fuels has to be enlarged. This network then could be remodelled for the distribution of H_2 in the more distant future. We suppose the development process to happen in this way, as disjointed jumps in the underlying technology are unlikely considering the look-in-effect and the path dependent development process.

In general, path dependence means that a state of the world reached today is more influenced by decisions taken yesterday then on probability or coincidence. For our example of the gasoline car, the path dependence may be triggered by the starting lightning incognition or by Henry Ford decision to run his cars on gasoline rather then on ethanol. But the following development process of automobiles then mainly focussed on the improvement of the gasoline powered engine, which led to a very strong lock-in-effect from our point of view.

In literature, 3 different types of path dependency are identified. Roy (1996) distinguished between 3 forms of dependency which all have to come with measurable inefficiencies. In his "weak path dependence" two alternatives are equally efficient, but one is chosen and it survives. “Although these alternatives may differ from one another in important ways, the choice has no efficiency consequences”. The second form, he calls it the “semi-strong form path dependence” which means a choice that "has become inefficient but is not worth changing." The error occurs, because of imperfect information which led to forecasting errors. The third form is the “strong-form path dependence” which means a "highly inefficient structures that society cannot eliminate." With the term “cannot eliminate, he means that changes could only be achieved at costs which may equal or exceed the surplus of overcoming the current situation. In the case of global warming, we are not able to switch to alternative, more environmental friendly technologies at acceptable costs on short notice. Another problem occurs out of the problem of measuring the economical consequences of the global warming process. Even if the Stern Report assigned a number on the expected damages, lots of politicians and economists doubt or dispel his work. As long as the cost and consequences of burning fossil fuels are considered as uncertain or less strong in their outcome, it’s hard to argue people into spending lots of money for a technological change.

Liebowitz and Margolis (1995) gave a quite similar definition of the problem. It is the third degree of path dependence which Liebowitz and Margolis identified as the one which matters in our network effect consideration. In this form, consumers are well aware of the negative consequences of their actions, but still are not able or unwilling to change it by themselves. It could happen that each consumer prefers alternative bio fuels due to environmental concerns, but if each thinks everyone else is buying a fossil fuel powered car, and we care about compatibility, all might buy this kind of car. "We each maximize privately given this expectation and it turns out that our forecasts are correct, yet we each end up worse off that we might have and the socially optimal level of welfare will not be reached".

In our considerations from a technical point of view, "path dependent" not only means the economic interpretation that a state of the world is based on decisions made in the past. It also describes a process, in which incremental or small changes in the technology are supposed to be more successful in achieving a switch to another technology. The step by step intermixture of ethanol to conventional fuels not only allows the car manufactures to adopt their engines to the new fuels. It also enables the bio fuel industry to find ways to increase the production level in a sustainable manner and adjust to the growing demand.

3 Classification and Analysis of Alternative Fuels

3.1 Hydrogen (H_2)

Hydrogen has no derivate, but there are differences in the transformation as fuel. There are three concepts of use, the liquid hydrogen (LH_2), gaseous hydrogen out of liquid hydrogen ($LCGH_2$) and compressed gaseous hydrogen (CGH_2)

- **Chemical characteristics / Production**

Hydrogen has very special physical and chemical characteristics. Hydrogen is gaseous under standard conditions with a density of 0,089 g/l. The boiling temperature is 20,38 K and hydrogen diffuses through smallest foramina. Therefore hydrogen is difficult to use as an energy carrier. But on the other hand it is easy to handle, because it is nontoxic, environmental neutral, no hazardous to water, not corrosive and hydrogen is no carcinogen. And the biggest advantages are the high octane number, the high net calorific value of 119,97 MJ/kg and the fact, a combustion of pure hydrogen is emitting only water.

Hydrogen is an energy carrier. That's why you need a primary energy source to convert the primary energy into hydrogen bounded energy.

It is possible to use every primary energy source to produce hydrogen. The process of producing hydrogen bounds the energy of the primary energy source on the hydrogen.

In general, there are two common processes to produce hydrogen, the electrolysis method and reformation method.

The electrolysis converts the electrical energy into hydrogen bounded energy. Therefore you need a lot of electrical energy to produce hydrogen the reason is an efficiency of only 50%. Electricity generated by renewable energy like hydropower or wind for the electrolysis of water creates very low emissions. In comparison to this electricity generated by a coal-fired power station causes relatively high emissions.

Electrolysis separates the elements of water-H and oxygen (O)-by charging water with an electrical current. Adding an electrolyte such as salt improves the conductivity of the water and increases the efficiency of the process. The charge breaks the chemical bond between the hydrogen and oxygen and splits apart the atomic components, creating charged particles called ions. The ions form at two poles: the anode, which is positively charged, and the negatively charged cathode. Hydrogen gathers at the cathode and the anode attracts oxygen.

The reformation process needs as raw material natural gas, coal, gasoline, diesel, alcohol or gas out of biomass. The reformation needs heat for the process instead of electricity. Two chemical reactions occur simultaneously during the reformation process. An exothermic partly oxidation supplies the heat and emits hydrogen and carbon dioxide. An endothermic reaction takes the heat and supplies also hydrogen and CO_2.

Equation one is the exothermic and equation two the endothermic reaction of the reformation process for methanol.

$$CH_3OH + 0{,}5O_2 \rightarrow 2H_2 + CO_2 + Q \qquad (1)$$

$$CH_3OH + H_2O \rightarrow 3H_2 + CO_2 - Q \qquad (2)$$

The hydrogen has to be stored after the production. It is not useful to store hydrogen under standard conditions, because of a low density and accordingly to this the low energy content per volume unit.

The energy content per volume unit has to be increased for storage and an application as fuel.

Two techniques are used for this, the liquefaction and the high pressure compression. You have to cool down the hydrogen under the boiling temperature for the liquefaction and to pump the liquid hydrogen into special tanks. It is also possible to compress the hydrogen until a very high pressure. The energy content per volume unit of hydrogen is the highest after the liquefaction, although this method needs a huge amount of electrical energy. Hydrogen production has a very low efficiency, only 19% / 24%[9] of the primary energy input is stored in the hydrogen. The gasoline production has an efficiency of 85% in comparison to this.

[9] 19% with liquefaction
24% with compression

- **Application and Concept of use**

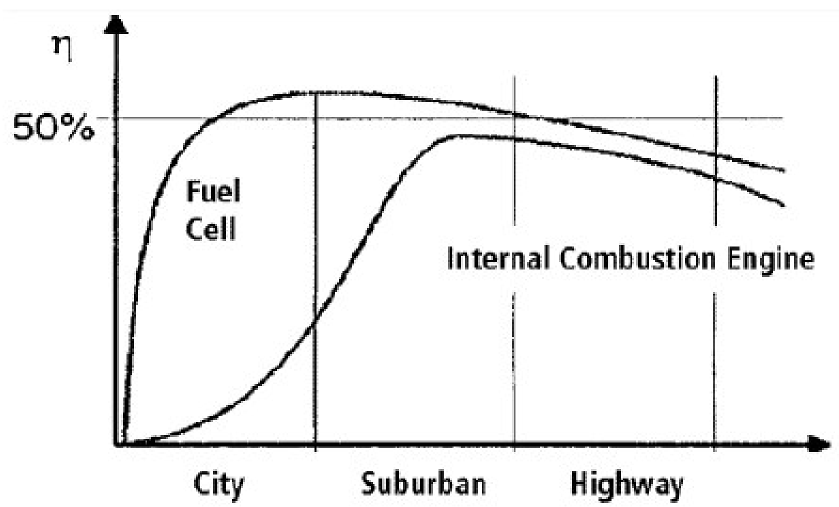
The consideration of the application starts with the problem of the on board storage of hydrogen. Liquid hydrogen is difficult to store, because you have a continuously evaporation for the cooling. After a period of time the on board storage is empty, even without driving, because the hydrogen evaporates. Furthermore the storage technology is difficult to handle and expensive, because you need lots of special parts. This is necessary because the huge difference in temperature (330 K) form the storage to the engine. The companies BMW and Linde Gas AG developed a version of an on board storage for the BMW 7 model.

Pressurized hydrogen is easier to handle, but it has a limited driving range. The car producers VW, DaimlerChrysler, Ford, GM/Opel and Toyota have developed test versions of this storage system.

Hydrogen can be applicated very easily for fuel. A light modified combustion engine can use hydrogen for fuel. DaimlerChrysler showed a hydrogen impulse car with combustion engine in 1998. BMW offers a "serial" hydrogen vehicle with combustion engine to special customers in 2007.

Hydrogen application for fuel has much higher potential for the fuel cell technology. The fuel cell's advantages are: good dynamic driving characteristics, high efficiency, small weight, small volume and electricity generation with only water steam emissions.

Graph 1: Efficiency comparison fuel cell vs. Internal combustion engine



Source: DaimlerChrysler (2007)

The existing problem of fuel cell technology is the reliability, currently a life time of 60000 operating hours can be guaranteed. The car producers demand 80000 operating hours. A serial production can be achieved in the years 2010 to 2012. DaimlerChrysler has already successful produced 10 research cars with the polymer electrolyt membran fuel cell technology. Opel, Ford, and Volkswagen have also produced some test cars with fuel cells. The companies DowChemical, DuPont, Ballard-

PowerSystems, NuCellSys, DaimlerChrysler, BMW, Ford, GM/Opel are involved in research on the fuel cell technology. Volkswagen, Honda and Toyota have their own research projects.

- **Emissions**

The emission balance of hydrogen is primarily influenced by the emission of the production and the distribution. The production is divided into the reformation process and the electrolysis. Particular the electrolysis is heavy subjected to way of electricity generation. Nuclear or renewable power plants don't have any emissions. Emissions of power plants that use fossil fuels are strongly depending on the fuel and efficiency. With the newest gas and steam turbine, the carbon dioxide emission for an amount of hydrogen is 6130 $g/l_{gasoline\ equivalent}$. A old coal fired plant has 12700g CO_2 emissions per litre gasoline equivalent. These emissions are 15 to 35 times higher than the emission during the gasoline production.
The emission out of the reformer technology is significant less than the emissions caused by the electrolysis. A production of one litre gasoline equivalent out of natural gas emits 3200 g CO_2, which is still 8 times higher than the emission during the gasoline production. Reforming oil or methanol creates comparable emissions as natural gas.
Hydrogen's distribution emissions depend on what powers the transport mode: a truck engine in liquid or gaseous transportation or a pipeline's pumps and the distance of transport. Hydrogen does not have any vehicular emissions.
It is very difficult to calculate the well to wheel emission, because there are so many coefficients, which might have an influence. That is why the result has a big spread.

Table 1: Emissions of Hydrogen

Fuel	NO_X	CO	CO_2
	Distribution Emissions		
Gasoline	100	100	100
Hydrogen	1132	639	771
	Well to Wheel Emissions		
Gasoline	100	100	100
Hydrogen	79-864	0-12	5-362

Source: OECD (2000): Automotive Fuels Future p. 40

- **Costs**

There are different techniques existing to produce hydrogen, because there is no standardized production and distribution technology. On site conditions determine the producing process. So these conditions determine the specific cost of the hydrogen, too. Those conditions are the frequency of vehicle tank filling process and accordingly to this the filling method, storage capacity of the fuel station, demand of hydrogen and the distance to the hydrogen production facilities. The following assumptions are valid for these conditions. The fuel stations have only a small demand of hydrogen ($50kg_{H2}$/d), so the capacity is small and the filling frequency is also limited at the beginning of the implementation. The filling technology for CGH_2 is the multi bank system. Table 2 shows the different specific cost, of on site a centralized production of CGH_2 for that amount of hydrogen and this special filling technology.

Table 2: Cost of CGH_2

Hydrogen source	Electrolysis	Natural Gas Reformer	Methanol Reformer	Centralized (Pipeline)	Centralized (Trailer)
Hydrogen (€/kg)	0,00	0,00	0,00	8,77	1,39
Capital Cost (€/kg)	2,42	4,14	2,76	0,77	1,70
Feedstock Cost (€/kg)	0,00	1,66	1,42	0,00	0,00
Electricity Cost (€/kg)	2,76	0,51	0,46	0,15	0,14
Running Cost (€/kg)	0,55	0,84	3,19	0,55	0,78
Cost (€/l gasoline equivalent)	1,56	1,94	2,12	2,76	1,10

Source: Altmann (2003) p.47

2000 hydrogen stations are needed to achieve a rough area coverage. This network could supply hydrogen for 276000 cars and it would take at least 1.250.000.000 € to install this stations.

The influence of the hydrogen on board storage system to the costs is significant. Table 3 shows the costs for liquid hydrogen under the same conditions as table 2, but with a high pressure pump.

Table 3: Cost of LH_2

	Production Cost	Transport Cost	Capital Cost	Electricity Cost	Running Cost	Sum
€/kg	1,71	0,17	2,05	0,00	1,40	5,45
€/l gasoline equivalent						1,46

Source: Altmann (2003) p.57

The investment costs for liquid hydrogen are 644.000.000 € to reach the network size of 2000 stations.

- **Distribution pathways**

The distribution of hydrogen to the fuel stations requires other ways than the distribution of gasoline. There are three ways to distribute hydrogen to the fuel stations. The production of hydrogen directly on site of the fuel station offers the opportunity to avoid transportation. The disadvantages of this method are the high specific production costs, because the share of the investment costs of the production facility are very high.

With a centralized production is it possible to use the advantages of the economics of scale and accordingly to this the specific cost for the production are less than specific cost for the production with decentralized production units. For the centralized production are existing two possibilities for the transport of the hydrogen. First it is a transport via pipelines, but currently there is no existing pipeline network. The second possibility is a transport with special transporters via street, rail or by ship.

It is also necessary to install new technologies at the stations to refuel a car with hydrogen. The technologies depend on the concepts of use of hydrogen as fuel (liquid or compressed gaseous) and the capacity of the hydrogen station.

Two different techniques are existing to fill compressed gaseous hydrogen into the car. The multi-bank-storage system is independent to the fuel station capacity. Therefore the hydrogen storage is divided into three or more storage units (banks). These banks have different pressures. The refuel process starts with the hydrogen out of the storage unit with the lowest pressure. Hydrogen form a higher pressure bank will be taken, if the pressure difference is almost equalled. That process goes on until the high pressure level is reached and the filling ends. The good utilization of the storage capacity is the large advantage multi-bank storage system. The compressor has the only task to refill the emptied storage after a filling again to the maximum accumulator pressure. This can already take place for emptied banks, while other banks are still active in the refuelling procedure.

Another concept to refuel cars, is the booster concept. The booster concept for small fuel stations has one compressor. This compressor compresses the hydrogen on storage pressure. It takes the gas out of the storage and compresses it on the necessary filling pressure. The booster method with one compressor limits the cost for small fuel stations. However different compressors are used for the different tasks at larger fuel stations: One, which goes for filling the stationary storage and another one, which takes over the filling process. This is useful to avoid long time for the refuel process.

The filling strategy for liquid hydrogen stations can be differentiated, too.

A possibility for filling liquid hydrogen out from a stationary tank into a vehicle is the use of a liquid hydrogen pump, which pumps the hydrogen into the car. This strategy is recommendable especially for fuel stations with a high capacity.

The conditioning storage is the cheaper possibility, because you do not need any pump. Therefore one defined quantity of liquid hydrogen is filled into the conditioning tank. Then a small part of the filled in hydrogen evaporates and returns into the conditioning tank, which leads there to an increase in pressure. The difference of pressure between the conditioning storage and the fuel tank is sufficient to press the hydrogen without pumps within an acceptable time into the fuel tank.

There is also the possibility to supply liquid hydrogen to the fuel station and apply gaseous hydrogen for fuel. For the refuelling of gaseous hydrogen out of liquid hydrogen are existing three different concepts.

The first one is the concept of the high pressure pump. A high pressure pump presses the liquid hydrogen into the vehicles tank and creates an essential pressure in the liquid phase. Heat exchanger heats the hydrogen up.

The conditioning storage is the second possibility. This is a combination of a conditioning system and evaporators. The liquid hydrogen evaporates and a heat up increases the pressure. A multi bank storage system stores the gaseous hydrogen and the pressure differences form the multi bank storage and car tank presses the hydrogen into the car.

The booster compressor concept is the third possibility to get $LCGH_2$ into vehicles tank. A liquid hydrogen pump and connected heat exchanger creates a medium pressure in the storage. The booster compresses the hydrogen fills the gaseous hydrogen into the car.

The different concepts show, that a standardized refuel technology depends on storage applications of the vehicles producers and the physical conditions after the production.

3.2 Biological Alcohol Fuel

Ethanol (C_2H_5OH)

The majority of the world wide production of alternative fuels is ethanol. Ethanol can be mixed in every proportion with gasoline. The two main technical applications of the relation are mixtures of 10% ethanol with 90% gasoline (E10) and a mixture of 85% ethanol with 15% gasoline (E85). Brazil is the only state that uses the derivate of E25. The brazilin fuel is a mixture of 25% ethanol and 75% gasoline.

Ethyl-Tertiaer-Butylether

Ethyl-Tertiaer-Butylether (ETBE) is a derivate synthetic produced out of ethanol. ETBE is a composite of 47% ethanol and 53% fossil isobutene. ETBE provides a basis to increase the octane number of a fuel. The European law allows a mixture of 15% ETBE and 85% gasoline.

- **Chemical characteristics / Production**

Ethanol is an alcohol, is liquid and easy combustible. Therefore ethanol has a very good combustion attitude, even better than gasoline or diesel, caused by the high octane number 110. The fuel value is 21,06 MJ/l. At ambient temperatures, alcohols can easily form an explosive vapour above the fuel in the tanks. In accidents, however, alcohols present less danger than gasoline because of their low evaporation speed alcohol concentration in the air stays low and not explosive. Ethanol is produced from the fermentation of sugar by enzymes produced from specific varieties of yeast. The feedstock for ethanol is biomass, an energy carrier of sun energy.

Traditional fermentation processes rely on yeasts that convert six-carbon sugars to ethanol. Glucose, the preferred form of sugar for fermentation, is contained in carbohydrates and cellulose. Because carbohydrates are easier than cellulose to convert to glucose, the majority of ethanol currently produced is made from corn, which produces large quantities of carbohydrates. Also, the organisms and enzymes for carbohydrate conversion and glucose fermentation on a commercial scale are readily available.

The production of ethanol out of glucose is done by the dry mill process. This process concludes 7 major steps.

1. Milling**.** The feedstock passes through a hammer mill which grinds it into a fine powder called meal.
2. Liquefaction**.** The meal is mixed with water and alpha-amylase, then passed through cookers where the starch is liquefied. Heat is applied at this stage to enable liquefaction. Cookers with a high temperature stage (120-150 degrees Celsius) and a lower temperature holding period (95 degrees Celsius) are used. High temperatures reduce bacteria levels in the mash.
3. Saccharification**.** The mash from the cookers is cooled and the secondary enzyme (gluco-amylase) is added to convert the liquefied starch to fermentable sugars (dextrose).
4. Fermentation**.** Yeast is added to the mash to ferment the sugars to ethanol and carbon dioxide. Using a continuous process, the fermenting mash is allowed to flow through several fermenters until it is fully fermented and leaves the final tank. In a batch process, the mash stays in one fermenter for about 48 hours before the distillation process is started.
5. Distillation**.** The fermented mash, now called beer, contains about 10% alcohol plus all the non-fermentable solids from the corn and yeast cells. The mash is pumped to the continuous flow, multi-column distillation system where the alcohol is removed from the solids and the water. The alcohol leaves the top of the final column at about 96% strength, and the residue mash, called stillage, is transferred from the base of the column to the co-product processing area.
6. Dehydration**.** The alcohol from the top of the column passes through a dehydration system where the remaining water will be removed. Most ethanol plants use a molecular sieve to capture the last bit of water in the ethanol.

7. Denaturing**.** Ethanol that will be used for fuel must be denatured, or made unfit for human consumption, with a small amount of gasoline (2-5%). This is done at the ethanol plant.

The conversion of cellulosic biomass to ethanol parallels the corn conversion process. The cellulose first has to be converted to sugar by hydrolysis and then fermented to produce ethanol Cellulosic feedstock (composed of cellulose and hemicellulose) are more difficult to convert to sugar than are carbohydrates. The conversion of cellulosic biomass to ethanol increases the potential feedstock for the production of ethanol. A large variety of feedstock are currently available for producing ethanol from cellulosic biomass instead of using only corn or other glucose containing food. It is possible to use agriculture waste, forestry waste and even paper as raw material for the production of ethanol. Particular agriculture waste represents a tremendous resource base for biomass ethanol production

Two common methods for converting cellulose to sugar are dilute acid hydrolysis and concentrated acid hydrolysis, both of this use sulfuric acid. Dilute acid hydrolysis occurs in two stages to take advantage of the differences between hemicellulose and cellulose. The first stage is performed at low temperature to maximize the yield from the hemicellulose, and the second, higher temperature stage is optimized for hydrolysis of the cellulose portion of the feedstock. Concentrated acid hydrolysis uses a dilute acid pretreatment to separate the hemicellulose and cellulose. The biomass is then dried before the addition of the concentrated sulfuric acid. Water is added to dilute the acid and then heated to release the sugars, producing a gel that can be separated from residual solids. Column chromatographic is used to separate the acid from the sugars.

The highest potential for ethanol production from biomass, however, lies in enzymatic hydrolysis of cellulose. The enzyme cellulase simply replaces the sulfuric acid in the hydrolysis step. The cellulase can be used at lower temperatures, 30 to 50oC, which reduces the degradation of the sugars. In addition, process improvements now allow simultaneous saccharification and fermentation (SSF). In the SSF process, cellulase and fermenting yeast are combined, so as far as sugars are produced, the fermentative organisms convert them to ethanol in the same step. In the long term, enzyme technology is expected to have the biggest payoff.

- **Applications (Companies and Concepts of use)**

There are different applications for ethanol fuel. It is possible to use pure ethanol as fuel for a special combustion engine, but these engines are no serial production because there are performance- and guarantee problems. For that reason a mixture of gasoline and ethanol is used as fuel.

Serial combustion engines can be used for a small percentage of ethanol addition to gasoline.

Fuels containing up to and including 10% ethanol will not void the applicable warranties with respect to defects in materials or workmanship. However high performance cars like Ferrari or Porsche do not recommend fuels that contains ethanol.

A modified combustion engine will be needed for a higher share of ethanol at the fuel. Some car producing companies offer these engines that can use until a share of 85% (E85) ethanol. These cars are flexible fuel vehicle, because with this car is it possible to use fossil fuels and E85. The Companies Ford, General Motors, Nissan and Saab offer a flexible fuel vehicle for the fuel E85. The flexible fuel models from Ford and Saab do not have a higher price than standard fuel cars.

- **Emissions**

For M. Wang (2005) exist four key parameters for ethanol emission effects.

It depends on the energy use for chemical products like herbicides and insecticides. The methods of farming and their key data's like corn and biomass production , soil N_20 and NO_X emissions and the energy intensity. It also depends on the ethanol production for example the ethanol yield and the vehicle fuel economy (E10 versus E85)

A complete way for a comparison is to compare the fuel ethanol with the fuel to be displaced by ethanol, in this case gasoline.

You can distinguish between the emissions during the feedstock production, feedstock transportation, fuel production, fuel distribution and vehicular emissions. The result is the emission along the supply chain, from well to wheel.

1. Emissions from producing agricultural biomass stem from tractors and other equipment used in cultivation and the production and use of fertilisers. Cellulosic material generally requires less energy input and may need less fertiliser than agricultural feedstock.
2. Emissions of for the feedstock transport depend on the length of the transport and the kind of transport e.g. by ship or by truck.
3. Emissions from ethanol production depend on the fuels used for the necessary steam and electricity. Emissions for ethanol conversion from cellulosic material are higher than from feedstock rich in sugar or starch because it requires more energy.
4. Distributing alcohols resembles gasoline and diesel distribution.
5. Many factors influence vehicle emissions, which vary considerably. Particular the different vehicle technologies. Emissions from alcohol fuels compare quite well with gasoline and diesel. Ethanol has almost the same emission in CO_2 like gasoline but lower emissions in CO.

Ethanol application (E85) produced with the dry mill method reduces the emissions of CO_2 about 31% per km in comparison to gasoline.

The Ethanol NO_X emissions will increase, but the emissions of CO and CO_2 will decrease in comparison to gasoline.

For bio fuels apply in general: only the emissions caused by an energy input out of fossil fuel counts in the emission balance, because these emissions are not atmosphere neutral.

The table 1 from the shows the emissions along the fuel chain in relation to gasoline in percent.

Table 4: Emissions of Ethanol

	Feedstock			Transportation			Production			Distribution			Application			Well to Wheel		
	NO_X	CO	CO_2	NO_X	CO	CO_2	NO_X	CO	CO_2	NO_X	CO	CO_2	NO_X	CO	CO_2	NO_X	CO	CO_2
Gasoline	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
E(100) sugar	716-1845	980-1827	180-1611	100-150	288-500	177-333	549-700	514-10714	0	142-538	143-650	143-281	33	40	100	122-154	22-52	34-67
E(100) cellulose	595-750	196-276	528-611	80-250	250-2500	167-1833	880-1333	5500-17500								81-117	17-24	16-26

Source: OECD (2000) Automotive Fuels Future p.40

- **Costs**

You have to consider two cost sectors for a cost survey of ethanol, that are production cost and distribution cost.

Ethanol production has two cost components, capital costs and variable costs, the latter including feedstock costs and cash operating expenses.

The feedstock cost includes already the purchasing corn and the transport cost to the production plant. The other variable cost are electricity, fuels, waste management, water, enzymes, yeast, chemicals, denaturant, maintenance, labor and administrative costs. Currently the milling method is the most used method to produce ethanol. Therefore price of ethanol depends on the cost of the milling method. The feedstock costs for dry mill are 0,32 US$ per litre gasoline equivalent according to Gallagher/Shapouri 2005. The variable costs are 0,17 US$ per litre gasoline equivalent. The production cost without capital cost are 0,49 US$ per litre gasoline equivalent.

Particular the feedstock costs differ very strong from Europe to America. Therefore the variable production cost in Europe are 0,80 US$ and Brazil 0,35 US$ per litre gasoline equivalent.

The capacity of the conversion plants is still limited, that’s why you have to invest into new plants or to expand the existing capacity. The capital costs for new plants range from 0,42 US$ till 1,20 US$ per litre gasoline equivalent. Average investment to expand existing ethanol production capacity was 0,15 US$ per litre, ranging from 0,05 US$ to 0,26 US$.

In future the conversion of cellulosic biomass will decrease the cost of the feedstock. And these feedstock cost will stay relatively constant over a long period of time, caused by a big offer of agriculture and forest waste. But the conversion of cellulosic biomass has high capital cost. The savings in feedstock have to compensate this high capital cost. Forecasts of the Energy Information Agency show that the production cost will decrease with the conversion of cellulosic biomass into ethanol.

The distribution costs depending primarily on the volume of related energy content of gasoline. Ethanol has lower energy content per litre than gasoline, so you have higher distribution costs.

The cost components of the distribution cost are transport, storage, administration and interest of working capital.
The Distribution cost for Ethanol are 0,16 US$ per litre gasoline equivalent, they are 33% higher than the distribution cost of gasoline.

- **Distribution pathways**

It is not necessary to install new technology for the distribution. The resemble chemical characteristic of a mixture ethanol and gasoline compared to pure gasoline allows to use the actual distribution pathway. There are no technical problems to apply the usual storages and the usual pumps at the service stations. There is a current state of 40 installed E85 gas stations in Germany.

- **Potentials**

The annually worldwide growing biomass could theoretically cover the world's fuel consumption. But restrictions for food production environment protection, or the application of biomass for construction material prevent the exploitation of the theoretically potential.
In the most optimistic scenarios, bio energy could provide for more than two times the current global energy demand, without competing with food production, forest protection efforts, and biodiversity. In the least favourable scenarios, however, bio energy could supply only a fraction of current energy use by 2050, perhaps even less than it provides today. Therefore the range of the potential of ethanol has a very wide spread. The average value, calculated by the U.S. energy information administration, of the theoretical potential is between 11855 million litre and 23710 million litre bio ethanol for the year 2050.

3.3 Biological Diesel

- **Biomass to liquid fuel (BTL)**

A biomass to liquid fuel is a synthetically fuel out of a organic feedstock. BTL fuel own the highest theoretical possible market share of every kind of biological diesel.
Vegetable Oil
Vegetable Oil is a derivate of the biological diesel. It pressed out of oil containing fruit of a plant. It is easy to handle and doesn't take high investments into vehicles technology. However the agricultural potential for oil containing plants is very limited.
Fatty Acid Methyl Ester (FAME)
Fatty Acid Methyl Ester is currently the most used derivate of the group of the biological diesel. But there are lots of disadvantages against BTL fuel. The canola has to be very intensive refined. The Fatty Acid Methyl Ester is very aggressive to the sealings of the engine, therefore the modification cost are

high. It is not possible to filter the sooty particle with the existing filtration methods, that's why FAME fuel is strong carcinogenic.

- **Chemical characteristics / Production**

Synthetically fuel which is produced by biomass to liquid method has a very similar characteristic as diesel. The combustion attitude is comparable in spite of a lower viscosity and a much higher cetane number. The volumetric energy content is 7 % lower than diesel, 32,5 MJ/l. BTL doesn't contain any sulphur and condiments and the combustion emits less nitrogen oxides and sooty particle than a diesel combustion.

The big advantage of BTL fuels is the fact that different raw materials can be used. The spectrum reaches from straw, bio wastes and forestry waste up to energy plants, which are cultivated particularly for the fuel production. The entire plant can be used with the production of BTL fuels, while for conventional bio fuels often only parts of the plant are useful.

The production process concludes 5 major steps according to the company Choren.

1. Milling**.** The feedstock passes through a hammer mill which grinds it into a fine powder.
2. Gasification. The feedstock has to be converted into a synthesis gas, to produce a liquid fuel from the biomass. The biomass (water content 15 - 20 %) is carbonised in the first process stage by a continuously partial oxidation with air or oxygen at temperatures between 400 and 500 °C. This process develops tar containing gas and solid carbon. The tar containing gas is oxidized with oxygen under not stoichiometrically conditions. This happens in a combustion chamber with a temperature above the ash melting point.

The grounded solid carbon is injected into the hot fumigator. The grounded solid carbon and the fumigator react endothermically in the gasification reactor to synthesis gas. That gas is a mixture of hydrogen and carbon monoxide.

3. Gas Cleaning. The gas cleanup is the link between gas production and use. Sulphur connections, nitrogen compounds and other harming components have to be removed from synthesis gas, because they can damage the catalysts in the following synthesis procedure.

The right proportion of hydrogen and carbon monoxide is reached in this stage with help of a water gas reaction, that's increase the share of the hydrogen in synthesis gas. This is necessary to for the following Fischer Tropsch synthesis.

4. Synthesis. The Fischer-Tropsch process is a catalyzed chemical reaction in which carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt. The Fischer-Tropsch synthesis converts the synthesis gas into a liquid fuel.
5. Preparation. The produced liquid hydrocarbons are selected into heavy -, central and light parliamentary groups. The liquid hydrocarbons are refined after that procedure. The characteristic of the fuel can be determined by an according blending.

- **Application and Concept of use**

This synthetic fuel can be used by every diesel engine. A softly modification of the diesel engines optimises the dynamic driving characteristics, but even this modification creates no high purchase costs for the consumer. The production process allows a special fuel engine tuning to create a lower fuel consumption of the vehicles particular for the next generation of combustion engines (Combined Combustion System), which is impossible with fossil fuels.

The companies Choren, Volkswagen, DaimlerChrysler, Shell are connected in research and development projects and produce already synthetic fuel out of biomass.

- **Emissions**

For biofuels apply in general: only the emissions caused by an energy input out of fossil fuel counts in the emission balance, because these emissions are not atmosphere neutral.

The emission along the fuel chain is the sum of the emissions of biomass production, feedstock transportation, fuel production, distribution and the vehicular use.

The comparison of fossil diesel with BTL fuel shows, that synthetic fuel out of biomass has a enormous greenhouse gas saving potential. The savings in greenhouse gas emission from well to wheel are 61% CO_2 equivalent[10] according to the Lifecycle Analysis (2004).

The influence to the saving result of the distance for feedstock transportation and distribution is limited. For example a transport with a truck about a 200 km distance instead of 50 km, influences the greenhouse gas savings only by 4% (57% vs. 61%).

However there are also disadvantages. An extensive use of wood could lead to higher acidification over fertilisation of the ground. The grad of utilisation feedstock source determines this pollution.

- **Costs**

The main two cost components for the cost of the BTL fuel are the distribution costs and the production costs.

The costs for the distribution are depending on the distance and the way of transportation, storage and administration. Heat value of a synthetic fuel out of biomass is almost equal as the heat value of diesel. Therefore the distribution cost are very similar, they are ca. 0,10 €/l.

The production costs from BTL fuel are totally different to the costs of fossil diesel. Fixed and variable cost determine BTL`s production cost. Variable costs are mainly cost for the feedstock and the fixed costs are mainly financial costs.

The feedstock costs fluctuate very strong, because of the many varieties for raw material. The range of cost is between 0,04 € per litre gasoline equivalent and 0,30 € per litre gasoline equivalent. The feedstock average cost are around 0,10 € per litre gasoline equivalent.

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[10] All emissions are weighted with their global warming potential value

Financial cost depending on the investment cost and the estimated burden of interest. The costs of investment depend on the choice of the production area. You can use synergy effects, if it is possible to construct a biomass to liquid plant in a connection to a existing refinery or chemistry factory. Investment cost of 490.000.000€ is the result of this synergy effects. The DENA calculated production cost for BTL fuel of 0,90 € per litre gasoline equivalent for the shown feedstock and investment cost.
A plant without a link to such facilities would cost 620.000.000 €. Therefore the DENA calculated production cost for BTL fuel of 1,10 € per litre gasoline equivalent. The DENA study showed also, that a realistic optimisation (reachable until year 2010) of the technical process would lead to a decrease of cost of 0,20 € per litre gasoline equivalent.

- **Distribution pathways**

It is not necessary to install new technology for the distribution. There are no technical problems to apply the usual storages and the usual pumps at the service stations. And it is also possible to use the existing pipelines and trailer transporters for the distribution of the synthetic fuel out of biomass.

- **Potentials**

The annually worldwide growing biomass could theoretically cover the world's fuel consumption. But restrictions for food production environment protection or the application of biomass for construction material prevent the exploitation of the theoretically potential. The currently unused agriculture area in Germany could produce the feedstock for 50% of the German fuel consumption according to Scheffer (2004). The U.S. energy information administration published a forecast of the world's biomass to liquid fuel production in the year 2050. The technical potential reaches form 12 exa Joule per year up to 455 exa Joule per year. The world business council for sustainable development calculates fuel consumption for year 2050 of 160 exa Joule. The technical potential for synthetic fuels out of biomass is between 7,5% and 285% with a reference to the both assumptions.

3.4 Electrical solutions

- **Derivations**

There exist several forms of electrical solutions in the transport sector.
First you can use the electrical engine as a stand alone solution. But then you have to take the whole energy stored in a battery. And if you run out of energy, it needs some time to fill the batteries up again.
Second there are many different kinds of electrical hybrid engines in combination with ordinary petrol or diesel engines. Here you can use "normal" fuel which has a very high energy density to get safely to your destination. And in several circumstances, which are mostly connected with high fuel consumptions, for instance stop and go traffic, the electrical engine can help to save fuel. In many

situations it is useful to have a combined generator which can get back energy from the driving speed who will be terminated in ordinary cars by breaking.

- **Chemical characteristics / Production**

Electricity is an energy form which consists to 100 % of exergie, which means that you can transform it completely to other forms of energy. This implies a high level of use and use forms.
Electricity can be produced centrally in huge power stations or locally in the car.
The problem of electricity is, that it is difficult to store and the storage need a lot of space and weight in the car.

- **Applications (Companies and Concepts of use)**

Hybrid cars are the most used form of electrical powered cars. TOYOTA is the first producer who has several hybrid cars in his product mix.
A hybrid car is a passenger automobile that is driven by a hybrid engine, which is any engine that combines two or more sources of power, generally petrol and electricity. On the one hand you have the parallel hybrid - on the other hand you have the series hybrid - the two main types of petrol-electric hybrid cars. Both use petrol-electric hybrid technology, but in totally different ways.
In a parallel hybrid car, a petrol engine and an electric motor work together to move the car forward, while in a series hybrid, the petrol engine either directly powers an electric motor that powers the vehicle, or charges batteries that will power the motor. Both types of hybrids also use a process called regenerative braking to store the kinetic energy generated by brake use in the batteries, which will in turn power the electric motor.
A newer trend is a combined hybrid system, which has features of both series and parallel hybrids. They incorporate power-split devices allowing for power paths from the engine to the wheels that can be either mechanical or electrical.
Both parallel and series hybrids have small petrol engines, and produce much less pollution than standard petrol cars, but also produce much less power - hybrids generally produce between 60-90 horsepower, while the average petrol engine probably produces about double that. To overcome this power gap, hybrid cars are designed with ultra lightweight materials like carbon fiber or aluminum. Hybrid cars are also build to be more aerodynamic than most cars, allowing them to "slice" through air instead of pushing it out of the way. All these factors combined equate to a super efficient form of car that gets excellent fuel economy and helps the environment by cutting down on pollution.

- **Emissions**

The emissions depend on how the electricity is produced. The electricity can be generated in a power plant with fossil fuels or with nuclear elements. This implies the known CO_2 and other emissions which mainly depend on the supply chain. As there are the construction of the power plant, the fuel, the efficiency of the process and the delivery system (network). Electricity can also be produced by renewable sources which have mostly a very good emission balance.

The emissions of hybrid vehicles, as compared to conventional vehicles, are reduced in two ways. Electrically driven engines combined with regenerative braking are emission free. When the petrol engine is used, it uses much less fuel than conventional engines, and less fuel combustion equals less emissions.

The manufacturing and production of hybrids generate slightly more greenhouse gas emissions than the production of similar traditional cars. Hybrids recoup this added environmental impact over the lifetime of the vehicle because emissions are lower during normal operation. As a consequence, the overall environmental benefits of hybrids would seem to increase as more miles are driven. But if these miles are on the highway, the emissions savings are not that great.

- **Costs**

Hybrid cars cost an average of € 2.500,00 to € 3.000,00 more than comparably equipped petrol vehicles. These higher fixed costs in the beginning turn into significant higher resale prices for used cars.

The variable costs depend on how the hybrid car is used. If it is mostly used in town there are fuel savings between 20 % and 40 % but if it is used mostly on the highway there are no significant savings possible.

The costs of a real electrical car depend on how the electricity is produced and how complicated and expensive the production of the engine equipment is. But there exists no data because there is no real electrical car available.

- **Potentials**

The potentials for hybrid cars are enormously high, because there are significant advantages.

It's already a tested system which is available all over the world but there is still a high innovation rate in this sector.

Real electrical cars are only a theory at the time. The main limiting factor is the storage capacity and the weight of the storage which implies a minimum distance of reach and an adequate efficiency of the complete car.

- **Distribution pathways**

There is no need for a separate distribution for hybrid cars, because it is an ordinary car with much better energy efficiency which uses the normal petrol or better alternative fuels.

On the other side there are electrical networks all over the urbanised landscape so that electrical tank stations for real electrical cars are not really a problem.

3.5 Gaseous Fuels

- **Derivations**

The main gaseous fuels usable for combustion in automobile are Natural Gas (NG), which can be purchased as Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) as well as Biological Gas (BG).

- **Chemical characteristics / Production**

There are different ways to get gaseous fuels.

First, you can get fossil gas from the earth which is called natural gas (NG). NG is located in geological formations under the surface of the earth and often it is located in combination with oil.

NG is a mixture of hydrocarbon and non-hydrocarbon gases. It consists to about 90 % of methane (CH_4), especially the Russian one. To reduce the volume of the NG, for a higher energy density, it can be compressed (CNG) or cooled deeply down to about - 161°C (pure Methane - 162°C) and so it becomes liquid (LNG), then the LNG needs only $1/600^{th}$ of its original volume.

Second, gas can be produced by several processes from any kind of biomass (included biological waste) which is called biological gas (BG). BG consists 55 % - 70 % of methane and 25 % - 40 % of carbon dioxide (CO_2). The components of the BG are very different depending on the production process of the BG and what the starting products are. BG can also be compressed or liquefied.

- **Applications (Companies and Concepts of use)**

Using gas in a power engine is not really a problem, because power engines burns always a gaseous mix inside. The problem is storing the gas in the car in a quantity that allows the car to drive about 500 km without a tank stop. That's why we have to use CNG or LNG. By using CNG you need a very strong tank which can store CNG by a pressure of about 200 bar and who has also enough security reserves in case of an accident. The same problem has the tank station. On the other side LNG needs very low temperature to stay liquid and that can only be managed with very specialized high-tech tanks with expensive materials and a very good isolation.

Many companies have cars which can use gaseous fuels, for example OPEL, Daimler-Chrysler and so on. Most of them use CNG because it is easier to handle than LNG. In Berlin the buses drive completely with gaseous fuels (great job).

- **Emissions**

Generally gaseous fuels are very clean fuels with low emissions and they are easy to use in the engine. The main component is methane CH_4 which has a very good ratio between carbon and hydrogen. Hydrogen is one of the best energy sources (H_u = 120 MJ/kg) and has water as emission. The carbon which is the reason for the carbon dioxide emissions has a ratio of $n_H/n_C = 4$. On the other side petrol or diesel has a ratio of $n_H/n_C \approx 2$, because they have long carbon-hydrogen molecules. So theoretically gaseous fuels (especially methane) have only half of the CO_2 emissions then oil based fuels. But there are also other factors for a real CO_2 balance. Because you have to transport the gas and therefore you need an installed pipeline network with high pressure or a LNG transportation system which needs a low temperature. If there is a pipeline network in use, it will be a very efficient way to transport the gas and deliver the tank stations. To liquefy the gas it has to be cleaned up (so that no component gets frozen) and it needs a high energy input to get the temperature down to - 161°C.
By using biological gases there are also CO_2 emissions but this CO_2 is not fossil.

- **Costs**

NG is cheaper than oil but there are high volatilities in the marked prices. NG production needs very high specific investments (especially in infrastructure like pipelines), which are sunk costs. That's why there exist many long term contracts between the producers and the buyers of the NG. In these contracts exists often a link between the oil and the NG prices. That's why it is difficult to get a "real" market price for the NG on the one side and on the other side there has to be undertaken enormous investments by the firms to reach a higher supply for the transport sector.
A more liberalised market is the LNG market because there are not so high specific investments needed. For instance a LNG tanker (which is a high investment) can reach all places in the world and sell there freight in the most interesting market. And the LNG terminal can be build near the production place of the NG and deliver different income LNG tanker.

- **Potentials**

Gas has a very big potential. Because there are huge fossil NG quantities with reserves to production ratios about 60 years (oil has about 40 years). There are also high exploration ratios for new NG reserves all over the world. Furthermore NG reserves are located all over the world and not so extremely concentrated like oil reserves.
BG has an endless potential because it growths every year and the production ways are becoming much better especially in the last years.

- **Distribution pathways**

To use the gas in the transport sector, there have to be taken enormous investments in the infrastructure, especially in tank stations.
In countries who have a complete gas pipeline network to distribute the gas into the houses for heating (like Germany), this network can also be used to deliver the tank stations, so there is only a little part left which has to be transported on the road.

4 Case Studies

4.1 California

4.1.1 Political Intentions and Instruments

Today and also in the future, mobility and flexibility are factors of competition deciding about success and failure. Therefore an important and necessary part of the market is the transport sector. But also the trend in the society owning several cars per household has decisive influence on the demand of fuels. A result of the growing need of transport-services and the wish of mobility is an increase in the energy demand accompanied with an increase in the CO_2-emission. So the state has different possibilities control this demand there, such as incentive or tax- instruments. The aim of these instruments must be the invention of alternatives to existing technologies which can reduce the dependency on mineral oil on the one hand and achieves a lead in competition in form of new technologies on the other hand.
Acceptance in the population for alternative fuels should also be created with the help of public effective programmes and privileges. In the following, possibilities of implementation will be described at the examples Sweden and the United States with focus on California.

4.1.2 Implementation

Already in the 1970`s, there were programs reducing the dependence on mineral oil and the emission of GHG in the United States. So in 1975, the government passed the “Energy Policy and Conservation Act” which was amended by the “Motor Vehicle Information and Cost Saving Act.” With the help of this law the producers of cars and light-duty trucks had to give information about consumption specific details for the sale of their cars. Electric cars or hybrid vehicles may be included in the average fleet calculations and a credit is given for flexible fuelled vehicles. For uniform and checkable regulations, the CAFE - Standard was created. This standard provides reference values for the consumption of a vehicle in the combined use on highways and country roads. It also contains maximum values for the consumption in this test cycle.

The transport sector causes approximately one third of the CO_2 emissions in the USA. Cars and light-duty trucks have a share of more than 50 percent on this production. For this reason the "Partnership for a New Generation of Vehicles" (PNGV) program was passed in the year 1993. The PNGV was a joint research and development program between the Environmental Protection Agency EPA and the three largest car manufacturers in the United States and should last ten years. Aims of this partnership were the improvement of competitiveness in vehicle manufacturing and the implementation of fuel efficiency and emissions technology for the use in conventional vehicles. Another aim was the development of a vehicle achieving up to three times the fuel efficiency of a current comparable vehicle.

In the year 2002 the PNGV Program was replaced and improved by the FreedomCar Program. In form of a public-private-partnership between the U.S. government and the three large automobile manufacturers the development of the hydrogen fuel cell technology should be improved. But also the mass production of affordable hydrogen-powered fuel cell vehicles and the hydrogen-supply infrastructure should be reached. These developments were supported by funds. But also petrol dependent technologies shall further be supported in order to achieve more fuel efficiency. Strategic aims were the development of affordable mineral oil independent technologies and the building of supporting infrastructure. Furthermore, these new technologies should be compatible to several cars and should not only work in one type of car. In January 1999, on further action was started. So since that date, there has been charged no licence fee for alternative fuel vehicles (AFVs) when the purchase of those is clearly more expensive than comparable conventional cars. Another program implemented in the year 2002, was the Efficient Vehicle Incentive Program. It was created to reduce the dependence on oil and to increase the use of environmentally friendly vehicles. Another purpose of this program was to provide incentives for vehicles offering public benefits like energy efficient transportation or fuel diversity. The structure of that program was created in the way that the Energy Commission can gauge customer response and allow modifications to improve market response as necessary. Unfortunately it ended in 2002 because of state budget limitations. The State of California takes even a more fastidiously way concerning environmentalism. Since January 1, 2006, every city or county is authorized to require that 75% of the passenger cars and/or light-duty trucks acquired be energy-efficient vehicles, when awarding a vehicle procurement contract. Life cycle and consumption specific qualities have influence on this assessment. Until June 2007 the State Energy Resources Conservation and Development Commission in partnership with other State agencies has the task to work out a plan for the application of alternative energies. Within this plan, consequences of polluting air and water as well as the emergence of greenhouse effect shall be judged. It also shall include a minimum standard concerning fuel consumption of vehicles. Furthermore step-by-step aims shall be set for the subsequent years. Through another program a share of the registration fee of vehicles is used for the reduction of air pollution. An alternative to the system of the motor vehicle tax in Germany at present is the taxation of vehicle weight which is imposed flatly every year. Therein AFVs were subsidized in form of lower taxes. Another programme promotes the purchase of home refuelling facilities and the relocation in certain environmental reserves. Furthermore in California providing energy through biomass burning shall become a part of the energy strategy. Another action is called the “Bioenergy plan.” An aim of that plan is the increase of the share of new purchased car owned by state up to 50 percent in 2010. These vehicles shall be AFVs, of course. Moreover, the purchase of new environmental friendly school buses is subsidized by public funds. In the „State Energy Program“(SEP) public-private-partnerships become promoted, which take part in the use of AFVs and the building of supporting infrastructure. In the past five years, California participated very successfully in this program founded in 1996. California got between 20 and 33 percent of the nationwide provided funds. Beside the support of developing new technologies, there exist programmes for increasing efficiency of conventional technologies, too. So the current state of technology shall be promoted and also cleaner diesel technologies shall be developed with the help of the “Diesel Emission Reduction Fund“(DERF). The fund is financed through fees charged on high emitting trucks.

In the year 2009, there will be a law in California, which commits automobile manufacturers to reduce the GHG emission of their cars. This law does not contain any new limiting values but demands the implementation of the regulations of January 2005.

4.2 Sweden

4.2.1 Political Intentions and Instruments

Also the state Sweden obliged itself to active participation in environmentalism and GHG reduction within the framework of the Kyoto Protocol. Additionally in the beginning of the year 2006, the Swedish government set itself the ambitious aim to be able of abandoning fossil fuels in 2020. The motive, as well as in other countries, is to decrease the dependence on these energy sources first and renouncing completely in the following years for being independent of supply especially in bottle neck cases. Consequently also Sweden launched research and development programs for alternative fuels and efficient technologies for ensuring the safety of transportation on the one hand and reducing air pollution and GHG emissions on the other hand.

4.2.2 Implementation

In Sweden, traffic causes 61 per cent of CO_2 emissions. Conventional energy resources like petrol and diesel have a share of 91 per cent of these emissions. So the aim will be a substitution of 15 per cent of fossil fuels to alternative fuels till 2010. Sweden was aware of these potentials since several years.

For this reason „The Swedish Transport and Communications Research Board"(KFB) launched a bio fuel programme in the year 1991. Research and development of equipment and systems using alternative fuels were tasks of this programme in collaboration with partners of the industry. But only biogas was given a chance in long term. Ethanol from sugar was seen as a resource with low potentials because the usage of sugar stands in competition to the food industry.

The following overview shows the expected potentials of alternative fuels depending on their point of introduction:

Alternative	**Alternative that can satisfy 0-10 % use**	**short term (10 years)**	**Alternative that can satisfy more than 10% use**	**long term (>20 years)**
Fossil Raw Materials				
Reformulation petrol		X	X	
Reformulated diesel		X	X	
Natural gas				X
Methanol from natural gas			X	X
Dimethyl ether from natural gas			X	X
Blend of diesel and vegetable oil esters	X			
Renewable raw materials				
Methanol from cellulose				X
Methanol from sugar- and starch-containing plants	X			
Etanol from cellulose				X
Ethanol from sugar- and starch- containing plants	X			
Vegetable oils	X			
Esters from vegetable oils	X			
Biogas	X			X
DME from cellulose				X
Hydrogen from renewable sources				X
Electricity from renewable sources				X

Source: Potential use in Sweden of a variety of fuels and conversion techniques; modified version; KFB, SIKA, NUTEK, 1996

Additionally in the year 1991, the “Carbon Dioxide Tax” was introduced with the consequence of a significant decrease of CO_2 emissions. Six years later, in 1997, the KFB launched on more programme to demonstrate the technological state of the art. These demonstrations were conducted in four cities, namely Stockholm, Trollhattan, Linkoping and Uppsala. Results showed that ethanol and biogas are viable alternative fuel options and provided useful information to various interested parties (politicians, distributors, vehicle operators, etc) on future investments in bio fuels. But these bio fuels cannot compete in price with fossil fuels in today's market. As well, the import of Ethanol is much cheaper than producing it in the country.

The following overview shows the distribution of vehicle types with regard to their energy sources

FUEL	**TYPE OF VEHICLE**
Ethanol	approx. 300 buses 7 lorries approx. 100 flexible fuel vehicles
Combined fuels (15 % ethanol in petrol)	24 buses 20 lorries
Biogas	approx. 50 buses 2 lories approx. 50 dual-fuel vehicles
Natural gas	approx. 180 buses approx 20 lorries
Electricity	approx. 100 electric cars 9 electric hybrid buses

Furthermore, “The Environmentally Sustainable Transport System (EST) Project” was launched. This project is a collaboration of 11 government authorities an industry organisations working on lowering CO_2 emissions and air pollution in long term. Thereby possibilities of taxation were examined, too. In Sweden, 25 per cent of car purchases are company cars. These cars often are heavier and have a higher need of fuel. Because of the new regulations, it has to be paid for private use. The result was a decrease of kilometres driven with company cars and a reduction of CO_2 emissions. In 2002, the tax was lowered for environmental friendly vehicles. Sales of these cars increased from 3500 cars in 2002 to 6 000 cars in 2003. In the end of the last year, there already were about 12000 units. Most of them were company cars. These AFVs, like the Saab 9-5 with flex-fuel-engine or the Volvo V70 with bi-fuel gas engine, are popular in taxi companies, too. Possible incentives for these firms are extra lanes beside the cost factor, i.e. at the front of airports. However, the share of AFVs in Sweden’s is about one per cent, but constantly increasing. Sales of light duty trucks increased about 44 per cent last year.

Consequently the demand of alternative fuel was rising about 25 per cent in 2006 compared to 2005 (see NGV Global; “Swedish Appetite for Alternative Fuels Continues”). But due to that rise in demand, there were temporary fuel shortages although all large fuel stations must provide by law one alternative fuel, at least. These fuels will still be excluded from taxation till 2008. Finally, owners of AFVs do not have to pay road tolls and congestion taxes since 2005. These taxes were introduced in areas with high traffic density. The money is used to support road infrastructure developments.

4.3 Prospects and Potentials

Several development and demonstration programmes showed that there are alternatives to conventional fuels, offering solutions for transportation, waste management, agriculture and forestry. Thereby the collaboration of numerous groups of interested parties, like car manufacturers, government, oil companies and transport companies was strengthened. But the expensive technologies are still a considerably barrier. For this reason, there still must be research and development activities for more efficient and less cost intense technologies taken as well concerning combustion or car design, too. The promotion of alternative fuels still must be expanded for wider understanding of environmental consequences and energy security. Another aim is a better harmonisation of legislation, standards and regulations regarding the usage of alternative fuels in vehicles. Finally, external costs of building infrastructure or air pollution reduction shall be internalized through a roll over in all fuel prices.

5 Policy Implications for Germany

The issues environmentalism and reduction of CO_2 emissions became very important in the media in the last weeks and nearly every day new suggestions are made to solve these problems. The German government wants to achieve ambitious targets while its period of EU – chairmanship, too. It is expected that these EU targets are pointing the way for the other big industrial nations in the world, like the United States, India or China. But also in Germany, the implementation of issues concerning emission reduction is difficult and provokes discussions about the influence of the car manufacturer lobby again and again. So they are gibbeted for not fulfilling their voluntary aim of producing more environmental friendly vehicles. But the manufacturers give the incisive reply that there is no demand for these cars for one thing and the problem lies in the character of these cars for another thing. As the Germans car manufacturers produces vehicles in the upper and luxury class and sports cars predominantly, these cars are equipped with lots of electronics and/or they have a powerful engine. Obviously, it needs the help of political incentives for a change of mind. The government must sensitize the public for environmental critical factors and has to guide this development process. The number of tangible projects demonstrating alternative fuel technologies with an effect on the public opinion has to be extended. As well, the purchase of AFVs should be subsidized to increase demand achieving economies of scale in production besides the positive influence on climate. Consequently, car manufacturers can offer AFVs to comparable prices like conventional technologies. Subsidies have to be temporally limited, until the installed base is large enough to provide the sufficient economies of scale in production as well as in consumption. The tax deliverance of the grime particle filter over a 4 year period in Germany could help to increase consumer's sensitivity for environmental topics, In this case, a differentiated implementation as done in Sweden or in California is imaginable because there is a considerable share of company and municipal cars in Germany, too. Hence, a minimum share of AFVs could be set or these cars could be subsidized by a lower taxation. Additionally, there are new opportunities concerning the reformation of vehicle tax. So there is also potential for tax incentives like in California. Furthermore, incentives for public transportation companies shall be created for switching to vehicles operating with alternative fuels. In the last years, single pilot projects were launched in collaboration with the NEOMAN AG in that concern. This company develops CNG-engines, as well fuel cell engines for vehicles used in the public transport sector. In this manner there still is need for R&D activities especially fort the fuel cell technology because investment costs are still five times higher compared to conventional buses. However, the CNG-technology is very successful and considerably cheaper than fuel cells. In addition, this technology already fulfils the EEV-standard (Enhanced Environmentally Friendly Vehicle-Standard) even today which is stricter than the Euro 5 Standard (see Website NEOMAN AG). Another possibility for a successful implementation of alternative fuels is to increase the supply of them by using unplanted regions like in the example of Sweden. In these areas, energy plants can be cultivated for the production of alternative fuels. Furthermore, the share of these fuels in petrol shall be increased. This step has to be harmonized with possible subsidies offered for the purchase of AFVs because there can appear problems concerning compatibility with existing technologies. Moreover, alternative fuels shall be exempted from tax again for creating further incentives. F the implementation of a CO_2 tax should be checked in that concern like in Sweden, 1991. Another possible starting point for a controlled implementation of alternative fuels could be seen in collaboration with the car manufacturers. So the automobile industry could take part in the emission trading. In accordance to the Midstream Case (see Klimawirksame Emissionen des PKW-Verkehrs und Bewertung von Minderungsstrategien; Wuppertal Institut 2006) car manufacturers must buy certificates for the amount of sold vehicles. As a result environmental friendly cars have to be produced by them in order to reduce their costs. So on the one hand the purchase as well the usage of AFVs can be funded.

As alternative fuels, mainly the gaseous one, may lack of the infrastructure needed for their distribution, the initial network might have to be provided by the government. This could be refinanced by a partly taxation of these fuels, which then would raise the price on a level with gasoline.

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