Progress Report 2004

Perspectives for Germany

Our Strategy for Sustainable Development

- Extract -☐
☐
"The fuel strategy - Alternative fuels and☐
innovative drive systems"☐
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Section E. III., pages 166 - 192, Imprint

III. The fuel strategy

Alternative fuels and innovative drive systems

1. Current situation

a) Reducing consumption of fossil fuels

Oil is the fuel of traffic. In answer to the increasing global demand for oil, owing to limited available resources and the effect on the climate of fossil energy sources, consumption of fossil fuels must be reduced. Consequently, the development of alternative fuels and energy-saving drive systems is imperative to ensuring sustainable mobility.

b) Fuel strategy goals

In its Strategy on alternative fuels and drive technologies, the Federal Government is pursuing the following goals in particular:

- Consumption of fossil fuels is to be reduced and, thus, the dependency on oil decreased (safeguarding supply).
- Greenhouse gas emissions generated by traffic are to be reduced (climate protection).
- Promising alternative fuels and drive systems that also have high availability potential are to be identified (innovation and efficiency).
- Action required to ensure progress with efficient promising alternatives is to be determined and coordinated into a programme of implementation measures (implementation).

In summary, the Federal Government believes that, given the long-term economic, traffic-related and ecological implications, a promising strategy for the application of competitive alternative fuels and drive system technologies is required. Above all, the innovative potential for alternative fuels and drive technologies should be used to create growth and employment. Thus, such action will not only significantly contribute to environmentally friendly mobility, but also to overall sustainable development in our country.

c) Promising alternatives

The fuel strategy is not a question of finding the "ideal fuel or engine of the future", but rather of identifying the fuel options and drive system technologies that are the most promising. Subsequently, the limited resources available from the state and economy need to be concentrated on these. This provides orientation in terms of which developments are considered feasible and, above all, illustrates which fuels and drive technologies are relevant for future direction.

The fuel strategy is oriented in line with the development goals of the European Union. On this note, in its resolution of October 2002, the European Parliament called upon the Commission to "swiftly draw up a long-term strategy for biofuels and other alternative fuels in consideration of their ecological effects and, thus, send out a clear signal for investment in this sector".

A fuel strategy developed in cooperation with science and industry, which is incorporated into European and international strategies, will secure planning for investment and provide incentives for innovation in the long term. This, in turn, smoothes the progress of industry in maintaining a technologically and economically leading role on the world market in the future. Innovation in relation to fuel and efficient drive system technologies can make an important contribution in this respect.

2. Method of approach

To maintain the overview within this complex subject, a stringent method of approach is needed.

a) Status quo (paragraph 3)

Initially, a comprehensive determination of the status quo is necessary. This must illustrate and evaluate the current position of national, European and international activities aimed at developing alternative fuels and drive systems.

b) Evaluating the alternatives (paragraph 4)

The multitude of possible alternative fuels and drive systems must be evaluated on the basis of uniform economic and ecological sustainability criteria.

c) Identification of promising alternatives (paragraph 5)

On the basis of the assessment matrix, promising alternatives are to be identified which fare well from a climate point of view and which simultaneously offer great potential in terms of volume and international market penetration.

d) Need for action and programme of measures (paragraph 6)

The next step is to ascertain what action needs to be taken in order to develop the promising alternatives identified and tap their potential (programme of measures).

3. Status quo

Given its essentially export-oriented automotive industry and its position in the heart of Europe, a “fuel strategy” based on a national approach makes little sense for Germany. Hence, deliberations on a strategy for sustainable alternative fuels and innovative drive systems concepts must fit into the European and international environment. In Japan and the USA in particular, efforts are being made to develop innovative drive systems and alternative fuels with considerable state sponsorship.

a) Important fuel options

Traditional, currently marketable fuels

Natural gas (predominantly methane) in compressed form (CNG) can be directly used as a fuel. The same applies for **autogas/liquid gas** in liquefied form (liquefied petroleum/natural gas [LPG], propane/butane mix).

Given its high octane rating, natural gas is suitable for commensurately adapted Otto engines. The advantage natural gas has over conventional petrol and diesel fuels lies in its particularly low emissions of NO_X and particulate matter, such as its potential to minimise CO_2 emissions in comparison with existing vehicles. Compared to other fossil fuels, use of natural gas is currently associated with higher costs for engines, storage units, as well as in terms of investment, operation and maintenance costs for service stations. In the medium-term, significant potential for savings exist in this area through mass production of natural gas vehicles. Worldwide, there are around 9 million liquid gas vehicles and approximately 2.5 million natural gas vehicles, of which around 1 million are in Argentina and around 0.4 million each in Italy, Brazil and Pakistan. Over 3 million vehicles in the European Union currently run on liquid gas, with more than 420,000 driven by natural gas.

Bio-diesel (FAME) is made from fat or oily plants (rapeseed/sunflower; RME) using methanol and can be mixed with traditional diesel fuel as an admixture of up to 5%. With its annual production capacity of around 1.1 million tonnes (2003), Germany is currently the world's leading producer of biodiesel. Production has increased 10-fold over the last decade; however, given the limited area for rapeseed cultivation, it is anticipated that further expansion of capacity in the future will only be limited.

The use of **pure plant oil** as fuel is limited in Germany to the application of rapeseed oil. Currently, it is used in a few thousand private vehicles and a small number of agricultural machines.

Traditional production of **bioethanol** has used biotechnological fermentation of raw materials containing sugar. Possible raw materials in Germany are, in particular, starch crops, potatoes or sugar beet (production capacity for 500,000 tonnes from starch crops is currently under construction). With respect to the fuel sector, bioethanol is used particularly in Brazil, where it is essentially made from sugar cane. Bioethanol production from lignocelluloses (wood residue, biomasses without sugar content) is currently at the development stage (see below). In accordance with DIN EN 228, ethanol can be mixed with traditional petrol in an admixture of up to 5%.

On account of the global distribution of petrol, of all the regenerative fuels outside Europe, ethanol has the largest distribution. The major ethanol producers and users are Brazil (approx. 9.5 million tonnes annually) and the USA (approx. 4.8 million tonnes annually). Within the EU, bioethanol is produced for the fuel sector to a minor extent in France, Spain and Sweden. Brazil, the USA and Sweden also use flexible fuel vehicle technology (FFV). In these vehicles, larger bioethanol quantities can be mixed with petrol.

Ethyl tertiary butyl ether **(ETBE)** is a chemical mix derived from (regenerative) ethanol and (fossil) isobutylene. ETBE is not used as a pure fuel, but is used as an admixture of up to 15% with petrol – predominantly used in France and Spain[13].

Biogas is a metabolic product of methane bacteria that results from biochemical decomposition of liquid organic substances (biomasses, waste and other organic remainders) by way of unaerobic treatment. Through purification it takes on the quality of natural gas and can be used in natural gas compatible vehicles. In Germany biogas is not currently used as a fuel, rather exclusively in the non-mobile area. In Sweden and Switzerland, biogas can be bought at public filling stations. Currently, Sweden and Germany are the only countries to have introduced a standard for biogas as a fuel.

Synthetic fuels, new developments – not yet market viable

Synthetic fuels are fuels produced from synthetic gas (using the Fischer-Tropsch process), which in turn derive from fossil **coal (CTL)** or **natural gas (GTL)**. In addition, **biomass (BTL)** particularly lends itself as a base raw material for synthetic fuels.

The particular interest of the mineral oil industry in **GTL** from natural gas lies in the fact that there are large natural gas reserves in geographically unfavourable marginal areas. Given the high cost of transporting liquid gas, tapping these reserves is not an economically viable proposition. In addition, there are also large reserves of natural gas in the form of petroleum gas that, to date, have been burnt off unused. **GTL** production costs are predominantly determined by the cost of the source of energy used (feed). Costs fluctuate significantly depending on whether "stranded gas" (gas from remote gas fields) is used, or whether gas is obtained from gas fields forming part of the overall infrastructure. The advantage of **GTL** fuels predominantly lies in their high cetane rating and the absence of odour and sulphur. Compared to traditional fuels, there are no benefits in terms of the reduction of CO_2 with **GTL** and **CTL**.

The base material for the manufacture of **BTL** is synthetic gas, which, in principle, can be produced from any type of biomass. **BTL** is not currently being produced commercially. Its high quality is commensurate with that of GTL fuel. BTL fuels are also free of contaminants. The benefit over synthetically produced fuels derived from natural gas (or coal) is its **CO_2 advantage**. **BTL** can be used as an admixture or as a pure fuel in diesel engines.

Production of bioethanol through the "saccharification of wood" is a long recognised fact; however, it is only recently that processes have been developed which enable **bioethanol production from wood, straw or other plants (lignocellulose)**. Using such methods, which no longer require sugar or starchy raw materials, the biomass basis of ethanol production can be broadened considerably.

[13] ETBE can be used to replace fossil fuel MTBE as an octane rating enhancer

Hydrogen can, in principle, be produced with the aid of all primary energy sources (fossil, regenerative and nuclear fuels). The spectrum of different hydrogen manufacturing processes and the raw materials used for such production is extremely diverse. Nonetheless, the difference in raw material base in terms of non-renewable (fossil and nuclear) and renewable (regenerative) primary energy sources is of paramount importance in evaluating hydrogen as a source of energy. All regenerative primary energies – solar, wind and wave energy, hydropower, geothermal energy etc. – which can be utilised in the form of electricity, can therefore also be transformed into **hydrogen**.

Hydrogen, with respect to mobile applications, can be used in Otto engines or fuel cells. Storage is possible in liquid form at very low temperatures (LH_2), or in the form of gas under high pressure (CGH_2).

b) Current situation in Germany

aa) Current use of alternative fuels in Germany

Alongside the traditional petrol and diesel fuels, alternative fuels being used on the roads in Germany are essentially biodiesel, natural gas and liquid gas.

In 2003, biodiesel as a pure fuel was the only biofuel with considerable market relevance in Germany. As of 1 January 2004, in addition to biogenic pure fuels, biogenic admixtures (e.g. biodiesel, bioethanol or ETBE) for fossil fuels have been exempted from mineral oil tax within the scope of the Ecological Tax Reform. Since that time, the extent of biodiesel used in Germany as an admixture for fossil diesel – to the permissible maximum of 5% – has notably increased.

With an overall total of 54 million vehicles in Germany and given that less than one in every thousand and only around 20,000 vehicles use natural gas, this form of fuel only holds a minor share in the overall fuel market at the present time. Through the mineral oil tax incentive introduced in 1995 and extended to 2020, natural gas should continue to increase its share in the fuel market. This is also supported by the doubling of natural gas filling stations to around 1,000 in Germany throughout the next two years, which will provide wide coverage of supply.

Consumption of fuels in Germany 2003

	in 1,000 tonnes	Share of total fuel consumption in %
Total fuel consumption	53,600	100
Petrol	26,000	48.5
Diesel	27,600	51.5
Natural gas (CNG)	47	0.08
Liquid gas/autogas (LPG)	113	0.2
of which biogenic fuels		
Biodiesel	800	1.4
Rapeseed oil (pure)	5	0
Ethyl tertiary butyl ether (ETBE)	0	0
Bioethanol	0	0
Biogas	0	0

Similar to natural gas, with 15,000–20,000 vehicles, liquid gas only has a share of less than one per thousand in the total fuel market in Germany. Through the existing mineral oil tax incentives, which will initially apply until 2009, a slight increase in market share is also anticipated for this fuel. By the end of 2006, around 1,000 filling stations should be offering liquid gas.

bb) Activities on the part of industry

German industry – particularly the automotive and plant engineering industries – has for many years been an active participant with respect to the research and development of alternative traffic concepts and, consequently, has become one of the global leaders in this area. Within the scope of European initiatives, such as the "Alternative Fuels Contact Group (AFCG)" or the "Hydrogen Technology Platform", German companies occupy an important role.

In Germany, all national automotive companies as well as the oil companies BP/Aral, Shell and Total are involved with the Transport Energy Strategy (TES), which, amongst other things, is pursuing a common position with regard to future alternative fuel options.

Strategies of the automotive companies

Volkswagen (VW) has developed a fuel strategy centred on the development of **synthetic fuels**. VW is initially focussing on GTL fuels, but is also simultaneously committed to projects looking into the use of BTL fuels. The advantage here is that these fuels can be mixed with traditional diesel fuels. VW is not currently publicly involved in the area of hydrogen fuel and fuel cells.

DaimlerChrysler (DC) is pursuing a "double strategy". Alternative fuel options such as synthetic fuel, including BTL fuels, are a welcome "additional option" for DC, but the long-term objective centres on hydrogen as a fuel. Furthermore, DC has begun development of so-called "hybrid concepts" and has launched its first natural gas vehicles onto the market – as have BMW and VW. Alongside Toyota and General Motors (GM), DC is the world's largest producer of fuel cell vehicles.

BMW is wholly committed to hydrogen for the future and, in line with this, has its "own transition strategy". At the moment BMW is developing small fuel cell prototypes, but is also aiming to speed up the introduction of hydrogen as a fuel and expand the necessary associated infrastructure by using (liquid) hydrogen in (dual-use) Otto engines. (Commercial vehicle manufacturer **MAN** is also pursuing a similar concept).

Opel and **Ford** have immense capacity in Germany for research and development. In light of the fact that these activities are embedded in the respective international company strategies, they are reported in paragraph 3.c).

cc) Development goals for alternative fuels

In terms of the further application of alternative fuels to 2020, the Federal Government is principally focussing on the goals formulated by the European Union. The Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport (Biofuels Directive) was adopted in May 2003. It aims to increase sales in biofuels to 2% of the fuel market by 2005 and to 5.75% of the market by 2010. Furthermore the EU Commission presented an optimistic development scenario, which assumes a 20% share for alternative fuels by 2020 and illustrates how this could be structured overall in a communication on this topic:

	2005	2010	2020
Biofuels	2%	5.75%	8%
Natural gas		2%	10%
Hydrogen		2%	5%

Against the background of EU enlargement and the development of new technologies – such as synthetic fuels – the EU Commission announced in summer 2004 that it would be re-examining these objectives.

In Germany, the share of biofuels stood at 1.4% of overall fuel consumption in 2003. As detailed in the first report on implementation of the EU Biofuels Directive in July 2004, the Federal Government is striving to achieve a share in overall fuel consumption of at least 2% for biofuels for the year 2005.

dd) Research activities in Germany

Programmes in the area of research and development (R&D) within Germany are currently concentrating on innovative drive system technologies and the mobile application of fuel cells, the use of natural gas and liquid fuels based on sustainable resources.

R&D – Development of general strategies

Programmes within the scope of the Environmental Research Plan (ERP) examine the development of general strategies for alternative fuels and drive system technologies. To this end, € 1.1 million is being invested during the period 2000-2004 and focusses on the following research goals:

- Determination of a basic foundation for accelerated market introduction of environmentally friendly and innovative drive system and vehicle concepts for commercial vehicles;
- Development of a general strategy for the introduction of alternative fuels, particularly regeneratively produced hydrogen as a fuel for the automotive sector;
- Development of natural gas vehicle motor up to the demonstration stage in order to accelerate market introduction;
- Continued development of special natural gas vehicle technology.

Since 1995, around € 35 million have been invested in national pilot projects for the application of natural gas in various areas of road transport.

Since 1998, the Federal Government has been a member of the "Transport Energy Strategy (TES)", which is a consortium of German and European automotive and oil companies. Currently the members are specifically involved in the Clean Energy Partnership (CEP), which is managing the joint construction and operation in Berlin of Europe's first public hydrogen filling station. The Federal Government is supporting the project with a total volume of € 5 million (project duration 2003–2007).

R&D – Energy research and technologies

Major programmes of the Federal Government on "Energy research and technologies" are predominantly concerned with developing technologies for the rational and environmentally friendly provision of electrical and thermal energy, for example:

- Demonstration of the entire chain of a solar hydrogen energy industry, including utilisation of hydrogen in the automotive sector,
- Development of battery technology for application in electric vehicles;
- Fundamental development of fuel cell technology for mobile applications.

These measures were essentially completed by the end of the 1990's. Thanks to additional funding from the Future Investment Programme (ZIP), it has been possible to support the following measures also relating to the transport sector:

- Development and testing of a zinc/air battery system in a demonstration vehicle (Bremen Institute of Industrial Technology and Applied Work Science; total funding € 6 million).
- Projects to construct and test fuel cell vehicles, including realisation of hydrogen infrastructure (Stuttgarter Straßenbahn AG, Hamburger Hochbahn AG, HEW, Berliner Verkehrsbetriebe, Stadt Barth, Audi AG; total funding € 9.4 million).
- Renewable fuels produced from biomass (CHOREN Industries GmbH; total funding € 5.4 million).

However, since these ZIP projects came to an end, development programmes in the area of "Energy research and technologies" are no longer the focal point in the transport sector.

R&D Biofuels

Development funding for ongoing biogenic fuel projects currently stands at around € 4.0 million. Basis for current research and development into biogenic fuels is the Federal Government's development programme entitled *"Nachwachsende Rohstoffe"* (Renewable resources), which was introduced in 2000.

With the first R&D projects on **synthetic biofuels**, in particular BTL, a pioneering direction of development has been set that not only makes a significant contribution to sustainable mobility, but could also open up economic prospects for domestic agriculture and forestry. Within the scope of this, research is currently being carried out on, amongst other things, establishing a pilot BTL fuel facility for production on a large technically relevant scale. In addition, the Federal Government

also set up a BTL information platform this year to improve the information exchange and tap synergy effects.

Due to the fact that the production and use of biodiesel and bioethanol (from sugar beet and starch crops) is state-of-the-art technology, development funding is only being applied to a limited extent at present. Development initiatives relating to plant oil are currently only focussing on agricultural application. According to industry assessments, in the future, plant oil as a fuel will only be applicable in niche areas and will not offer an alternative on the open market.

R&D Innovative drive systems

The "Mobility and Transport" programme of the Federal Government promotes the development and demonstration of alternative drive systems. This encompasses the drive system (combination of efficient Otto engines with electric motor/generator drive systems) and the associated energy management (battery storage systems for energy retrieval and recycling during the journey), as well as the necessary simulation instruments that enable initial analysis of operational processes and the efficiency of individual concepts.

These R&D projects also include specific development of new electrical drive components for electric and hybrid vehicles. These are based on high performance batteries for hybrid vehicles that ensure high performance, while simultaneously offering long life and a high degree of safety, for example, in the case of accident.

Concepts for pioneering driving methods that are adapted to the transport flow are also being investigated. In this respect, these vehicle concepts and their coordinated energy management strategies demonstrate that an energy saving potential of up to 20% could be achieved.

Based on these conceptual studies, various personal vehicle/hybrid concepts are being specifically planned with decisive participation on the part of vehicle manufacturers and the ancillary industry. New concepts for hybrid drive systems are being installed into test vehicles in order to clarify fundamental questions with respect to battery lifetimes and whether operation is in line with requirements. As such, the achievable potential for CO_2 reduction can also be more reliably assessed on the basis of experience gained by actually operating a system in real conditions.

Within the "Mobility and Transport" funding programme, funding of € 17.1 million was made available during the period 1999 to 2003 for the purpose of developing environmentally friendly drive systems. This activity will also continue.

ee) Tax incentives for alternative fuels in Germany

Tax policy framework conditions created by the Federal Government have had a decisive impact on the dynamic development of alternative fuels in Germany and the fact that Germany has, consequently, taken a leading position within Europe. Nevertheless, analysis needs to be carried out to establish the extent to which fuel-specific tax reductions are consistent with targeted objectives (CO_2 reduction, increased safeguarding of supply, efficiency).

In Germany, mineral oil tax law currently provides tax relief, for example, in terms of tax allowances for biofuels, natural gas, liquid gas, as well as the possibility of tax relief for the use of mineral oil for experimental purposes. Depending on their biogenic level, biofuels are currently exempt from mineral oil tax until the end of 2009.

Given the current rates of mineral oil tax for petrol and diesel fuels, the tax exemption on biofuels and tax relief for natural and liquid gas, considerable subsidies are needed in Germany in order to achieve EU goals. Based on the current rates of mineral oil taxation, estimates based on expert analysis of rolling stock development predict the following tax losses: For 2010, tax subsidies would amount to € 3,000 million per year (5.75% biofuels, 2% natural gas); in 2020 to approximately € 5,000 million (8% biofuels, 10% natural gas). Nonetheless, the subsidised fuels are showing overwhelmingly positive external results.

Since 2004, hydrogen as a fuel has essentially been subject to mineral oil tax; however it is granted tax exempt status under a special dispensation.

Funding of fuels, as at 1 July 2004

Product	Raw material source	Type of tax relief	a) Standard rate b) Reduced rate	Tax per MWh
FUELS ON THE MARKET IN 2003				
Petrol[1]	Crude oil	none	a) € 654.50/1,000 litres	€ 72.58
Diesel[1]	Crude oil	none	a) € 470.40/1,000 litres	€ 47.45
CNG	CNG Stranded/flare gas	Reduced rate until 2020	a) € 31,80/MWh b) € 13,90/MWh	€ 13.90
Liquid gas/ LPG	Stranded/flare gas Crude oil	Reduced rate until 2009	a) 1217/t b) 180.32/t	€ 13.92
Bio-diesel (pure or 5% admixture)	From fat (FAME) From oil plants (RME)		Bio share tax free	
Rapeseed oil (pure)	Oil plants	Tax free		
Ethyl tertiary butyl ether (ETBE; 15% admixture)	Starch crops Sugar beets	Bio share tax free		
Bioethanol (5 % admixture)	Starch crops Sugar beets	Bio share tax free		
Biogas	Old, waste and animal fats Energy plants	Bio share tax free		
OTHER FUEL OPTIONS (NOT OR NOT YET MARKET RELEVANT)				
Synthetic/ designer fuels	Natural gas (gas to liquid/GTL)	none	a) € 654.50/1,000 litres	
	Coal (coal to liquid/CTL)	none	a) € 654.50/1,000 litres	
	Old, waste and residue wood, Energy plants (BTL)	Bio share tax free		
Bioethanol	Lignocelluloses (residue wood)	Bio share tax free		
Ethanol (fossil)	(fossil) Flare gas (stranded)	Reduced rate until 2020	a) € 31.80/MWh b) € 13.90/MWh	

Product	Raw material source	Type of tax relief	a) Standard rate	Tax per MWh
Fatty acid ethyl esters (FAEE)	Oil plants, Old, waste and animal fats	Bio share tax free		
Methyl tertiary butyl ether (MTBE; 10% admixture for Otto engines)	Crude oil	none	a) € 654.50/1,000 litres	
	Natural gas	Reduced rate until 2020	a) € 31.80/MWh b) € 13.90/MWh	
Dimethyl ether (DME)	Natural gas	Reduced rate until 2020	a) € 31.80/MWh b) € 13.90/MWh	
Compressed gaseous hydrogen (CGH_2)	Natural gas Stranded/flare gas LPG	Reduced rate until 2020	a) € 31.80/MWh b) € 13.90/MWh	
	Coal	none	a) € 654.50/1,000 litres	
	Biogas Old, waste residue wood Energy plants	Tax free		
	Conventional power		a) € 20.50/MWh	
	Regenerative power	in case energy is fed into the grid, otherwise tax free	a) € 20.50/MWh	
Liquid hydrogen (LH_2)	Natural gas	Reduced rate until 2020	a) € 31.80/MWh b) € 13.90/MWh	
	Coal	none	a) € 654.50/1,000 litres	
	Old, waste and residue wood Energy plants	Tax free		
	Conventional power		a) € 20.50/MWh	
	Regenerative power	in case energy is fed into the grid, otherwise tax free	a) € 20.50/MWh	

[1] Petrol: unleaded and sulphur-free; Diesel: sulphur-free

c) International development

Strategies of the automotive companies

Against the background of strict emissions legislation – above all in the USA, Toyota and Honda already offer fully developed **hybrid drive system**s with Otto engines as an alternative drive form. Opel/GM and Ford are adopting the same course. Toyota claims to already have sold more than 100,000 corresponding vehicles in Japan and the US and is now launching a successive model on the market.

Opel/GM is the pioneer with respect to mass production of **natural gas** vehicles. Other manufacturers of liquid and/or natural gas driven vehicles are, for example, Volvo, Renault, Ford and Fiat. In addition, individual manufacturers, such as Ford and VW, offer flexible fuel vehicles.

Moreover, American and Japanese automotive producers are leading the way in **fuel cell development** and already operate their own hydrogen vehicles.

International research activities and development programmes

While research activity in Germany and Europe is focussing equally on fuel development and innovative drive system technologies, international research activity, such as in North America or Japan, is concentrating more on the development of drive system technologies. Recently, particularly large-scale hydrogen and fuel technology programmes have been initiated in this area.

European Union

In recent years, the EU has been involved in numerous **biogenic fuel projects** and their distribution throughout the EU or within the framework of development cooperation (e.g. "STEER" and "COOPENER" projects).

Particular focus has been placed on the areas of biodiesel and bioethanol. As such, sponsorship has been given to projects dealing with the production of ethanol using materials containing lignocelluloses, such as wood or straw, in order to expand the fuel base. Within the scope of the 6th Framework Programme, projects were sponsored that, amongst others, addressed the production of BTL fuels (e.g. "RENEWS" with around € 10 million and "CHRISGAS" with around € 8.8 million).

In its 5th and the current 6th Framework Programme, the EU has supported the **development of alternative drive systems**. Research projects to develop alternative drive systems place focus on fuel cell development as well as fostering the development of short-term alternative applications, such as hybrid drive systems. For example, three vehicles with hybrid drive systems that are close to the production stage have been developed by a project consortium of automotive manufacturers with German participation. At the same time, so-called "mild-hybrid" drive system concepts were also realised (electro-engines/generators combined with combustion engines and starters/generators with electric acceleration function using storage batteries).

At the end of last year, in coordination with and as a supplement to national activities, the EU Commission called for submission of project proposals relating to hydrogen and fuel cell drives for transport systems in its 1st invitation to tender of the current 6th Framework Programme. In connection with this, the EU Commission set up the European Hydrogen and Fuel Cell Technology Platform, HFP, in January 2004. This platform is tasked with drawing up a concept to ensure a smooth transition for the European energy industry, from its present predominant reliance upon fossil fuels to becoming a "hydrogen industry" (HyWays).

United States of America

The fuel market in the USA is dominated by petrol; with diesel only playing a marginal role. Consequently, application of biofuels in the USA is dominated by bioethanol. In 2001, consumption of ethanol stood at 6.8 million m3 (1.6% of petrol consumption). Market introduction is being supported by tax concessions and admixture constraints for oxygeneous fuel components (Clean Air Act).

The 2003 "Energy Policy Act" (HR6), which is not yet in force, also provides for further biofuel incentives. Thus, it is anticipated that biofuel will amount to 18.9 million m^3 of fuel consumption by the year 2012.

In the USA in the mid-1990's the PNGV Programme (Partnership for a New Generation of Vehicle) was jointly set up by the government and the three largest national **car manufacturers**, General Motors (GM), Ford and Chrysler. This is a joint research and development passenger car programme which, in the course of the 10-year programme, aims to produce an appropriate 3L saloon car in line with American conceptions. Nevertheless, it is not yet apparent whether the project's goals can be achieved. Meanwhile, the PNGV programme has expanded its remit to include a broader and more long-term research programme for the US automotive industry (foreign partners are largely excluded), which encompasses activities relating to telematics and, in particular, fuel cell and hydrogen technology programmes. In this respect, in 2003, the American government also expanded initiatives to promote hydrogen and fuel cell technology by means of additional programmes (Freedom Car – with around USD 1,700 million and Freedom Fuels – with around USD 1,200 million).

Tax incentives for alternative fuels on an international scale

Existing fuel duties in Europe are predominantly characterised by historical limitation to fossil fuels (cf. **mineral oil tax**). By contrast, separate rates of tax for alternative fuels (with the exception of autogas/LPG) are not common. Currently, within the scope of the European Energy Tax Directive now in effect, moves are underway to harmonise the widely differing levels of taxation.

Notable in the USA is the fact that both federal duties as well as state duties are levied on fuels used for transportation. Generally, it is apparent that rates for fossil fuels are extremely low in the USA and, moreover, special rates of duty on alternative fuels are widespread.

4. Assessment of alternatives

The current situation – in Germany and Europe – is defined by a large number of technological processes and ideas for potential alternative fuels and the possibilities for their production and application. Given the lack of transparency in this situation, uniform analysis of the manifold alternatives within a single matrix that includes specific economically and ecologically sustainable criteria is urgently required. Since the summer of 2003, this task has been performed by an inter-disciplinary specialist study group (see table of the next site).

Within this so-called **"matrix process"**, the potential of all known fuel production options – currently amounting to around 270 – is to be assessed for the period to 2010 and for the period to 2020.

Group of experts "Fuel matrix"	
Members of the Transport Energy Strategy (VES)	Mineralölwirtschaftsverband e.V.
German Association of the Automotive Industry (VDA)	Federal Environmental Agency (UBA)
Agency of Renewable Resources (FNR)	IFEU, Heidelberg
Institut für Energetik und Umwelt gGmbH, Leipzig	dena - German Energy Agency
Mineral Oil Analysis and Quality Management	Ludwig-Bölkow-System-Technik (LBST)
Institute for Energy Process Engineering and Chemical Engineering, TU Freiberg	
Consulting federal ministries	
Federal Ministry of Transport, Building and Housing (BMVBW)	
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)	
Federal Ministry of Economics and Labour (BMWA)	
Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL)	
Federal Ministry of Finance (BMF)	
Federal Ministry of Education and Research (BMBF, in the field of drive system technology)	

a) Assessment criteria

All technological activity and, consequently, also the use of alternative fuels and drive system technologies, is intertwined with an environmental impact. Nevertheless, the decisive factor for an overall assessment is how these technologies should be evaluated in comparison to traditional technologies, both today and in the future.

Essential factors are the previously mentioned criteria:
- climate impact,
- availability/safeguarding supply and
- efficiency.

The result of the specialist group's efforts is a **"fuel usage matrix"** for the years 2010 and 2020 that illustrates potential fuels in connection with the respective drive system concept which, in the opinion of the experts, are suitable in terms of contributing to the future fuel supply.

In addition to analysis provided by the IFEU, the "European Well-to-Wheel Study" by CONCAWE/EUCAR/JRC [CONCAWE 2003] was selected as an essential data basis for the study group. The results of this study expand upon important previous studies, particularly those by the TES and the General Motors Study [GM 2002]. Indeed, there are currently no other data bases in existence, which provide a similar scope and which are supported by the important European protagonists. Nonetheless, the data basis should be further expanded in the future.

A comprehensive account of the results of the "matrix process" work and corresponding conclusions are detailed in **the full repor**t produced by the "expert group" on the "matrix process". It is recommended that matrices set out in the report for 2010 and 2020 are read in association with the report text. The full report is available at **www.bmvbw.de**

aa) Potential for reducing greenhouse gases

The benchmark for assessing **"climate impact"** is the contribution that each fuel can make to reducing greenhouse gas emissions through its use in the appropriate vehicles. An expedient and meaningful comparison of the different fuels can, however, only be achieved within the scope of a Well-to-Wheel (WTW) analysis, i.e. the route the fuel takes from "its source to the wheel". This requires that a "fuel assessment" encompasses both its production and supply as well as its use in a vehicle.

In this respect, it should be borne in mind that a fuel's possible contribution to reducing emissions is not to be understood as a projection, but rather as its potential. As such, statements refer to the maximum contribution that a fuel could make by a specified date under the most favourable conditions. These conditions comprise the technically achievable potential quantity of the fuel, the technological stage of development of the vehicles/drive systems and their possible market penetration within the specified period of analysis.

The following table shows a summary of the fuel usage matrices compiled by the specialist group, classified according to the respective potential reduction in greenhouse gas emissions (ranges) of potential fuel/drive system combinations, with an estimation of the respective quantity potential for 2010 and 2020. All fuel paths include greenhouse gas emissions on a "Well-to-Wheel" basis. Assessment relates to the potential quantity of the fuels on the fuel market based on current legal and technological conditions.

Comprehensive details can be read in the above-mentioned full report.

CO_2-reduction potential per vehicle kilometre and estimated quantity potential

Fuel/drive system combination with potential CO_2 reduction of 0 to 33% ▶Note: There are no marketable options with higher CO_2 potential for the period up to 2010. Reference: petrol and Otto engine, standard of technology 2002: 189g CO_2 - equivalent/vehicle kilometre		**Estimated market potential in 2010** (values cannot be added up)	**Estimated market potential in 2020** (values cannot be added up)
Diesel fuel, diesel engine	Crude oil	55%	65%
Petrol, Otto engine	Crude oil	45%	35%
Bio-diesel (5% admixture, diesel engine)	Bio-diesel from various sources	max. 2.75%[0)]	max. 3.25%[0)]
Bioethanol (anticipated: 5% admixture, Otto engine)	From sugar beet From wheat	max. 2.25%	max. 1.75%[1)]
Natural gas (CNG), Otto engine	Via pipeline	0.5 -1%[5)]	2 - 4%[5)]
LPG, Otto engine	Crude oil refining Natural gas refining	max. 0.4%	max. 1%
Ethyl tertiary butyl ether (ETBE); 15% admixture, Otto engine	Ethanol from sugar beet, Isobutylene from crude oil Ethanol from wheat, Isobutylene from crude oil	max. 0.5%	max. 2.7%[2)]
MTBE (10% admixture), Otto engine	Methanol from natural gas	max. 0.5%	max. 0.5%
Dimethyl ether (DME), diesel engine	Reforming of natural gas DME synthesis	0	0[3)]
Fuel/drive system combination with CO_2 reduction potential of 33% to 66% ▶ Fuels that may only be market relevant subsequent to 2010			**Estimated market potential in 2020** (values cannot be added up)
Compressed hydrogen (CGH_2), fuel cell engine	Liquid hydrogen (LH_2), fuel cell engine		2 – 4 %[4)5)]
Steam reformed from natural gas	Steam reformed from LPG Steam reformed from natural gas and subsequently liquefied		
Fuel/drive system combination with CO_2 reduction potential of over 66% ▶ Fuels that may only be market relevant subsequent to 2010			**Estimated market potential in 2020** (values cannot be added up)
Synthetic diesel fuel (BTL), diesel engine	Biomass gasification (residue wood/short rotation wood), Fischer-Tropsch synthesis		2 - 4%[4)]
Synthetic petrol, Otto engine	Gasification of lignocelluloses (residue wood/short rotation wood), methanol-to-gas process		2 - 4%[4)]
Bioethanol, Otto engine	Hydrolysis and fermentation of lignocelluloses (residue wood/short rotation wood)		1.3 -2.6%[0)4)]
Dimethyl ether (DME), diesel engine	Gasification of lignocelluloses (residue wood/short rotation wood), DME synthesis		0
Methane, Otto engine	Biogas (residue substances) Through gasification of lignocelluloses (residue wood/short rotation wood)		2 - 4%[4)5)]
Hydrogen (Otto engine and fuel cell engine)	Through reforming biogas Through gasification of lignocelluloses (residue wood/short rotation wood) Through electrolysis with regenerative electricity		2 - 4%[4)5)]

0) In addition, biodiesel will also be used to a certain extent in future as a pure fuel, particularly with respect to rolling stock.
1) Through the use of so-called flexible fuel vehicles a limited market potential could emerge in 2020. The share of bioethanol in 2020 could decrease depending on the introduction of BTL fuels onto the market; however, if new technologies in the production of bioethanol from a pure vegetable basis (lignocelluloses) are successful, the share could rise to over 1.75%.
2) 15% ETBE admixture indicates the use of 7.5% Ethanol.
3) Not assessed, as no current vehicle development.
4) Limited on account of the possibility of availability in 2020.
5) Limited on account of size of rolling stock on the market in 2020.

bb) Availability/safeguarding supply

A realistic estimation of the actually **available** and accessible energy sources for use in fuel production is of immense importance for the transport sector. Relevant (technical) potential with regard to quantity is expected for biofuels and to a certain extent for natural gas and liquid gas and, after 2020, for hydrogen.

Typical for all alternative fuel options is the fact that they compete for limited energy sources with the frequently more energy-efficient electricity and geothermal sectors. Thus, analysis/discussion must also constantly take relevant alternative use into consideration.

(1) Biofuels

Given the minimal risk they represent for water and soil and their low toxicity, biofuels have advantages over fossil fuels. Moreover, they contribute to added value and employment, particularly in rural communities.

In terms of the availability of biofuels, consideration must be given to the fact that use of these fuels for energy essentially gives rise to a "competitive situation" for available biomasses between the non-mobile sector and the transport sector. Of the total energy produced from biomasses in 2003, 82% was devoted to thermal power, 7.8% to electricity generation and 10.2% to fuels. This breakdown reflects the fact that, notwithstanding other factors, due to the high level of efficiency of CHP plants, using bioenergy potential in the non-mobile sector is associated with significantly higher efficiency with respect to the reduction of climate gas emission than is the case in the mobile sector. As a result of structural changes in the electricity and geothermal sectors and, in particular, also with respect to innovative biofuels, this ratio will need reassessing in the long term. Essentially, thermal power is based on the use of wood, with electricity based on the use of waste wood and biogas. The contribution to fuels has been rendered by rapeseed, which until today is the most important biomass cultivated by German agriculture.

Hence, on the one hand, the Renewable Energy Sources Act (EEG) and the Market Incentive Programme are fostering the use of biomasses for generation of electricity and thermal power. And alongside the stated sustainability goals, there is also the development goal that aims to double the share of regenerative energy sources used for electricity generation and primary power demands by 2010 as compared to 2000. On the other hand, it is also anticipated that fuels will be produced from biomasses to an increasing extent. Currently, competitive applications are being examined in order to ascertain the realistic potential for thermal power and electricity generation on the one hand, and the production of fuels on the other.

The biomass potential that could be used for the generation of thermal power, electricity and biofuels is not currently being fully exploited. However, long-term developments, for example during the course of agricultural policy reform, give rise to the expectation that larger areas will be made available for use with respect to energy, including for biofuels.

The climatic impact is not the only aspect that could prove decisive with respect to utilisation between the mobile and non-mobile sectors. The question of

safeguarding supply of fuels is also an important factor. In this respect, the question of fuel diversification is of relevance, especially given the fact that biofuels for fuel consumption could reduce the transport sector's dependency on oil.

The question of biomass availability in Germany is overshadowed by the question of possible options for importing biofuels. Indeed, initial studies into the surface area potential within the 25 Member State EU indicate that the situation in other EU states is not essentially different from that in Germany. Accordingly, it is not expected that surface area potential will expand in any of the countries of the EU 25 that constitute a multiple of domestic open areas. Nevertheless, it is anticipated that further liberalisation of global trade will result in increased biofuel imports from third countries. With respect to such imports, steps should be taken to ensure that biomasses are cultivated and produced in harmony with the demands of sustainable development in order to avoid negative ecological or social consequences impacting on the country of origin or the world climate. Similarly, in terms of well-to-wheel evaluations, the climatic impact of alternative forms of surface area utilisation must also be considered.

In this context, due to the problem of surplus sugar, the option of developing a specific fuel system (beyond admixtures) for bioethanol is being discussed. However, this is predominantly rejected by industry on account of the high costs for its infrastructure (logistics and filling stations). Solving the problem through so-called Flexible Fuel Vehicles (FFV), which can be filled with both traditional fuels as well as bioethanol, currently only has niche potential in Germany (e.g. for fleet operators). Nevertheless, German companies are regionally (e.g. Brazil, USA) involved in the development and market launch of FFV.

(2) Natural gas and liquid gas

Natural gas is a fossil fuel – as is liquid gas – and, consequently, a limited source of energy. It can be used in a whole host of ways, thus, competitive application is a consideration in this area too. The specialist group "Fuel Matrix", which established the basis of the alternative energy strategy, has concluded that the realistic estimation of market share to 2020 for natural gas as a fuel is 4%. The gas and water industry's professional association *Bundesverband der Gas- und Wasserwirtschaft* is assuming a 10% share in terms of its investments. Moreover, there is also the possibility that natural gas could play a bridging role for other alternative fuels. The realistic estimated market share of liquid gas as a fuel by 2020 is 1.5%.

(3) Hydrogen

Hydrogen will only attain commercial significance in the fuels market after 2020. A share of 2% is considered to be an important threshold by the experts.

In particular, electricity from offshore wind farms can and should make an important contribution to the future energy and environmental policy of the Federal Republic. In this respect, the dena – German Energy Agency is coordinating a study that is examining the technical, ecological and commercial potential of using electricity from offshore wind farms to produce hydrogen. This could represent one method for regenerative production of part of the level of hydrogen required. Results are expected around the end of 2004.

cc) Efficiency

Most of the new, innovative techniques for producing alternative fuels are still in the early stages of development. As a consequence, statements on the efficiency of alternative second generation fuels remain within the realm of uncertainty. Accordingly, current estimates of the cost of producing such fuels are also significantly higher than the cost of conventional fuel production. For example, without tax exemption biofuels would currently only be competitive if the price of oil was around USD 100 a barrel. This does not, however, include consideration of external cost savings.

Nonetheless, through further technological developments and improvements in production and large-scale manufacture, these costs can be reduced in comparison to established technologies. Specifically with respect to the development of long-term scenarios, which extend over a period of several decades, the temporal dynamics of cost trends play a decisive roll in identifying economically viable development strategies. The competitiveness of alternative fuels is also enhanced by the generally anticipated tendency for oil prices to rise. Further development into this area should also examine the economic cost/benefit ratios of individual fuels.

b) Results of the assessment matrix

The following portrays the above-stated assessment criteria in an overall view. As a principal result, alternative fuels and innovative drive system technologies in Germany are identified, which are economically and ecologically viable in the long term according to the current train of thought.

aa) Potential to 2010

The **potential** of fuels and drive systems to 2010 is assessed as follows:

- To 2010, increases in efficiency for diesel and Otto engines as well as innovative drive system concepts are clearly of top priority.
- The current structure of the fuel market will essentially remain unchanged. Further optimisation of fuel quality will result in additional consumption improvements.
- Natural gas as a fuel (CNG) and to a lesser extent also autogas (LPG) will have lower market potential.
- Traditional biofuels such as biodiesel and bioethanol will play an important role, particularly as admixtures. Quantities of biodiesel and bioethanol currently available in the EU will, however, not be sufficient to reach EU targets (2010: 5.75% share). Additional capacity, as well as imports from third countries could nevertheless increase the share of each.
- It is not anticipated that biomass-to-liquid fuels (BTL) will have larger production capacity in the short term. The position is similar with respect to gas-to-liquid fuels (GTL). Depending on the construction of industrial scale facilities, they will therefore have gradually increasing relevance in the fuel market throughout the coming years. A certain level of imports could be the case by the end of the decade, if the currently planned construction of GTL plants (Quatar, Alaska) is completed by then.

In summary, it is not expected that any essentially new concepts in addition to the currently known alternative fuel options will arise in the fuel market to 2010. This is due, on the one hand, to the fact that in the few remaining years to 2010, it will not be possible to develop production capacity in the relevant quantities for the technologically well-developed alternatives; and on the other hand, other alternatives require a considerable amount of development.

Therefore, short-term potential for reductions in the consumption of fossil fuels and greenhouse emissions to 2010 will essentially be achieved by increasing the biogenic share of fuels and, in particular, by increasing efficiency in terms of drive system technologies. Further development of conventional engine technology (efficiency increases in traditional Otto engines) and innovative drive system technologies (hybrid concepts combining Otto engines, electric motors/generators, electric storage and energy recycling) could result in an additional reduction in fossil fuels in the mid-term and pave the way for wider application of regeneratively produced fuels.

bb) Potential to 2020

The **potential** of fuels and drive systems to 2020 is assessed as follows:

- Also in the period to 2020, increases in efficiency for diesel and Otto engines will play a central role.
- Natural gas (CNG), and to a lesser extent LPG, will continue to gain an increasing share in the fuel market, up to a total of 5%. The associated potential reduction in climate gas for the 2020 fuel market is estimated to be up to 2%.
- Compressed methane (CMG) from biogas can supplement or substitute the availability of natural gas as a fuel. The fuel matrix for 2020 states a market potential of 2% to 4%.
- According to EU targets, biomass fuels should reach a volume of up to 8%. If this target is to be achieved, in addition to traditional biofuels, synthetic biofuels will also have to gain an increasing share. Above all, BTL fuels have high potential depending on available biomasses. As BTL fuels gain an increasingly greater foothold in the market, the consumption of biodiesel and ethanol should decline.
- Global capacity for the production of synthetic fuels from natural gas (GTL fuel) will continue to be expanded. Estimates to 2020 anticipate around 10 million tonnes/annum for GTL. In terms of greenhouse gas emissions, this fuel is disadvantageous compared to petrol and diesel fuels.
- Hybrid concepts (e.g. energy regeneration on braking and recycling during drive operation) will increasingly be incorporated into drive systems.
- Post 2020, hydrogen as a fuel will gain increasing importance. A 2% share (approx. 1 million vehicles) is considered to be a decisive threshold for the start of market penetration. To facilitate development and acceleration of a corresponding infrastructure, hydrogen can be used more cheaply in Otto engines than in fuel cells. However, fuel cells promise to deliver greater efficiency in the long term. Moreover, both systems need considerable development to become established in the future market and successfully contribute to climate improvement and safeguarding of supply, through the use of regeneratively produced hydrogen.

cc) Development dynamics

An overview of the scenarios for 2010 and 2020 demonstrates the dynamics of development:

- **Efficient drive system technologies** offer innovative ways to further reduce consumption in the short and mid-term with continued use of fossil fuels, including fuel alternatives. This relates particularly to combination drive systems (hybrids).
- Given the position for limited fossil energy sources, **biomasses** must be increasingly utilised for the generation of energy.
- With the **new generation of biofuels**, synthetic biofuels (BTL) and processes for extracting bioethanol from lignocelluloses, an opportunity exists to supplement traditional biofuels (biodiesel, bioethanol, ETBE) in the mid-term.
- The broad range of estimates relating to the market share of **natural gas** clearly indicates that there is potential for development in this area, which, in turn, is dependent on the available infrastructure, vehicle development and the availability of non-European natural gas.
- According to current assessments, fully **electric drive systems** with fuel cell supply will only be able to replace conventional drive system technology in the long term. On the one hand, this concept has excellent long-term potential with respect to quantity, but on the other hand, still requires extensive development.
- **Fuel cell technology** also requires considerable development. Yet, given the multifaceted synergies between mobile and non-mobile applications, these markets and areas of development support one another.

Today, the transport sector is more than 95% dependent upon oil. If this dependency is to be reduced in the long term, the above-stated dynamics must be exploited and, owing to the lengthy transition periods, early access to alternative fuels ensured.

5. Focussing on a small number of alternatives with high potential

An essential objective of the fuel strategy illustrated here is that the Federal Government, industry and scientific research concentrate the limited financial and other resources on fewer highly promising alternatives without completely excluding other developments.

This is to occur on the basis of the above-stated assessment matrix results. **Provided that the climatic impact is appropriate**, alternatives that are to be classed as promising are, above all, those which fulfil the following criteria:

- high potential for quantity,
- opportunities for market penetration.

Efficiency, particularly the cost of manufacturing such fuel, is likewise an important criterion. Currently, many alternative fuels and drive systems are still a long way from being efficient. As stated above, at present, reliable evaluation of the alternatives based on available knowledge and extremely limited experience (development stage) is barely possible. Consequently, this criterion is only adopted insofar as assessment is possible.

a) Increasing efficiency in petrol and diesel engines

Potential: The experts agree that beyond 2010 efficiency increases in petrol and diesel engines will be of the utmost priority. The potential for reducing fuel consumption is still nowhere near being tapped to the full. Above all, efficiency in this area is assessed far more favourably than with alternative fuels and drive systems.

Need for action: For all manufacturers, high fuel prices are a first-rate incentive for investment to achieve further increases in efficiency and remain competitive. Consequently, there is no longer any need for separate policy incentives.

b) Natural gas

Potential: Provided it comes from European sources, natural gas does have lower CO_2 emission than petrol and diesel in conventional engines, but does nonetheless have an impact on the climate. Above all, there are increasing indications that, with timescale delays and specific reductions in terms of availability and price, natural gas is running a similar course to that of oil. On the other hand, natural gas does have a certain significance for the transition to hydrogen. Overall, for the reasons stated, natural gas has limited potential for an increasing share in the fuel market. The industry estimates market potential by 2010 at 0.5% and by 2020 at around 3%.

Need for action: A tax allowance to 2020 for natural gas has already been concluded. It is likely that one in ten filling stations will offer natural gas by the end of 2007. Natural gas engines have already been developed and are currently being used. There is no specific need for further action.

c) Biofuels (biodiesel and bioethanol)

Potential: As admixtures to existing fuels, biodiesel and bioethanol will continue to play an important role. Their essentially large potential is restricted by limited areas for raw material cultivation (e.g. rape crops). A market share of 5% would represent a considerable contribution.

Need for action: As is the case for all biofuels, biodiesel and bioethanol are exempt from mineral oil tax. Research and development is only needed with respect to certain specific questions, for example, technology developments and effects on emissions. Through essentially privately financed model projects, analysis could be done on the question of whether additional potential for the application of bioethanol could be achieved through the use of FFV technology.

d) Synthetic biofuels from biomasses (BTL)

Potential: In the medium and long term, the new generation of biofuels manufactured synthetically from biomasses offer the greatest potential. Given that high-grade diesel fuel can be manufactured from all types of biomass (e.g. waste,

plants, wood) through gasification and subsequent synthesis, these fuels benefit from the advantage of having an extensive raw material base. Consequently, the potential for quantity is commensurately higher. Nonetheless, the competition from alternative applications of biomasses also needs to be considered.

Need for action: Demonstration BTL production facilities are currently in existence. Above all, an increase in efficiency is required in order to reduce costs. In this respect, the concepts need to be further developed on the one hand, while on the other, the next generation of plants must be built on an industrial scale so that potential can be utilised and practical experience gathered. Similarly, questions of logistics and integration into sustainable rural development and agricultural production still remain open.

e) Combined drive systems (hybrids)

Combined drive systems (hybrids) will become increasingly relevant. These use energy released during braking, store it (batteries) and then subsequently utilise it for drive propulsion. As such, they offer excellent potential for increased energy efficiency.

Need for action: Cars with combination drive systems have already been launched on the market by two manufacturers. Nonetheless, a significant need for development still remains in order to increase energy efficiency, battery performance and optimise the interplay of elements within the overall system. Research and development activities are being stepped up and spread across a broader basis.

The goal must be to produce vehicles suited to everyday use at acceptable prices. Analysis of the question regarding the extent of temporary support necessary for market introduction also needs to be examined.

f) Hydrogen/Fuel cells

Potential: In the long term (from 2020), hydrogen as a fuel will gain major significance. Hydrogen can be used directly in Otto engines, or with greater energy efficiency in fuel cells. Nevertheless, hydrogen is purely an energy storage medium, and only environmentally compatible if the electricity needed for electrolysis (production of hydrogen) is generated using renewable energies.

Need for action: Of utmost importance is the development of an efficient hydrogen industry (production, storage and transport) and production cost reduction. The next step are large-scale demonstration projects in order to gather practical experience. Drive system technology still requires development, particularly with respect to fuel cells.

g) The four alternatives with the greatest potential

In the next two decades, fossil energy sources will still determine the fuel market - given that their share is well over 80%. Other fuel alternatives will not be available in large quantities to this point. Consequently, a substantial contribution to the reduction of climate gases and future safeguarding of supply up to this point in time will essentially be achieved by optimising traditional engines and developing

more efficient and innovative drive technologies with lower fuel consumption. The complementary utilisation of alternative fuel options is important and worthwhile.

This analysis gives rise to the fact that the following **four alternatives demonstrate the greatest potential for reducing consumption of fossil fuels**:

– increased efficiency in petrol and diesel engines,
– synthetic fuels from biomasses (BTL),
– combined drive systems (hybrids),
– hydrogen (engines and fuel cells).

6. Planned measures

The objective of the fuel strategy lies in concentrating resources on the most promising alternatives and accelerating their development progress. These aspects have been illustrated in the above and the four alternatives with the greatest potential stated in paragraph 5. g). In the following, measures necessary for the four spheres of action are systematically ascertained and summarised into a programme of measures.

The following spheres of action are important:

– tax incentives,
– research and development,
– demonstration and pilot facilities,
– technical and legal standards.

In terms of making headway with promising fuels and drive systems, the Federal Government is merely one of the players. Above all, the state must set the right framework conditions with regard to fiscal incentives, R&D programmes and legal standards (e.g. safety and environmental protection). It is then the job of science to progress with research and development, the oil and energy industries to build fuel production facilities; and the automotive industry to make headway in developing drive system technologies. Only if each of the protagonists fulfils its task will the significant breakthrough be achieved. Thus, in terms of this fuel strategy, it is of even greater importance that understanding is reached between the protagonists with respect to promising alternatives and as to who does what.

a) Tax incentives

In terms of tax incentives, the Federal Government has already made important fundamental decisions in this legislative period. As such, subject to assessment for overcompensation, all biofuels are exempt from mineral oil tax until 2009. This time restriction arises from binding provisions in European law. However, with respect to the extensive investment necessary and particularly for fuel production plants, a more long-term perspective is decisive. On both a pan-European and national level, the Federal Government will press for biofuel tax incentives which extend beyond 2009. The conditions and extent of fiscal incentives depend on how necessary the tax relief is to achieve a greater market share. Furthermore they depend on the question how much tax revenue the German Government will loose due to these incentives.

Mineral oil fiscal framework conditions for hydrogen as a fuel are currently sufficient in terms of the fuel matrix results. According to currently applicable law, hydrogen is subject to mineral oil tax (taxation similar to that of natural gas as a fuel). However, in reality, tax is not imposed as the use of hydrogen in projects for the development of alternative drive system technologies can be exempted. Given that hydrogen will not play any major role before 2020 according to the fuel matrix results, introducing comprehensive provisions for hydrogen at the current time would be premature. A decision needs to be taken in good time regarding the point of transition from a project incentive to a tax incentive in consideration of market development and secure planning for investors.

All tax incentives for alternative fuels will need to be regularly examined on the basis of the criteria developed in this paper. Thus, the Federal Government is striving to achieve the same regular monitoring for all alternative fuels as is currently envisaged for biofuels. As such, the Federal Government will initially report to the German *Bundestag* regarding the market introduction of biofuels by 31 March 2005.

Essentially, it should be taken into consideration that any possible restructuring of support measures falls within the framework of existing financial planning and must take the difficult budget situation into account. In particular, this means that expansion of supportive activity in one area must be linked with examination of where supportive activity can be restricted in other areas.

b) Research and development

To date, the Federal Government has already placed essential focus on research and development for alternative fuels and innovative drive systems. In line with the promising alternatives detailed here, it is concentrating, on the one hand, on combined drive systems (hybrids) as well as on the production of liquid biofuels (BTL) on the basis of renewable resources. With respect to hydrogen, the emphasis of research and development has been on developing fuel cells for non-mobile and mobile applications.

The consultation paper for the 2005 budget envisages funding of around € 43 million for the market introduction and research and development relating to renewable resources, including for biofuels. If necessary, additional funding may be available within the scope of the Innovation Initiative *(Innovationsoffensive)*.

c) Demonstration and pilot facilities

Although research and development is generally focussing on the right areas, a second step to making a significant breakthrough that would be of benefit to promising alternative fuels depends on pilot and demonstration facilities being set up.

This applies particularly with respect to construction of plants for the production of liquid fuel from biomasses (BTL). The first plant with 1 MW has already been built in Freiberg (Saxony). The Federal Government is currently preparing a project for the development and construction of a second facility with alternative technology, which aims to provide answers to a number of technological, economical and ecological questions still open and which, amongst other things, should further

improve energy efficiency. On the basis of demonstration facilities, development of the necessary capacity on an industrial scale can be accelerated. This places demands upon industry in general as well as the oil and automotive industries. At the moment, dena – German Energy Agency is working with industry to prepare a timetable to create the technical and economic requirements for further investment.

The potential admixture of up to 5% bioethanol with petrol and of up to 5% diesel with diesel fuel also requires additional production capacity that does not currently exist. However, the technology is in place and by exempting biofuels from mineral oil tax, the Federal Government has sent out the right economic signal.

Development of an efficient hydrogen industry is of strategic importance. Above all, there is a need to gain experience from real facilities, in order that hydrogen can be produced by electrolysis using electricity from renewable energy sources more cost efficiently than has been the case to date. Expansion of offshore wind farms in the North Sea and Baltic Sea offer potential here. In all probability, it will not be possible to feed the total level of power produced into the electricity grid at economically viable conditions (network expansion). Ensuring that the level of available power anticipated here can be utilised requires greater experience with respect to production, storage and transport. This means that a strong hydrogen industry as a whole is required. Together with industry, the Federal Government is investigating how EU initiatives to develop larger regional "hydrogen pilot projects" can be used to further this aim. This theme is also being addressed by the *"Strategiekreis Wasserstofftechnologien"* (Hydrogen Technologies Strategy Group), which brings all the relevant protagonists together.

d) Technical and legal standards

As seen with examples from the telecommunications (UMTS) and information technology industries, technical standards can play a vital role in taking up a leading position internationally. The same applies with respect to alternative fuels and drive systems, where progress depends on close cooperation between state agencies and industry.

The task of the Federal Government is to ensure appropriate adjustment to the legal framework conditions pertaining to licensing and safety requirements for the hydrogen infrastructure and hydrogen driven vehicles. In common with the industrial partners of the transport industry's energy strategy, the Federal Government has commissioned a commensurate expert report on associated licensing and safety requirements.

7. Outlook

The fuel strategy outlined here leaves many questions as yet unanswered. It needs to be put into concrete terms and the concept further developed. Nonetheless, it sets a clear direction for the development and exploitation of alternative fuels and innovative drive systems. Overall, it sets specific priorities and outlines the need for action.

The subject will also be given a high priority by the Federal Government in the coming years. As such, the fuel strategy is also an important element of its innovation strategy "Partners for Innovation". The Federal Government will report on the progress of activities in its 2006 Progress Report (Sustainable Development).

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