SRU German Advisory Council on the Environment

Reducing CO_2 Emissions from Cars

Section from the Special Report
Environment and Road Transport

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Preface

Despite advances in many areas and particularly in technologies to deal with traditional air pollutants, there has been little overall improvement when it comes to the environmental impacts of the transport sector. The harm to human health and the environmental damage caused by road transport remain at unacceptably high levels. In response to this situation, the German Advisory Council on the Environment (SRU) – an independent institution that has advised the German government on environmental policy issues since 1972 and comprises seven university professors from a range of different disciplines – issued an in-depth Special Report on the Environment and Motorised Road Transport in June 2005 (SRU, 2005). Along with a comprehensive status report on the environmental effects of road transport, the Special Report contains a range of recommendations for integrated transport and environmental policy to allow more environmentally compatible transport management and design of motorised road transport without forgoing high levels of mobility. The recommendations include measures to allow:

– Development of vehicle technology for cleaner, quieter and more energy-efficient vehicles

– A holistic, integrative planning approach to environmental and transport policy goals and objectives, and their effective implementation

– Economic and regulatory instruments for road transport management

– Correction of traffic-inducing incentives in other policy areas.

One of the main focuses of the vehicle technology recommendations involves reducing CO_2 emissions from road transport and using environmental policy to do so. To ensure that these recommendations reach a broad specialist audience at European level, the Council is issuing this English language extract from its Special Report. The full German-language report (comprising almost 600 pages) is available online and can be downloaded from the Council's website (www.umweltrat.de).

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Executive Summary

Although alternative fuels like biomass and hydrogen are expected to offer significant reduction potential, at least in the longer term, the Council sees an urgent need to better exploit the technological potential to reduce specific CO_2 emissions from vehicles with conventional engines. Using available technology, it is possible to reduce average fuel consumption by more than 40 per cent in newly registered petrol-engined passenger cars and by up to 40 per cent in those with diesel engines. This means a drop in average CO_2 emissions from newly registered passenger cars to around 100 g/km. The main features include enhancement of specific engine technologies, ensuring that engines run in the optimum performance range through downsizing and improved gearbox spacing, optimum energy management, hybridisation, and reduced vehicle weight and rolling resistance. Measures that effect a change in consumer behaviour and driving habits also play a key role. This reduction potential should be exploited by introducing an emissions trading scheme to incentivise carmakers to bring average CO_2 emissions in new vehicles down to 100 g CO_2/km by 2012 as an interim target. Additional, longer-term targets could be set to achieve even greater reductions. To foster demand-side support for this system, vehicle taxation should be redesigned to focus on CO_2 emissions, be progressively structured and payable for several years in advance when buying a new vehicle. In order to prevent improved fuel economy from creating incentives for more travel, further steps to increase fuel prices are needed in the framework of the ecological tax reform.

1 Introduction

1. CO_2 emissions in the transport sector poses a key problem along with particle and NO_x emissions. If long-term climate protection targets are to be met, the transport sector must play its part by reducing its absolute CO_2 emissions. Climate change scenarios project that to meet a CO_2 reduction target in the region of 80 per cent overall by the middle of this century, CO_2 emissions from transport would have to fall by between 34 and 55 per cent by 2050 compared with 2002 (Enquete Commission, 2002). When it comes to the application of technical measures at source, part of the emissions reduction target could be achieved through greater use of alternative fuels and another part by reducing specific CO_2 emissions in conventional vehicles.

Scenario calculations commissioned by the German Federal Parliament Enquete Commission on Sustainable Energy Supply in Times of Globalisation and Liberalisation *(Nachhaltige Energieversorgung unter den Bedingungen der Globalisierung und Liberalisierung)* (2002) with regard to achieving an 80 per cent climate protection target show an average consumption among all registered vehicles of between 2.5 and 4.1 l/100 km for 2050 depending on specific scenario values (IER, WI and Prognos, 2002). According to a study commissioned by the Federal Environmental Agency (UBA), achieving an 80 per cent reduction in CO_2 emissions average overall consumption of 4.7 l/100 km for petrol and 3.8 l/100 km for diesel are assumed. Looking to the year 2050, consumption levels of 1.6 l/100 km in diesel-fuelled cars and 2 l/100 km in petrol-fuelled cars are deemed feasible (FISCHEDICK et al., 2002, p. 358 ff). This represents specific emissions of around 40 g CO_2/km for diesel cars and about 50 g CO_2/km for petrol-driven cars.

The agreement by the European Automobile Manufacturers Association (ACEA) to achieve average CO_2 emissions of 140 g/km for newly registered passenger cars by 2008 is therefore only an interim target. Further proposals aim at reducing specific CO_2 emissions in newly registered passenger cars to 120 g CO_2/km by 2012 (EU Commission, 2004a). In October 2004, the British government announced an official target under which by 2012, 10 per cent of new passenger cars purchased in Great Britain would emit less than 100 g CO_2/km (Department for Transport, 2004). If new car sales remain constant, a restriction of specific CO_2 emissions to 120 g CO_2/km from 2010 and to 100 g CO_2/km from 2015 would mean a drop in CO_2 emissions from passenger cars somewhere in the region of 10 million tonnes by 2020 (KOLKE et al., 2003). This represents around 6 per cent of the 165.9 million tonnes of CO_2 emitted by road transport in 2002 (see SRU, 2005, Figure 2.7).

2. In the pages that follow, Section 2 looks at past developments in transport-related CO_2 emissions, while Section 3 illustrates the available reduction potential from conventional engine technologies and from the use of alternative fuels. Section 4 then outlines the environmental policy measures needed to exploit this reduction potential. It looks at switching from self-regulation and voluntary compliance on the part of the European car industry to an emissions trading system that targets fuel consumption in vehicles and at a vehicle taxation system that places greater focus on CO_2 emissions than it has so far. Section 5 presents a summary of the key recommendations.

2 Current Status and Past Developments

3. Average fuel consumption of passenger cars in Germany dropped from 8.3 l/100 km to 7.8 l/100 km, or 6 per cent, during the period 1991 to 2002 (UBA, 2004). As measured when using the New European Driving Cycle (NEDC), market-weighted consumption in newly registered passenger cars in Germany was 6.9 l/100 km in 2003 (VDA, 2004a). Established in 1996, the NEDC is the EU standard test cycle (cold start and warm-up phase, four urban driving cycles and an extra-urban driving cycle) to assess exhaust and consumption levels on a roller test bed. It must be borne in mind, however, that passenger car fuel consumption measured under more realistic conditions is between 0.5 and 1 l/100 km above average consumption levels measured using the NEDC (RIEKE, 2002).

This drop in consumption resulted in a fall in specific CO_2 emissions from newly registered passenger cars. In the case of newly registered passenger cars made by German manufacturers, the reductions meant a drop from 187 g CO_2/km in 1998 to an average 173 g CO_2/km in 2003 (Figure 1: VDA, 2004b). This is due both to improved engine technology and to a higher share of diesel-fuelled passenger cars among newly registered vehicles – the number of diesel-engined cars bought in Germany rose four-fold, from 9.8 per cent in 1990 to over 40 per cent in 2003 (press release issued by the Federal Bureau of Motor Vehicles and Drivers [Kraftfahrt-Bundesamt] dated 29.03.2004). A clear increase in the number of diesel-fuelled vehicles purchased has also been observed at European level: from 23.1 per cent in 1994 to 40.9 per cent in 2002 (ACEA, 2005).

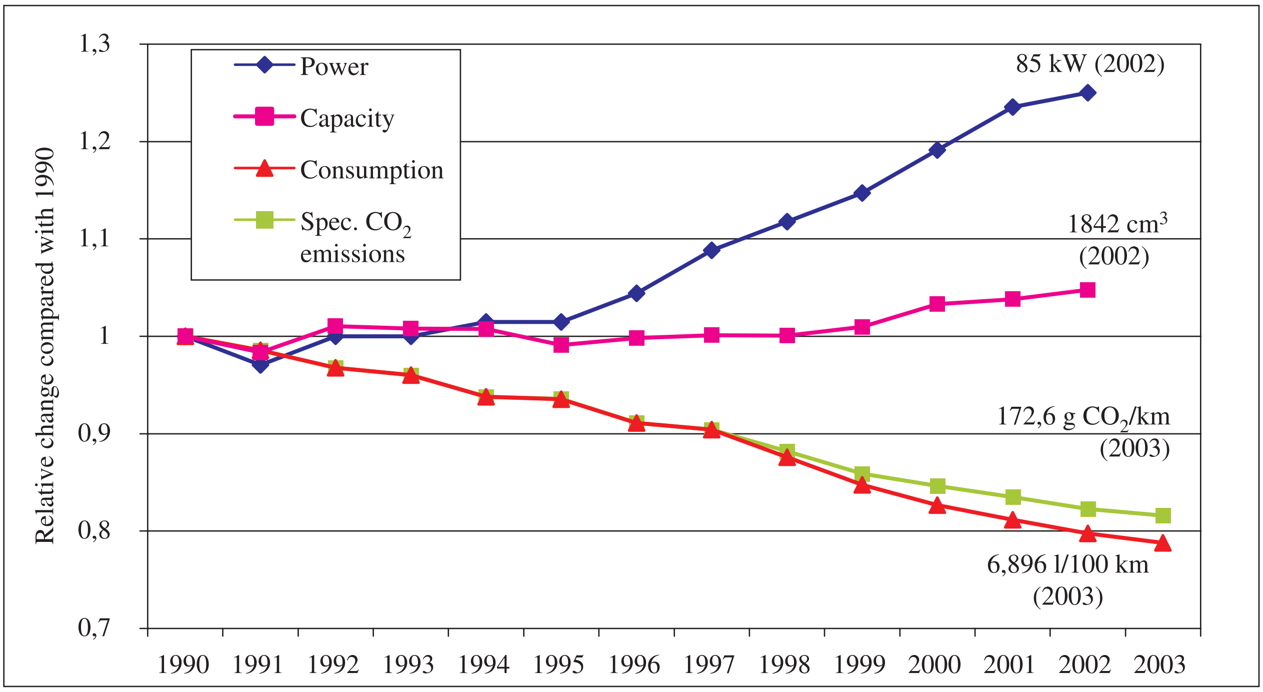
Given that passenger cars are only replaced on a gradual basis (the average age of a passenger car in Germany is around 6.6 years), the drop in specific CO_2 emissions from all registered passenger cars failed to match that from newly registered vehicles overall (Figure 1) (EEA, 2003). Nevertheless, there has been a 29 per cent drop in specific CO_2 emissions from passenger cars registered in Germany since 1960 (Figure 2). This drop would certainly have been greater had engine power remained the same (see Figure 1).

Specific CO_2 emissions from commercial vehicles have also decreased (to 629 g/km) following a 9 per cent drop in emissions among registered vehicles between 1960 and 2003 (Figure 2). According to the German Automobile Industry Association (VDA), fuel consumption in commercial vehicles fell by 30 per cent during the period 1970 to 2003 and now lies at around 33 l/100 km for a 40 tonne truck (VDA, 2003). A strong increase in traffic during the same period – both in passenger and commercial vehicles – resulted in absolute CO_2 emissions from passenger cars rising by a factor of 6.4 between 1960 and 2002, while absolute CO_2 emissions from commercial vehicles rose by a factor of 5.2 (see SRU, 2005, Figure 2.8). Fuel consumption by commercial vehicles – which in 2002 accounted for about a third of total fuel used for road transport – increased by 37.6 per cent between 1991 and 2002 (MWV, 2003).

There thus remains a need to fully exploit existing technological potential to reduce CO_2 emissions from vehicles if the climate protection targets outlined above (Para. 1) are to be achieved.

Figure 1

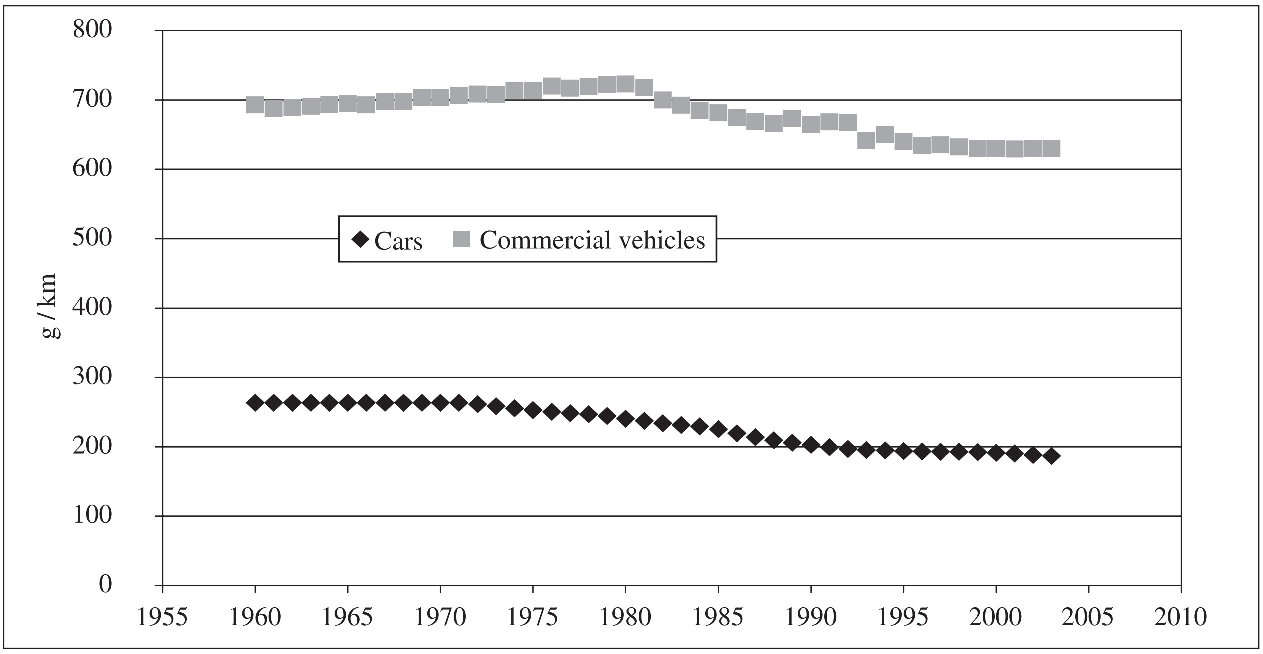
Trends in CO_2 Emissions (g/km), Consumption (l/100 km), Engine Capacity (cm^3) and Engine Power (kW) in Newly Registered Passenger Cars in Germany



Source: SRU/EA SG 2005/Figure 7.5. Data Source: ACEA, 2003 and VDA, 2004a,b

Figure 2

Trends in Specific CO_2 Emissions in Passenger and Commercial Vehicles Registered in Germany



SRU/EA SG 2005/Figure 7.6. Data Source: UBA, written correspondence dated 01.09.2004, Transport Emission Estimation Model (TREMOD), Version 3.1

3 Reduction Potential

4. The output of carbon dioxide is proportional to the amount of fuel used: full combustion of a litre of petrol results in around 2.28 kg CO_2, while a litre of diesel gives off 2.58 kg CO_2. This means that there are only two ways in which to reduce specific CO_2 emissions:

- By reducing fuel consumption in vehicles with conventional combustion engines (see Section 3.1).
- By using renewable, low-CO_2 fuels – partly in conjunction with new engine technologies (see Section 3.2).

3.1 Conventional Engine Technology

5. Technological measures to reduce fuel consumption in traditional combustion engines, as presented below, can roughly be divided between improving specific engine technology, keeping engine speed within an energy-efficient performance range, and optimised energy management. These engine technology measures are supplemented by reducing vehicle weight and rolling and air resistance, along with measures aimed at changing consumer behaviour and driving habits. Figure 3 shows energy consumption in a passenger car as measured in the New European Driving Cycle (NEDC).

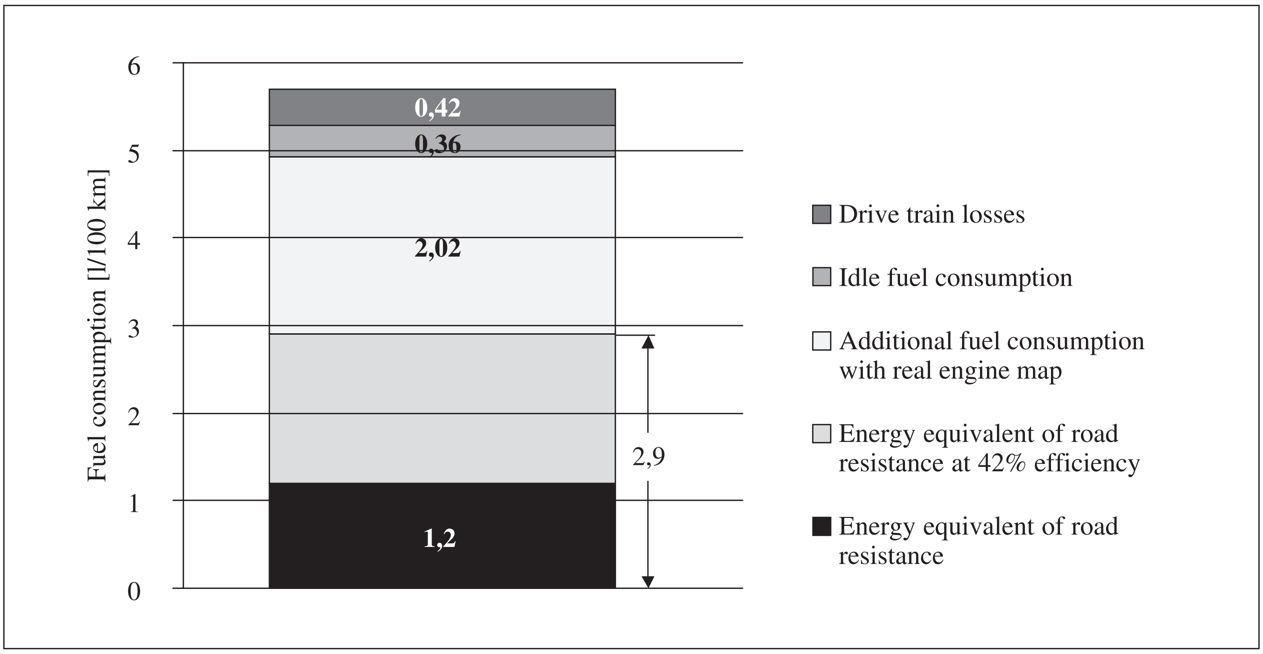
Improved Engine Technology

6. When it comes to optimising the combustion process, a distinction must be drawn between diesel and petrol engines. Options for improving petrol engine technology include direct fuel injection and variable valve trains. In conventional petrol engines (multi-point injection and carburettor), petrol and oxygen are mixed outside the combustion area. Huge losses occur because load control is managed by a throttle valve and this results in increased fuel consumption – especially at partial throttle. This is where significant savings potential is offered by engine control using direct fuel injection combined with stratified charge operation or variable valve control times (8 to 10 per cent reduction), cylinder cutout (6 per cent reduction) and reduced idling speed (1 to 2 per cent reduction) – especially in unfavourable partial throttle conditions (SCHMIDT et al., 1998; SALBER et al., 2001). Consumption could be cut by up to 18 per cent overall (SCHMIDT et al., 1998; SALBER et al., 2001; MERKER, 2002; MEHLIN et al., 2002; VDA, 2001, p. 22). However, because of their higher NO_x emissions, petrol engines with direct fuel injection require exhaust treatment with NO_x storage catalytic converters (NEUMAN and SCHINDLER, 2000) and they can also produce particle emissions at levels similar to those from diesel engines.

Diesel engines use between 15 and 20 per cent less fuel compared with petrol engines. However, specific CO_2 emissions during combustion of one litre of diesel is about 13 per cent higher than with petrol. The lower consumption levels with diesel are due both to a significantly higher compression ratio and direct fuel injection. Despite combustion with excess air, high-speed fuel injection can still lead to localised starvation and hotspots. These in turn can result in soot and NO_x emissions.

Figure 3

Energy Consumption in a Passenger Car in the New European Driving Cycle (NEDC)



Source: THIELE and MERKER, 2004

Further development of diesel engines thus places its main focus on better injection processes to allow more homogeneous mixtures and ultimately lower emissions (THIELE and MERKER, 2004). Lesser potential for optimising consumption lies in improved exhaust gas recirculation and further friction reduction (about 2 per cent each) (MEHLIN et al., 2000). In the longer term, the combustion processes in petrol and diesel engines are expected to converge (STEIGER, 2003).

Downsizing and enhanced transmission technology

7. Both types of engine attain the best degree of efficiency within a certain performance range. Downsizing and improved transmission aim to ensure that this range is exceeded as rarely as possible. In downsizing, engine capacity reduction forces the engine to work harder. Downsizing is supplemented by forced induction (turbocharging or electronically supported induction) to maintain the engine power (ELLINGER et al., 2002). Automatic gear boxes with wider gear spacing (6 or 7 gears) and hydraulically or electronically supported gear change can reduce consumption by around 10 per cent (HOFMANN et al., 2002). Automatic gear boxes could be further developed to use continuously variable transmission (CVT) for additional savings of up to 8 per cent (ELLINGER et al., 2002).

Energy management and hybridisation

8. Vehicles in city traffic do not actually use their engine power for about 45 per cent of the time (STEIGER, 2003). Thus, in city traffic in particular, fuel savings of up to 25 per cent could be achieved by an automatic start-stop mechanism that uses a flywheel system to switch the engine on and off (NEUMANN and SCHINDLER, 2000). Automatic engine cutoff can result in an overall reduction in fuel consumption of up to 4 per cent (ELLINGER et al., 2000). Savings of 3.9 per cent have been achieved in the VW 3 litre Lupo (Figure 7: MEHLIN et al., 2002).

In further hybridisation (strong or parallel hybrid), an electric motor with sufficient capacity to power the vehicle independently is installed alongside a conventional combustion engine. This allows three different operating methods: combustion engine, electric motor and a combination of both. The electric motor is usually designed for driving around town and the combustion engine for motorways and other longer distance travel. Use of the combustion engine in unfavourable partial throttle can thus be avoided: while performance demands are lower, the combustion engine still operates at a favourable level of efficiency with excess energy being used to recharge the battery. This also allows targeted downsizing of the combustion engine in that its weaknesses at partial throttle can be compensated for by the electric motor. The parallel hybrid enables regenerative braking, meaning that braking energy is recovered and stored in the batteries. Along with reduced emissions (with the exception of NO_x) (WALLENTOWITZ and NEUNZIG, 2001), the advantages of the parallel hybrid over petrol and diesel engines make for potential reductions in fuel consumption of between 25 and 34 per cent (ISENSEE, 2002; CONCAWE et al., 2003a).

The disadvantages of hybrid vehicles are their dual energy storage and dual engines. These affect the vehicle's weight and cost. Further developments (e.g. a starter generator system and associated omission of a starter motor and dynamo) will, however, enhance opportunities for serial production of hybrid vehicles (WB BMVBW, 2002). Toyota already offers a second generation hybrid in the form of its widely marketed Prius model which puts out only 104 g CO_2/km and carries less than 100 kg extra weight. Some European manufacturers have presented newly developed hybrid vehicles and have announced plans to put them into production (VDA, 2004c).

Electric vehicles

9. In contrast to parallel hybrids, whose attractiveness comes in the form of low fuel consumption and emissions coupled with high torque, a purely electric motor has significant disadvantages. While allowing emission-free driving (although any overall assessment must take account of electricity generation), the low energy density of batteries (about 1/100th that of liquid fuel) make large batteries necessary in order to achieve an acceptable range. This makes vehicles heavier, which in turn detracts from energy efficiency. The electric vehicles now available manage distances of around 100 km. On the whole, the disadvantages of electric vehicles built with available technology are so extreme that they are only considered suitable for use in a niche market (WB BMVBW, 2002; BIRNBAUM et al., 2002).

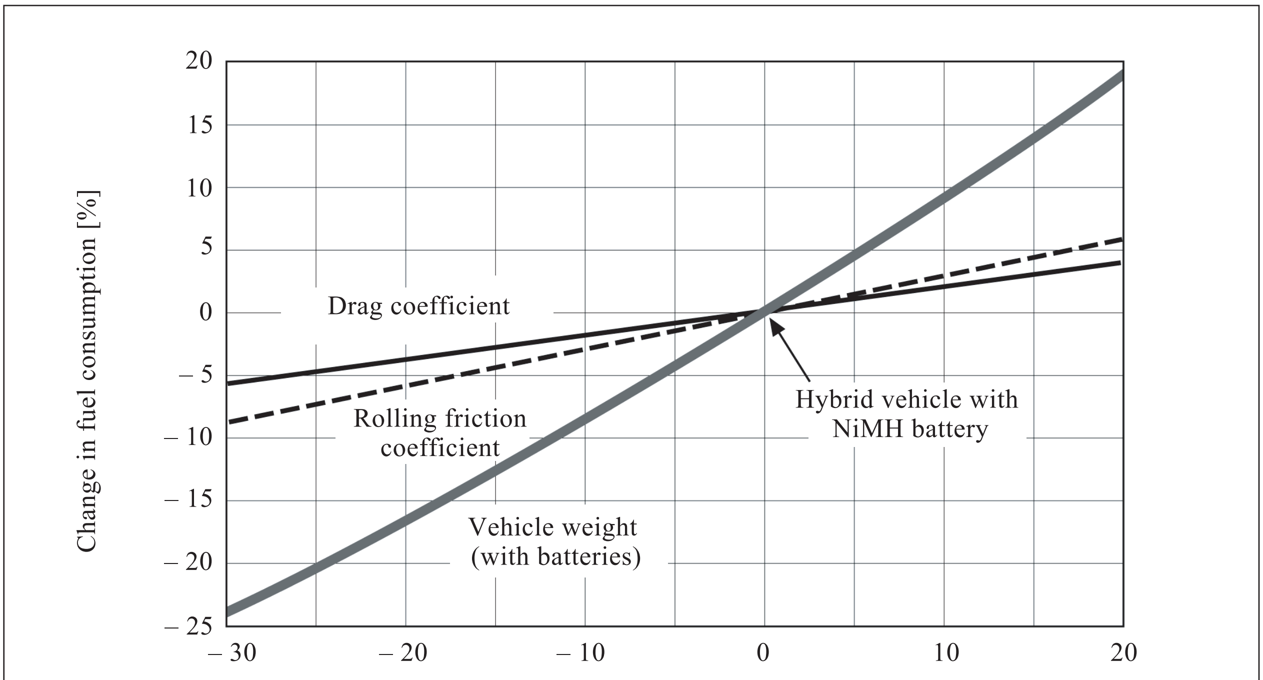
The electric motor would have great potential if a manifold increase in battery power could be achieved. The basic advantages compared with combustion engines (including their auxiliary equipment) lie in the comparatively simple technology and the avoidance of large quantities of exhaust heat given off and lost in mobile combustion engines (as is the case with hydrogen fuel cells). Even with the batteries available today, battery power is just as efficient as a combustion engine if the primary energy is generated in high-efficiency combined-cycle gas turbine (CCGT) power stations and even more so if generated in a combined heat and power (CHP) plant. With the current energy mix, however, electric motors compare unfavourably in terms of energy and CO_2.

Vehicle design (weight, rolling and air resistance)

10. In addition to drive train enhancement and optimised energy management, better fuel efficiency could be achieved by reducing vehicle weight along with air and rolling resistance. Figure 4 shows the impact of these vehicle parameters on fuel consumption in a hybrid vehicle. A reduction in vehicle weight offers the greatest potential for reduced fuel consumption.

Figure 4

Hybrid Vehicle: Impact of Vehicle Weight and Rolling and Air Resistance on Fuel Consumption



Source: JOSEFOWITZ and KÖHLE, 2002

A steady increase in vehicle weight has been observed over time: increased demand for comfort, safety, performance and versatility have all resulted in heavier vehicles. To compensate for the additional weight, stronger engines had to be installed. In many cases, this also meant installing bigger fuel tanks, which further increased the vehicle's weight. Thus, from 1995 the average weight of a vehicle rose by around 100 kg and reached 1,214 kg in 2002 (ACEA and offices of the EU Commission, 2001; 2003). This vicious circle regarding vehicle weight could be broken with the use of new materials and new assembly methods (Figure 5). VW expects potential reductions in vehicle weight of between 30 and 35 per cent overall (NEUMANN and SCHINDLER, 2000). A study conducted by Arthur D. Little on the outcomes of introducing a CO_2 reduction target of 120 g/km by 2012 reported potential weight reductions of 15 per cent for small cars, 18 per cent for middle-class cars and 30 per cent for luxury vehicles (Arthur D. Little, 2003, p. 26).

The reduction in fuel consumption resulting from reduced vehicle weight lies in the region of 0.3 to 0.8 l/100 km per 100 kg weight reduction (MEHLIN et al., 2002; ISENSEE, 2002). A 10 per cent weight reduction in the VW Lupo achieved fuel savings of 8 per cent. Other studies contain considerably more conservative figures, with fuel savings of 3.5 per cent per 10 per cent weight reduction (Arthur D. Little, 2003, p. 116).

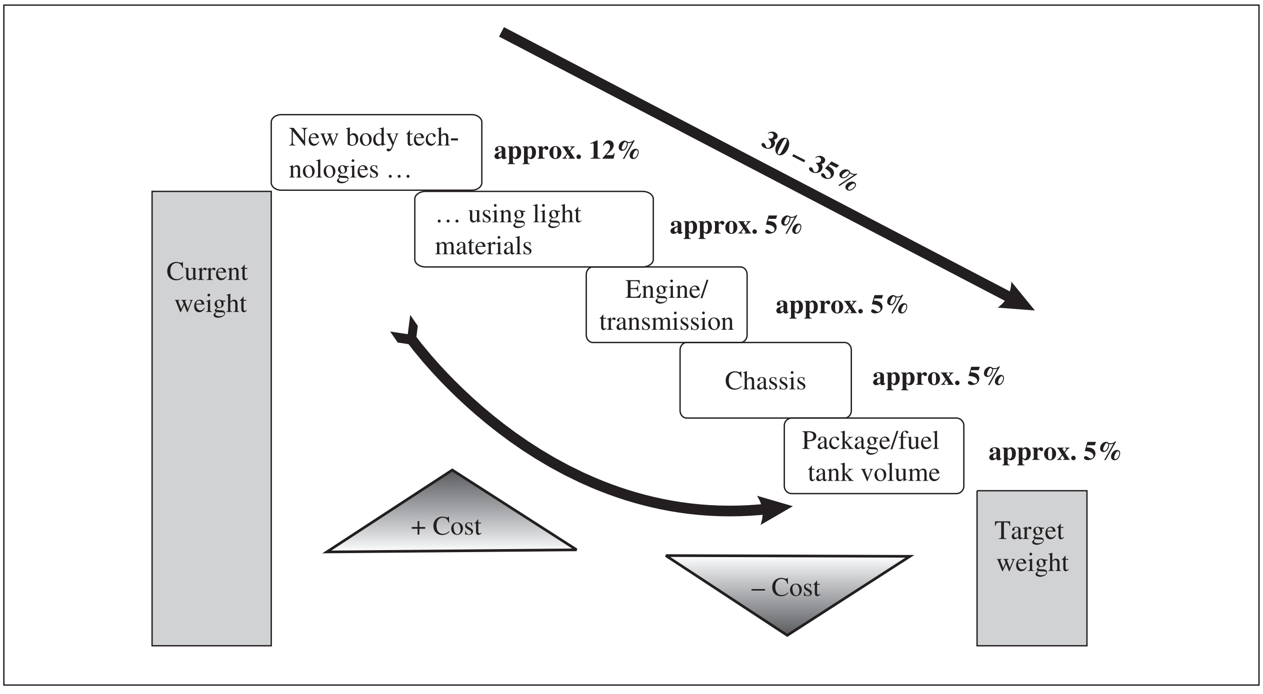
11. A 30 per cent reduction in tyre rolling resistance can achieve fuel savings of between 2 and 6 per cent depending on driving speed (SCHEDEL, 2001). The Federal Environmental Agency (UBA) estimates that the use of low-rolling-resistance tyres offers a potential CO_2 reduction of between 2 and 5 per cent in passenger cars and between 3 and 9 per cent in commercial vehicles (KOLKE et al., 2003). Additionally, a 10 to 20 per cent reduction in drag is thought possible with the use of more aerodynamic vehicle bodies without any significant restriction as regards passenger comfort (Enquete Commission, 2002, p. 216 f). The resulting achievable fuel saving potential in light commercial vehicles lies at around 4 per cent (EU Commission, 2004b).

Consumer behaviour (engine power and auxiliary equipment) and driving habits

12. Engine power, electrical auxiliary equipment like air conditioning, dashboard electronics and entertainment systems, and a range of components that supply electricity and hydraulics to a vehicle's various systems – all of which are largely determined by consumer behaviour – have considerable influence on fuel consumption and CO_2 emissions. Within a single decade, the number of new vehicles equipped with air conditioning rose from 15 per cent in 1992 to 72 per cent in 2002 (Arthur D. Little, 2003). The impact of this auxiliary equipment on fuel consumption in a middle-class vehicle in the New European Driving Cycle can result in up to 17 per cent more fuel being used (summer operation with air conditioning; WALLENTOWITZ and NEUNZIG, 2001, p. 34).

Figure 5

Potential for Weight Reduction in Passenger Cars



Source: NEUMANN and SCHINDLER, 2000

The additional CO_2 emissions caused by air conditioning alone lie between 3 and 8 per cent (EU Commission, 2004b).

The EU Commission estimates the impact of air conditioning on greenhouse gas emissions from vehicles at between 16 and 28 g CO_2eq/km. Of these, about one-third result from the higher CO_2 emissions caused by greater fuel consumption and two-thirds from the release of the hydrofluorocarbon HFC 134a (ECCP, 2003). For this reason, the proposal for a regulation on specific fluorinated greenhouse gases (EU Commission, 2003) contains a plan to phase out HFC 134a in mobile air conditioning systems. It requires that from 2014, new vehicles no longer be equipped with air conditioning units that contain HFC 134a (Article 10). Also, certain leakage rates may not be exceeded as of 2005 (Article 9).

13. In Germany, average engine power in newly registered vehicles rose from 69 kW in 1995 to 85 kW in 2002 (see Figure 1). If this trend towards higher performance vehicles continues, reducing CO_2 emissions will prove difficult. A 30 per cent reduction in engine power could, by way of contrast, reduce CO_2 emissions by between 13 and 19 per cent in petrol engines and between 5 and 15 per cent in diesel engines. A 50 per cent reduction in engine power could reduce CO_2 emissions by between 25 and 32 per cent (KOLKE et al., 2003).

14. A Progress Report issued by the Federal Environmental Agency in 2003 pointed to the potential that changed consumer behaviour and altered driving habits offer in reducing CO_2 emissions from road transport (KOLKE et al., 2003). The report showed that the introduction of a speed limit (see also SRU, 2005, Section 9.2) could achieve an 8 per cent drop in CO_2 emissions in non-urban areas, while reductions of 9 per cent (at 120 km/h) and 19 per cent (100 km/h) were possible on motorways. By providing consumer information (e.g. appropriate and attractive labelling of passenger cars, which is anyway required by the EU directive on energy labelling), consumers should receive assistance to enable them to choose a low-consumption vehicle. Fuel-efficient driving habits can also be promoted through a range of measures involving, for instance, driver training and the provision of information on using light oil. Companies with vehicle fleets could be given additional incentives for example in the form of company awards. Private individuals could receive financial incentives: perhaps a voucher awarded upon purchase of a new vehicle, giving them free training in fuel-efficient driving techniques. Vehicles would, of course, need to be equipped with a fuel consumption gauge as standard equipment. The Federal Environmental Agency estimates that such measures to promote fuel-efficient driving habits could provide additional CO_2 reduction potential of between 6 and 17 per cent.

Potential for reduced consumption in passenger and commercial vehicles: Summary

15. Combustion engines still have considerable potential for fuel-saving and associated CO_2 reduction. In the case of petrol engines, it is thought that measures involving the drive train in a middle-class vehicle (with CO_2 emissions of 164 g/km) could achieve fuel savings of around 38 per cent (Figure 6; and similarly ELLINGER et al., 2002; LANG et al., 2004; Enquete Commission, 2002, p. 216 ff; KOLKE, 1999, p. 47). Further measures such as weight reduction, reduced rolling and air resistance, and promotion of fuel-efficient driving habits can result in a 40 per cent or greater decrease in overall consumption (see also JOSEFOWITZ und KÖHLE, 2002). Future savings potential expected from diesel motors is significantly lower compared with petrol engines because diesel engines are less wasteful than petrol engines when run (as is often the case) at partial throttle (FISCHER, 1998). Also, significant increases in diesel motor efficiency have already been achieved with the use of electronically regulated direct fuel injection with extremely high charging pressures. Nevertheless, hybridisation and improved transmission could result in savings of around 32 per cent (Figure 6; see also JOSEFOWITZ and KÖHLE, 2002). Additional savings could also be achieved with a reduction in vehicle weight, reduced rolling and air resistance, and by promoting fuel-efficient driving habits. For the coming decades, therefore, optimised combustion engines will remain the dominant engine type and are unlikely to be replaced to any great extent by electric vehicles powered either by battery or fuel cells. Hybrid vehicles could, however, gain a larger share of the market (CHRISTIDIS et al., 2003; MERKER, 2002).

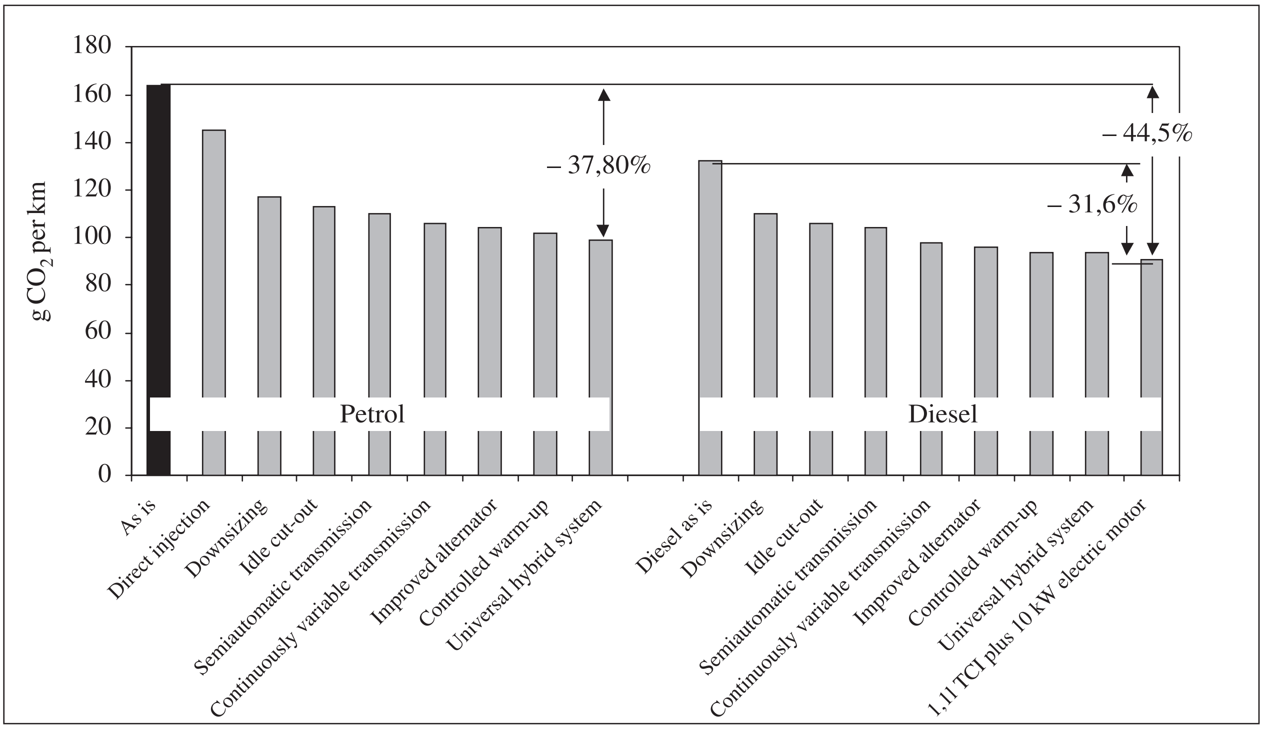
16. Carmakers have already demonstrated the opportunities available for improved fuel efficiency, both in production and trial models. Figure 7 uses the 3 litre VW Lupo to illustrate the available technology used to cut fuel consumption by more than 1 litre compared with a basic model. The fuel savings achieved came from an improved engine which contributed around 60 per cent, weight reductions which provided about 20 per cent and a further 20 per cent came from measures to reduce air and rolling resistance (PEHNT, 2001, p. 89 ff, with further references).

With the SmILE vehicle, a modified Renault Twingo, Greenpeace demonstrated that technical improvements could halve fuel consumption immediately without having to change the front cross-section of the vehicle which is largely responsible for passenger comfort (Greenpeace, 2004). VW has also shown what can be done with a 1 litre car, although their model deviates greatly from conventional vehicle designs. Toyota's middle-class Prius, a hybrid vehicle, puts out only 104 g CO_2/km (Para. 8) and performs similarly to other vehicles in its class.

17. With regard to commercial vehicles, the potential for reduced fuel consumption is thought to be lower than that for passenger vehicles because, for the most part, their engines have already been largely optimised for fuel consumption relative to vehicle-specific load capacity. Direct fuel injection diesel motors with a charger and sometimes with exhaust gas recirculation are the norm.

Figure 6

Drive Train Savings Potential in Petrol and Diesel Engines Compared with a Passenger Car with 164 g CO_2/km Emissions



SRU/EA SG 2005/Figure 7.10. Data source: ELLINGER et al., 2000

However, fuel consumption in commercial vehicles is expected to drop by as much as 5 per cent with the introduction of SCR technology (see also SRU, 2005, Section 7.2.2.2). Forecasts indicate reductions in average fuel consumption in commercial vehicles of between 5 and 7 or even 10 per cent for the period 1997 to 2015 (BIRNBAUM et al., 2002, p. 83 f).

3.2 Alternative fuels

18. Alternative fuels include all types of fuels with the exception of the petroleum products petrol and diesel. Natural gas, liquid gas, hydrogen and plant oil fuels fall into this category along with synthetically produced fuels made from biomass, natural gas and coal. The attractiveness of these fuels lies in the fact that their use can lead to a decline in CO_2 emissions and certain other air pollutants compared with petroleum products.

In its National Strategy for Sustainable Development, the German government lists a reduction in the use of fossil fuels as part of its fuel strategy. The ultimate aim being to reduce dependence on oil, improve security of supply and reduce greenhouse gas emissions. It also plans to use the innovative potential offered by alternative fuels and drive technologies in the hope of stimulating economic growth and employment (Bundesregierung, 2004). A further goal in the use of alternative fuels like natural gas is to reduce localised emissions in, for example, built-up areas.

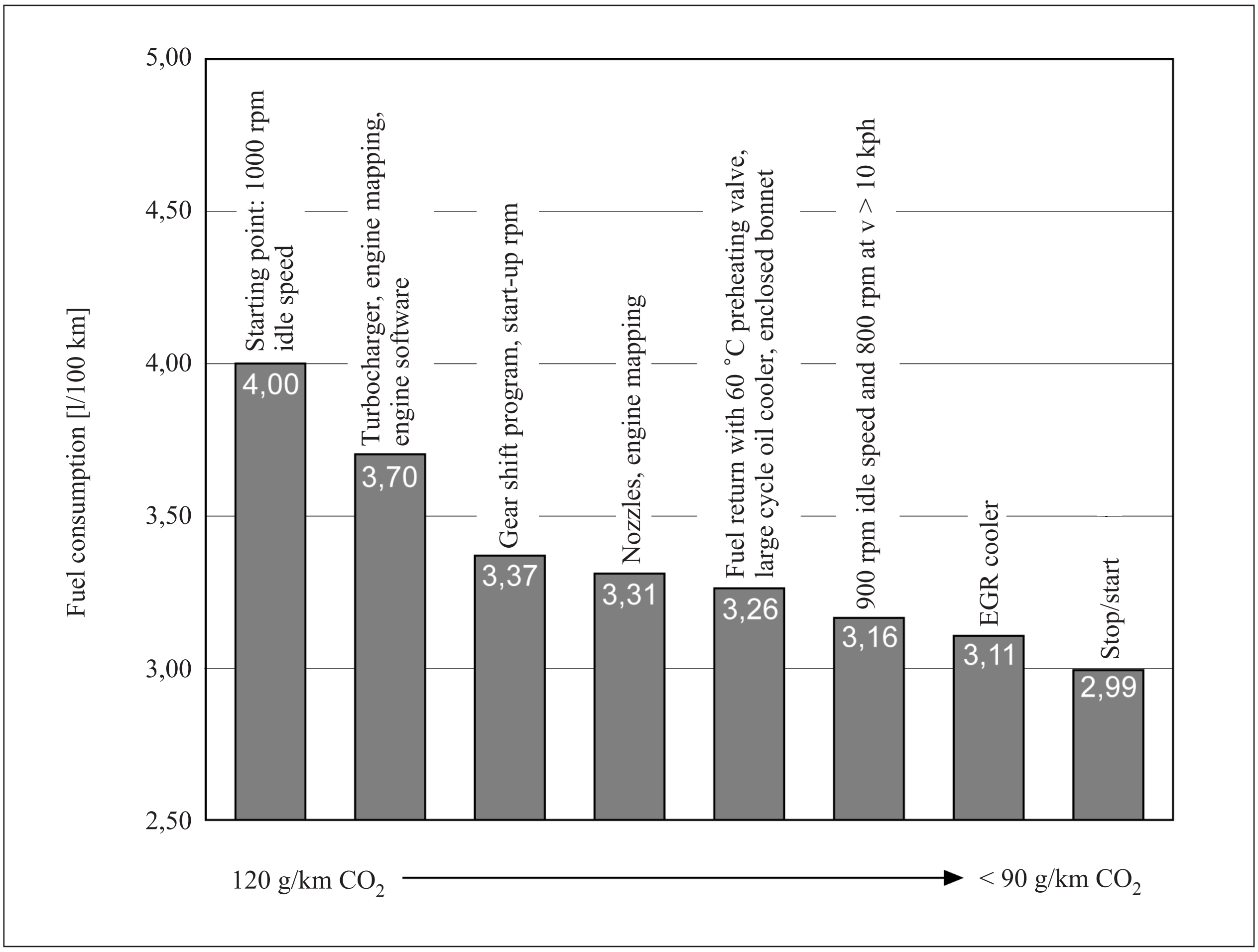
In its statement on Efficiency and Energy Research as Components of Consistent Energy Policy (RNE, 2004a), the German Council for Sustainable Development called for the transport sector to make its own contribution to energy and CO_2 savings. Along with a range of efficiency-enhancing measures, the Council also recommends stepping up efforts in the use of natural gas and synthetic and renewable fuels.

In principle, both environmental and economic aspects should be taken into account in decisionmaking on the use of alternative fuels. Consideration should be given to the competing uses for the few alternative fuels available and the substances they are derived from, be it stationary provision of electricity or heat or other uses of the raw materials themselves. Limited availability of fossil fuels means that the transport sector will be forced to use biofuels and hydrogen from renewable sources and other renewable energy carriers in the longer term.

Generally speaking, in relation to fuel needs, the quantities of biofuels that can be produced domestically are limited. For this reason, the potential biofuel contribution in reducing dependency on imported petroleum products is not addressed in this report. Nor are the competing uses

Figure 7

Effectiveness of Drive-Related Measures for Reduced Fuel Consumption in the 3 Litre VW Lupo



Source: PEHNT, 2001, p. 89, modified

for biomass, natural gas, etc. in the mobile and stationary sectors covered to any great extent. This would require a study of the energy and raw materials markets overall, which is not the aim of this special report and involves great uncertainty as regards the price of raw materials in the future, their availability, markets and technologies.

3.2.1 Biofuels

19. Biofuels are fuels produced from biomass and can be separated into two rough categories:

- Conventional biofuels that are already used in great quantities today. These include:
  - Plant oil methyl ester (biodiesel), rape seed methyl ester (RME) being the most common in Germany
  - Plant oils
  - Bioethanol made from sugar and starch plants, primarily sugarbeet and cereals in Europe.

  Biodiesel (RME) is the primary biofuel used in Germany and served 0.9 per cent of end energy consumption in road transport in 2003 (BMU, 2004a). Up to 5 per cent biodiesel can be blended with mineral diesel in all diesel vehicles. Some manufacturers have already approved their vehicles for unrestricted biodiesel use. Cold-pressed plant oils can also be used in modified vehicles at a ratio of up to 100 per cent (pure plant oil). Ethanol can be used as an additive in petrol. Conventional engines can cope with a mixture of around 15 per cent ethanol or synthetic methanol, while modified vehicles can cope with up to 100 per cent.

- Synthetic biofuels produced using biomass gasification and a subsequent synthesis process. The base material in the production of biofuels is not limited to oil, sugar and starch plant components. Whole plants and plant waste can also be used. The end product is either hydrogen or synthetic diesel generated using the Fischer-Tropsch synthesis process (see HAMELINCK et al., 2003). The latter technology is described as biomass-to-liquid (BTL); Volkswagen also calls its product Sun Fuel (STEIGER, 2002). The technology is still in its trial phase and a pilot project, 'synthetic fuels from renewable resources', was started in 2003. It offers greater quantity potential than conventional biofuels due to the broader base of raw materials used. However, systemic energy losses occur in BTL production: a large percentage of the energy contained in raw biomass is lost as exhaust heat during the production process. Only around 40 to 50 per cent of the fuel's energy is used (see data from PRINS et al., 2004; HAMELINCK et al., 2003). Energy-efficient use of biomass in the case of BTL therefore comes down to the recovery of process heat in production.

20. Coupled with its selection of the 'strong' sustainability model, the German Advisory Council on the Environment formulated a number of rules for the management of natural resources (SRU, 2002a, Para. 29). One of these rules is that non-renewable energy carriers and raw materials should only be used when a physically and functionally equivalent substitute renewable can be produced simultaneously. This rule requires further expansion of renewable energy sources, including biomass, on differing spatial and temporal scales (for a detailed report on the situation in Germany, see BMU, 2004b). Greater use of biomass is thus to be welcomed. The decisive factor, however, will be an accurate environmental impact assessment on the advantages and disadvantages of different scenarios and use variants given the dynamics of technological development, changing agricultural policy and foreseeable structural changes in farming.

Two key restrictions arise when it comes to biomass use: firstly, the goals and objectives of nature conservation, which must at minimum fulfil those of the Federal Nature Conservation Act (BNatSchG) and the EU Habitats Directive but may also extend beyond their respective provisions (see SRU, 2002b), and secondly, the arable land needed both domestically and overseas to actually produce biomass. A restriction on biofuel imports on the grounds of insufficient consideration of nature conservation requirements in the country of origin may conflict with the WTO Free Trade Agreement.

The following criteria must thus be applied when assessing available options:

- Energy efficiency
- Land use and compatibility with nature conservation goals
- Various environmental impact parameters (eutrophication, acidification, erosion, etc.)
- Economic viability
- Structural impact and effect on the jobs market.

Against the backdrop of ambitious long-term energy and climate policy targets (SRU, 2004, Section 2) and expansion of fluctuating energy sources like wind energy, it would make sense if the energy sector were to set a certain priority on using biomass in stationary provision of electricity and heat (see also BMU, 2004b). But this would not mean that the innovative technology track in the transport sector – BTL and GTL processes, for example – should be abandoned. Given its quantity potential and competing uses, however, domestic biomass could only play a significant role in the transport sector if that sector (like others) were to significantly reduce its overall energy consumption.

Potential use of domestic biomass in the transport sector should thus be focused on available arable land as dictated by nature conservation provisions. Consideration must also be given to additional factors such as demographic change and harvest yields (BMU, 2004b). Potential imports must be linked to clearly defined provisions such as those recently called for by the German Council for Sustainable Development in respect of wood imports (RNE, 2004b). One option would be to establish a certification system for biomass and biomass products.

Potential in Germany

21. Biomass as an energy vector comes in the form of waste substances (straw, waste wood, biowaste, etc.) and can also be produced by cultivating energy crops. The potential in using biomass to generate energy was the subject of a recent in-depth study on expanding the use of renewable energy sources in line with environmental needs (BMU, 2004b). The study looks at two different scenarios:

- The Basic Scenario in which the minimum requirements of nature conservation law are meant to be taken into account
- The Nature Conservation Plus Scenario in which nature conservation requirements receive greater consideration.

According to its description, the Basic Scenario should consider minimum nature conservation requirements. This appears questionable, however. While consideration is given to uses of biomass as considered desirable from a nature conservation standpoint (use of wood originating from landscape maintenance, for example), the minimum requirements laid down as regards establishing a network of interlinked biotopes, NATURA 2000 and responsible management practices, which would all lead to a reduction in biomass yields even in the Basic Scenario, go unheeded.

According to the current status on site registrations, the European NATURA 2000 environmental network will take up at least 8.6 per cent of available land for habitat conservation (BfN, 2005). This includes neither the areas needed to ensure coherence of the necessary corridors between the habitats nor the EU bird protection areas; the latter only overlap with Habitat Directive areas in a number of cases and currently take up some 7 per cent of available land. Nor can it be assumed that NATURA 2000 areas are identical to those of the national network of linked biotopes. Thus, the 10 per cent of available land for nature conservation needs allowed for in the Nature

Conservation Plus Scenario is in fact not even adequate in the Basic Scenario. A further weakness of the scenario model lies in the fact that the Nature Conservation Plus Scenario includes minimum requirements for erosion-prone areas while, despite the fact that erosion prevention is a component of good agricultural management practice, the Basic Scenario does not (Section 5 (4) of the Federal Nature Conservation Act (BNatSchG) and Section 17 (2) of the Federal Soil Protection Act (BBodSchG)).

It is therefore questionable as to whether the quantities of biomass crops contained in the Basic Scenario can be achieved while complying with currently applicable nature conservation provisions. Caution must therefore be taken to avoid overestimating the actual potential calculated under the Basic Scenario.

Compared with the Basic Scenario, the Nature Conservation Plus Scenario takes particular account of restrictions on land provision and use, and of those arising from provisions on linked biotopes, conservation and expansion of grasslands, exclusive use of erosion-prone land for multi-year crops, and water protection (e.g. riverside strips). As can be seen from the critique on the Basic Scenario, some measures that are taken into account in the Nature Conservation Plus Scenario are anyway part of prevailing nature conservation provisions. In some respects, therefore, and contrary to what its name implies, the Nature Conservation Plus Scenario contains no ambitious nature conservation targets of its own.

The potential indicated in both scenarios is technical potential. The price of making it available was not included in the study. Figure 8 shows the potential from waste substances, although around one quarter falls away as traditional waste for disposal – the biogenic component of household and bulk waste, sewage sludge and waste wood. The potential from biomass crops is shown in two different variants: full use of biomass cropland to produce solid biomass (1) and production of biofuels (2). The potential overall energy yield is thus the sum of the potential from waste substances and that from one or other of the two biomass crop variants. An annual yield of 80 GJ/ha was assumed when calculating the potential from the fuel variants (for comparison purposes: between 45 and 50 GJ/ha for RME, 87 GJ/ha for bioethanol derived from a combination of 50 per cent sugarbeet and 50 per cent wheat, and 85 to 90 GJ/ha for BTL fuels).

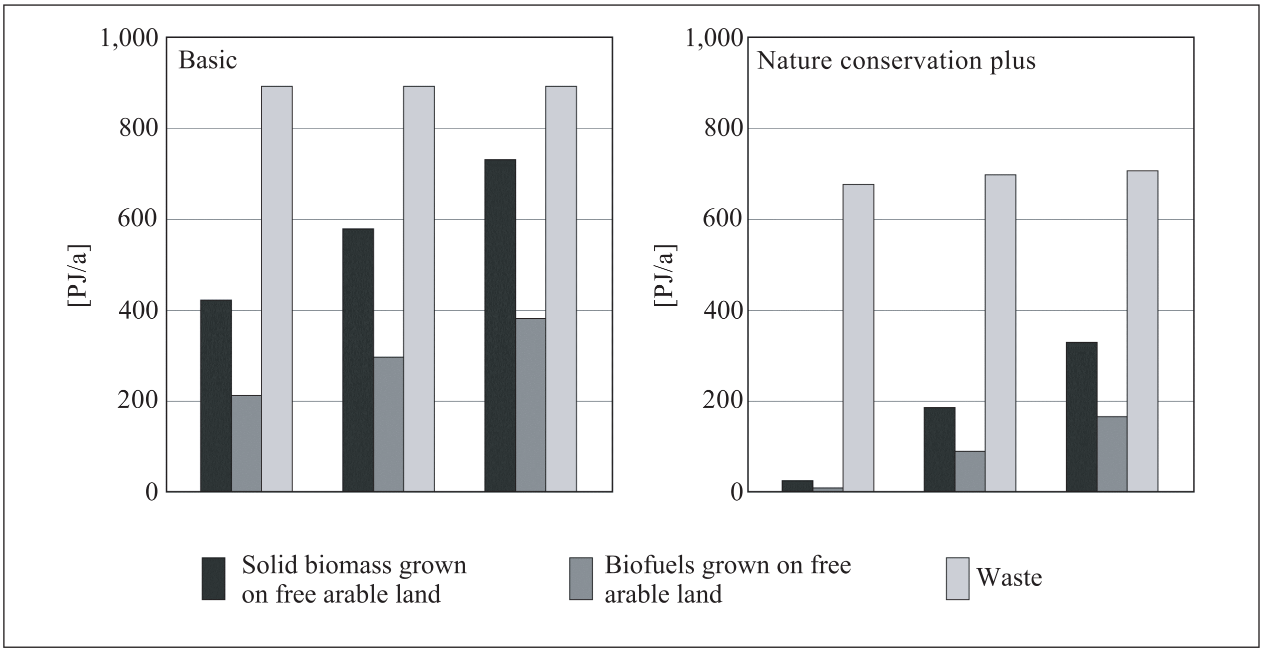
The study shows that:

- Intensive production of biomass crops stands in direct conflict with nature conservation efforts
- The energy yield from arable land on which fuel crops are grown is around half as much as from the production of solid biomass
- The potential from biomass crops will rise significantly over time, while that from waste substances will remain more or less constant.

The projected growth in biomass crop potential results from the expected growth in land yields in conventional plant production, plans to reduce over-production, and the

Figure 8

Biomass Potential for Energy Savings under Various Nature Conservation Requirements



Source: after BMU, 2004b, p. 160

shrinking population. In the medium and longer term, nature conservation activities will produce significant quantities of energy-giving biomass (wood from the maintenance of forest fringe lands and hedgerows, hay from landscape maintenance, etc.). There is great potential in hedgerow maintenance, although sufficient hedge biomass per area would have to be produced to make it viable (see METTE, 2003 on viability). This can only be guaranteed in part in northern areas of Germany (RODE, 1997). The Nature Conservation Plus Scenario also includes targets to expand ecoagriculture.

Figure 9 shows the area of land available for biomass crops in 2010 compared with the area needed to achieve the EU 5.75 per cent biofuel target (Directive 2003/30/EC). It shows the available land needed in both the Basic and Nature Conservation Plus Scenarios along with the crop coverage needed for the biofuel variants using biodiesel and ethanol derived from sugarbeet or wheat.

Under the Basic Scenario, the EU 2010 target of 5.75 per cent could be achieved if area-specific yields of ethanol production from sugarbeet were supplemented by biodiesel production. Land use under the Nature Conservation Plus Scenario would mean missing the EU target by a wide margin. Instead of the 5.75 per cent fuel share, this variant would produce 0.78 per cent sugarbeet and ethanol, 0.35 per cent wheat and ethanol and 0.31 per cent biodiesel (line in Figure 9). On the other hand, it must be noted that – as shown in Figure 8 – the Nature Conservation Plus Scenario projects a manifold increase in fuel potential in subsequent decades.

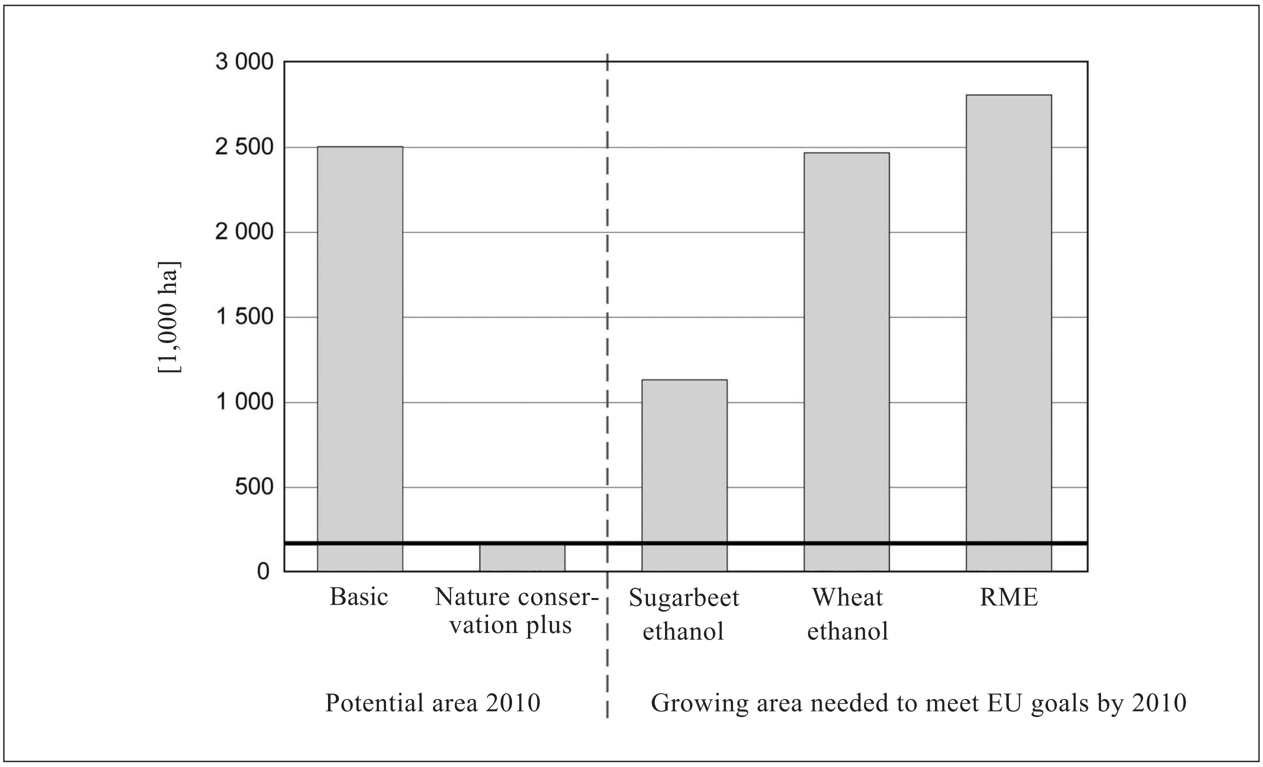
At European level, similar quantity potential is estimated for the production of biofuels in conventional agriculture. Thus, according to the EU Commission, using a maximum 10 per cent of arable land for biofuels would achieve an approximate 8 per cent share of the fuel market (EU Commission, 2001).

The figures clearly illustrate that at present, the quantity potential in domestically produced biofuels is around an order of magnitude of ten below that of the fuel quantities actually needed. Discussions on alternative uses for the available fuels and the land-use options for biomass production must therefore take account of the fact that current efforts touch upon only a small section of the fuel market. This aspect becomes less prominent if fuel consumption can be reduced (Section 7.3) and the projected potential actually used. Domestic biofuels could take a significant share of the fuel market under such conditions.

There is a need for in-depth study on imports of biofuels and raw materials for biofuel production. In a summary report, FRITSCHE et al. (2004) provide hope as regards crop-growing for fuel production in developing countries whose quantity potential, surprisingly, lies in the magni-

Figure 9

Crop Coverage Needed to Meet the EU 2010 Target of 5.75 per cent Biofuel and Available Arable Land



Source: BMU, 2004b, p. 162, modified

tude of the combined needs of the EU-25 *and* the USA. They also point, however, to possible social problems, anticipated environmental problems and the inability to fully evaluate imports based on sustainability criteria. In both the short and medium term, the authors see potential for developing countries to export biodiesel produced from a range of oils and fats, and also bioethanol; in the longer term, export of BTL fuels might be another possibility. The impacts on economic development, including on food supply and social structures, from the growth of this kind of export-focused production in developing countries is seen as similarly problematical to those involved in the production of other cash crops. FRITSCHE et al. (ibid.) have thus developed a checklist of the social and economic issues and the environmental impacts involved. This approach may well give rise to a certification system that at minimum would guarantee environmentally compatible production in the countries of origin.

Isolated consideration of biofuels does not provide the answer, however. What is needed is an integrated model for the production and use of renewable resources – one that includes evaluation of all production and use paths (material and energy uses). This is the only way to ensure the best possible use of what is a relatively small quantity of available biomass compared to the quantities of primary energy and petroleum used.

22. Use of biofuels is currently obstructed by comparably high production costs. At between 35 and 49 ct/l, the cost of producing biodiesel – the most widely used biofuel – is significantly higher than that of conventional diesel at 28.6 ct/l (MWV, 2004). The German Federal Environmental Agency believes that, even in the longer term, biodiesel will not become competitive because its competitive disadvantage is of a structural nature (KRAUS et al., 1999, p. 16). Production costs are strongly influenced by prices for the joint products rapeseed grist and glycerine. Both this and the associated uncertainty as regards the marketability of large quantities must be taken into account when expanding production. In some cases, plant oil that is produced and used on farms can compete with diesel when it comes to production costs. In Germany, production costs for bioethanol lie at best somewhere between 45 and 55 ct/l petrol equivalent (compared with productions costs of around 20 ct/l for petrol (MWV, 2004)), although costs of between 80 and 90 ct/l are not unthinkable (HENKE et al., 2002). The costs involved in the industrial-scale production of BTL fuels (Fischer-Tropsch diesel) are thought to be around 60 ct/l. Costs for the biomass used in the process make up around one-third of the production costs. Once all technological enhancement options have been exploited, production costs of around 40 ct/l can be expected at the very best (HAMELINCK et al., 2003).

Environmental impact of biofuels

23. Depending on type, management method and crop coverage, cultivating and producing biomass can have differing impacts on the environment and especially on nature and the landscape. If, for example, intensively farmed land is extensified by coppicing, then the cultivation of biomass crops can certainly have a positive impact on nature conservation. In the production of biofuels, however, sugarbeet, rapeseed and cereals are used that are usually produced in intensive farming. The use of fertilisers and pesticides eutrophies and pollutes waterbodies and neighbouring ecosystems, and indirectly promotes summer smog (Figure 10; see BMU, 2004b; REINHARDT and ZEMANEK, 1999). Alongside nitrous oxide (N_2O), a highly effective climate gas, ammonia (NH_3) also pollutes the atmosphere to cause acidification and eutrophication.

Apart from pollution from biomass crops, consideration must also be given to a range of other nature conservation-related impacts as listed below in brief:

- The impact of land management on groundwater replenishment
- The potential loss of valuable biotopes and species in need of protection due to use of set-aside land
- The potential loss of endangered accompanying flora species resulting from intensified land use
- The impact on biodiversity of using residual material from agriculture and forestry.

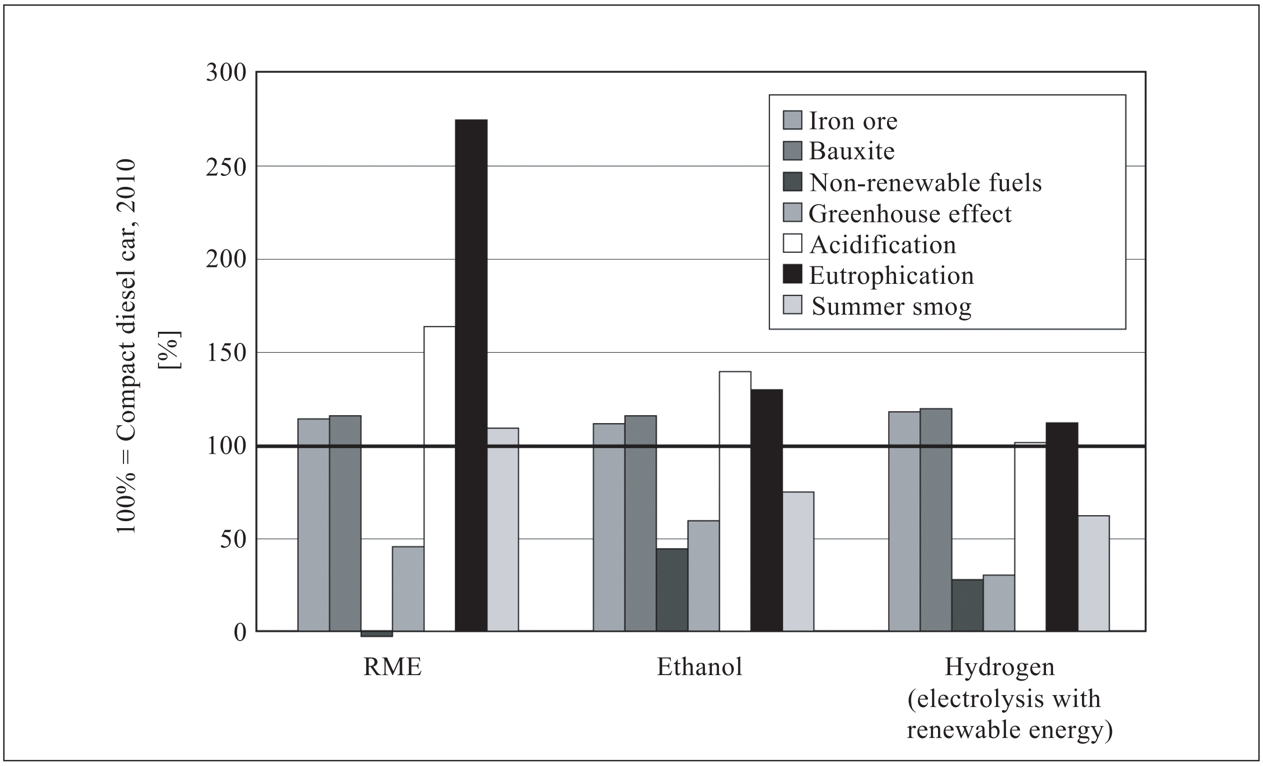
The full extent of the negative impacts from further expansion of biomass cultivation has yet to come to light. The impact of short rotation plantations on the plant and animal worlds remains unclear (for initial studies see LIESEBACH and ZASPEL, undated). Pollen from short rotation plantations could alter the gene pool in wild populations of tree species (within-species bastardisation). Reproduction in breeding species of these trees is mostly vegetative. Stocks of one variety are thus built up using one genotype, a practice which entails a high risk to surrounding wild populations from cross pollination. The genetic uniformity of such stocks poses the risk of sudden loss of the entire stock due to fungal and viral disease. Any great expansion in energy crop cultivation would lead, among other things, to significant changes in the landscape. For an in-depth discussion on the nature conservation aspect of biomass crops see RODE et al. (2005) and CHOUDHURY et al. (2004).

Biomass from forests could also be used to produce BTL fuels and hydrogen. Caution must be taken, however, to avoid intensification being introduced at the cost of nature conservation needs – removal of the deadwood so vital in biotope protection or nutrient-depleting overuse, for example. Any withdrawal not commensurate with local conditions can lead both to an imbalance in nutrient availability and to soil acidification (see also RODE, 1999a; RODE, 1999b). Tree harvesting performed at short-spaced intervals can significantly alter the aesthetic qualities of a forest or woodland.

Such qualitative impacts from land use are not specific to biofuel production alone but to biomass production in general. In the promotion of renewable resources, whether intended for material or energy use, the resulting conflicts with environment protection and nature conservation needs must be readily acknowledged and alleviated. The knowledge needed for this purpose has yet to be acquired.

Figure 10

Environmental Impact of Different Biofuel Paths



Source: BMU, 2004b, p. 85

In sum, environmental impact assessments show that while there are considerable advantages to be had from biofuels when compared with the use of fossil fuels and reducing greenhouse gas emissions, they are also disadvantageous given their contribution to acidification and eutrophication (Figure 10).

24. In biofuel combustion, only those quantities of CO_2 are released that the plants took from the atmosphere in the first place. This makes the carbon contained in biofuels climate-neutral during combustion.

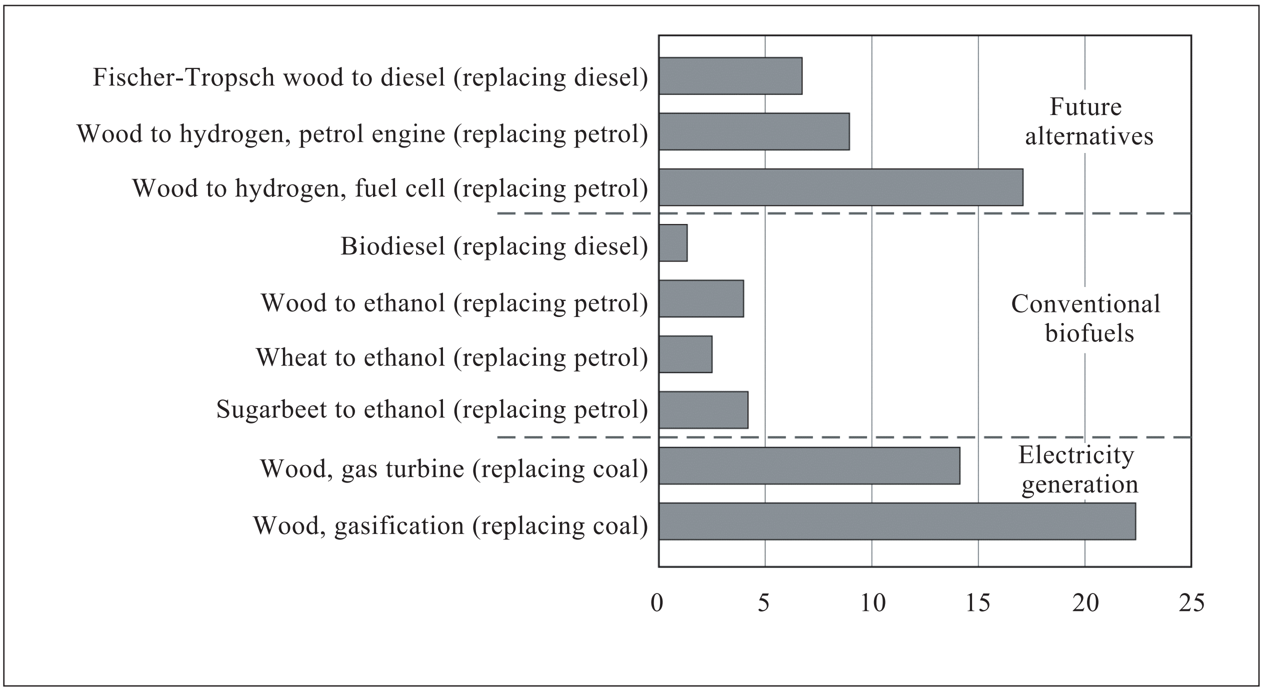
A look at the overall environmental impact of biofuels shows that energy yields per hectare are partly cancelled out by energy invested in crop production, transport and in downstream processing in particular. Special consideration must be given to nitrous oxide emissions (N_2O), which also harm the climate and reduce the net climate protection effect. Thus, in terms of the net contribution that biofuels make to preventing greenhouse gas emissions, a distinction must be drawn between the different types of fuels and their production methods. At worst, extremely high N_2O emissions can completely negate the net effect of replacing diesel with rapeseed oil (REINHARDT and ZEMANEK, 1999).

Compared with conventional petrol and diesel, the use of biofuels can reduce greenhouse gas emissions (see the environmental impact assessments in CONCAWE et al., 2004; REINHARDT and ZEMANEK, 1999; OERTEL and FLEISCHER, 2001; BMU, 2004b). Distinctions must be drawn between (1) greenhouse gas savings achieved compared with conventional fuels per land unit and (2) greenhouse gas savings achieved per kilometre. A given fuel can achieve different ratings in these two categories depending on the yield per hectare and any credits for joint products.

For example, due to the comparably high energy yields from sugarbeet, replacing petrol with ethanol derived from sugarbeet can achieve annual savings of around 12 t CO_2eq/ha; replacing diesel with biodiesel would achieve only about one-sixth of that amount (BMU, 2004b). Figure 11 uses data from a further study (CONCAWE et al., 2004) to show the area-specific impacts of different variants. It highlights, albeit to a lesser degree, the greater impact from sugarbeet ethanol compared with diesel (see also the area needed to achieve the EU target, Figure 9). For the near future, gasification of wood (short rotation plantations) offers the greatest greenhouse gas savings per unit area. This applies in particular when, rather than liquid fuel, the resulting product is hydrogen for use in fuel cells (SCHMITZ et al., 2003; CONCAWE et al., 2004).

Figure 11

Greenhouse Gas Savings Potential from Different Biomass Paths



Source: after CONCAWE et al., 2004

Per vehicle kilometre (i.e. litre of fuel), however, biodiesel does better as a substitute for conventional diesel (savings of 70 g CO_2eq/km) than sugarbeet ethanol used as a substitute for petrol (60 g) (CONCAWE et al., 2004). A similar conclusion is drawn in the environmental impact assessments contained in the Federal Environment Ministry study (BMU, 2004a). In terms of impact, biodiesel produces 57 g CO_2eq/km (despite three-fold nitrous oxide emissions) as opposed to 75 g CO_2eq/km from sugarbeet ethanol (see Figure 10). The better results with biodiesel come from credits for the joint products rapeseed grist and glycerine, which also effect the negative impact (meaning a saving) in the non-renewables category of the environmental impact assessment (Figure 10). This means that compared to sugarbeet ethanol, biodiesel requires considerably less energy from non-renewable sources. When looking at the per-kilometre data, it must be remembered that a vehicle's actual fuel consumption influences the results. The higher the consumption, the greater the savings potential from the use of alternative fuels. In a study conducted by the European Council for Automotive Research and Development (EUCAR), Conservation of Clean Air and Water in Western Europe (CONCAWE) and the EU Commission (CONCAWE et al., 2004), a comparison of alternative engine technologies in 2010 was based on a representative middle-class vehicle with greenhouse gas emissions of 139 g CO_2eq/km for petrol and 131 g CO_2eq/km for diesel. For petrol-driven hybrid vehicles, emissions of 118.6 g CO_2eq/km were assumed for 2010, although with emissions of 104 g CO_2eq/km, the Toyota Prius – already available as a production model – meets the study's criteria. The levels recommended in the study for 2010 represent a probable trend but not what is technically achievable. The potential errors arising from the uncertainty of this projection have little effect on the conclusions drawn in the study.

Given the differing energy yields per unit area and differing environmental impacts per unit fuel produced, the choice between fuel options is dependent on prescribed parameters (quantities and efficiency requirements). If maximisation of greenhouse gas savings through the use of available area is set as a target, the variants must be chosen that produce the greatest area-specific result. Application of a different set of criteria (e.g. use of non-renewable fuels in production or cost-effectiveness) would not necessarily provide the same environmental impact outcomes.

25. With regard to the various options for using biomass as a raw material, as motor fuel and for stationary electricity and heat generation, each type of use must be analysed in order to optimise the overall environmental costs and benefits. This applies both for specially grown biomass and for biogenic waste.

Compared with the energy derived from using solid biomass as fuel for stationary sources, biofuels have the disadvantage of lower energy yields per unit of raw material or crop area. Energy is lost during conversion and processing and, in the case of conventional biofuels, the yields from processed plant components are lower than those from miscanthus or short rotation plantations, for example. Depending on the form in which it is used, biomass used for electricity and heat generation can achieve similar (EYRE et al., 2002) or even higher CO_2 savings (BMU, 2004b; CONCAWE et al., 2004) than when used in vehicles (Figure 1 and Table 1). The greatest area-specific CO_2 savings can be achieved by using biomass in combined heat and power plants to generate electricity as a substitute for coal-generated electricity. Depending on the type of coal used and its origin, electricity generated from coal causes between 800 to 1 000 g CO_2eq/kWh_{el}, while generation from gas (again depending on its origin) causes 350 to 500 g CO_2eq/kWh_{el} (FRITSCHE, 2003). Electricity generated from biomass such as wood from short rotation plantations causes somewhere between 50 and 100 g CO_2eq/kWh_{el} (BMU, 2004b). Table 1 shows the achievable savings potential under such conditions.

Table 1

Greenhouse Gas Reductions from Various Uses of One Tonne of Biomass from Short Rotation Plantations

Type of Use	GHG Savings kg CO^2eq/t Biomass
Coal substitution, power station without CHP	650
Gas substitution, CCGT without CHP	270
Diesel substitute (Fischer-Tropsch synthesis)	290

SRU/EA SG 2005/Table 7.6.
Data Source: BMU, 2004b and FRITSCHE, 2003

From a greenhouse gas savings perspective (for the time being without considering the costs), the cultivation and use of solid biomass as a coal substitute in electricity generation is by far the most effective method. A comparison between the use of gas-generated electricity with that from biofuel, on the other hand, shows there is no appreciable difference between the two. If coal-generated electricity were to be replaced by gas-powered electricity plants in the longer term, then the environmental preference for biomass use for electricity production ceases to exist.

CO_2 abatement costs in using biomass crops for bioenergy from solid and liquid fuel are generally high compared to the cost of around €8/t CO_2 for an emissions permit for one tonne of carbon dioxide under the EU Emissions Trading Scheme (Status: European Energy Exchange, Leipzig, February 2005). This price represents the actual marginal abatement costs of emissions reduction incurred by a company participating in the emissions trading scheme and can thus be used as a realistic reference value for emissions abatement costs in the energy sector and much of industry in general. Table 2 shows greenhouse gas abatement costs for selected biofuel variants.

The „CO_2 Mitigation Study“ (QUIRIN et al., 2004) combined the findings from all available studies to produce bandwidths that show extremely large variation for all biofuels. This variation is partly due to the fact that prices for oil seeds and also those for the joint products grist and glycerine in biodiesel production are subject to high fluctuations in the global market; depending on relative price levels, up to half the costs of raw materials (oil seeds) can be covered by income from joint products. Another reason is that income from joint products was not taken into account in all the studies analysed because in some instances the marketing of such products is deemed problematic, especially if production is significantly expanded. The low abatement costs for biodiesel and the negative abatement costs for rapeseed and sunflower oil at the lower end of the bandwidth come from the study conducted by Kavalov et al. (2003) on the potential from biodiesel and bioethanol in the EU accession countries of 2005. Rather than looking at market prices for oil seeds, the study looks at production costs in relation to per hectare yields as raw material costs. It reports production costs for rapeseed at below €165/t for yields of approximately 2 t/ha, resulting in biodiesel production costs of less than 30 ct/l. If the costs of transesterification are deducted, then prices for rapeseed oil as a fuel amount to around or below 28 ct/l. This would explain the low or negative abatement costs. Abatement costs are by default dependent on the production costs of conventional fuels. For example, a study entitled Bioethanol in Deutschland (SCHMITZ et al., 2003) cites a drop in abatement costs for sugarbeet of between €100 and €250/t CO_2eq assuming an increase in the price of crude oil from $30 to $50 per barrel. Uncertainty due to fluctuating prices for crude oil, raw materials and joint products is generally seen as a downside of any abatement costing exercise. The values shown in Table 2, which derive from calculations done for the study, are based on current production costs for petrol, diesel and biofuels and data from the CONCAWE study (CONCAWE et al., 2004) on greenhouse gas savings. While the calculations for biodiesel do not take agricultural subsidies into account, the impact of subsidies for set-aside is not visible in the current prices for rapeseed (BROCKS, 2001). Prices for food rapeseed and non-food rapeseed, which may be cultivated on set-aside land, only differ by a few euros per tonne. A price difference of €25/t would reflect a subsidy impact of around 5 ct/l for biodiesel.

Compared with abatement costs in stationary electricity generation of around €50/t CO_2eq (BMU, 2004b) or with the price of emissions allowances, biofuel production is currently an expensive way to reduce CO_2 emissions. Assessment of future trends is largely dependent on available technology and its cost, both in transport and in the stationary sector. At present, for example, the use of wood-derived hydrogen in fuel cell vehicles would

Table 2

Costs of GHG Abatement Using Biofuel Variants

Fuel	Abatement costs €/t CO_2eq	Source
Biodiesel (rapeseed)	35–1,600 280–350(1) 110	QUIRIN et al., 2004 CONCAWE et al., 2004 own calculations
Biodiesel (sunflower)	0–750 220–260(1)	QUIRIN et al., 2004 CONCAWE et al., 2004
Rapeseed oil	– 50–1,000	QUIRIN et al., 2004
Sunflower oil	– 50–400	QUIRIN et al., 2004
Bioethanol (sugar cane)	20–150	QUIRIN et al., 2004
Bioethanol from sugarbeet	90–1,100 250–560(1) 500–1,000 320	QUIRIN et al., 2004 CONCAWE et al., 2004 SCHMITZ et al., 2003 own calculations
BTL (wood)	100–600 300 120	QUIRIN et al., 2004 CONCAWE et al., 2004 own calculations
Hydrogen (wood)	620–650	CONCAWE et al., 2004
See: EU Emissions Trading (February 2005)	approx. 8	European Energy Exchange, Leipzig

(1) Depending on use of co-products

SRU/SG 2005/Table 7.7

achieve a similar reduction impact to that from electricity generation, albeit with considerably higher abatement costs (BMU, 2004b, see Figure 11). A projection as regards the most effective use of biomass in the longer term is not possible due both to the uncertainties surrounding future technologies and the costs involved.

While other emissions that arise from the use of biomass as an energy vector are not discussed in this report, it must be pointed out that a critical eye should be kept on emission yields from any significant expansion of biomass use in stationary facilities, especially small facilities, not covered by the Ordinance on Large-Scale Combustion Plants (13th BImSchV).

26. The emissions from diesel engines are altered if conventional diesel is replaced by biodiesel – the changes achieved being dependent on the type of engine involved. Emissions due to less-than-full combustion tend to be reduced, while NO_x emissions increase. Reductions in particles, HC and CO are normally between 30 and 40 per cent, while the increase in NO_x amounts to between 10 and 20 per cent. A mixture of biodiesel and conventional diesel effects changes in emissions more or less in line with the biodiesel share of the mixture (MUNACK et al., 2003). The mutagenic impact of biodiesel soot is less than that of conventional diesel soot (BÜNGER et al., 2000; CARRARO et al., 1997).

No real conclusions can be drawn as regards plant oil-fuelled engines because the emission levels largely depend on the engine conversion rather than on the fuel. According to retrofitters Vereinigte Werkstätten für Pflanzenöltechnolgie (VWP Allersberg), complying with prevailing exhaust gas standards poses no problems when adapting conventional engines to plant oil. The difficulty lies in the fact that under current legislation, approval testing of modified vehicles is done with conventional diesel vehicles and thus the retrofitters must guarantee low emissions and reliable operation with both types of fuel.

3.2.2 Natural Gas

27. Natural gas can be used for transport, either in the form of highly compressed natural gas or as liquefied natural gas.

Compared with petrol, compressed natural gas (CNG) has the disadvantage of a lower energy density and thus achieves a lesser range on a full tank of fuel. With current gas storage methods and maximum pressure of 200 bar, some 4.5 times extra volume must be carried compared with petrol and four times as much compared with diesel in order to obtain the same amount of energy as from petrol (BACH, 2002; LEXEN, 2002).

The advantage of liquefied natural gas (LNG) lies in its low volume (compressed up to a factor of 600). However, it must be stored in a well-insulated tank at temperatures below –162 °C. From a climate perspective, the CNG option is slightly more beneficial due to the lower conversion losses compared with liquefied natural gas (RAMESOHL et al., 2003). In Germany, a trend has developed towards CNG in place of LNG. The chemical conversion process (Fischer-Tropsch synthesis) allows use of natural gas for production of synthetic fuels (Synfuel, GTL) and for conversion to hydrogen (RAMESOHL et al., 2003).

Natural gas in fuel form can be used as a substitute for petrol in petrol engines. Given the limited filling station infrastructure, most manufacturers rely on bivalent vehicles that can be driven on either petrol or natural gas. Natural gas engines make for soot-free combustion, extremely low NO_x rates and odourless exhaust gases. In terms of greenhouse gas emissions, a differentiated assessment is needed with regard to the upstream supply chain.

28. Well-to-tank greenhouse gas emissions from natural gas are highly dependent on assumptions regarding origin and transportation route parameters and pipeline losses: taking the entire processing chain into account and assuming the current most favourable EU mix, well-to-tank emissions could be as much as 30 per cent below those from petrol. In the case of a 7,000 km-long compressed gas pipeline or a liquefied gas pipeline, some studies calculate greenhouse gas emissions at between 60 to 85 per cent higher than those from petrol (CONCAWE et al., 2003a; RAMESOHL et al., 2003). New measurements have, by way of contrast, produced significantly lower pipeline losses in Russian gas pipelines. These should be taken into account in future calculations (Wuppertal Institute, 2005).

When it comes to bivalent vehicles, combustion of natural gas in a petrol engine is, in some instances, still less efficient than that of petrol (RAMESOHL et al., 2003; KOLKE et al., 2003). In adapted engines, CO_2 emissions can be expected to drop by some 20 per cent due to the better anti-knock properties of natural gas compared with petrol, with levels similar to those achieved by diesel engines. Without taking the upstream supply chain into account, specific vehicle emissions of 110 g CO_2eq/km (CONCAWE et al., 2003b; LEXEN, 2002) are projected for 2010. This is also similar to the figures for conventional fuels in improved combustion engines.

As regards well-to-wheel greenhouse gas emissions, a gas-powered vehicle is more advantageous than a petrol-driven vehicle if the current EU mix for natural gas is assumed; no benefits are detectable compared with diesel vehicles (Figure 10). Assuming that transportation distances for gas delivery will be greater in the future, the attractiveness of gas is lessened. The evaluation ultimately depends on pipeline losses and type of use. Given the relatively small advantage from gas as regards greenhouse gas emissions in the transport sector, pipelines losses have a greater impact on the assessment than they do in, say, energy and heat production (SRU 2004, Section 2.2.3).

From an energy and environment perspective, synthetic diesel produced from natural gas offers no real advantages over direct use of natural gas. In fact, the additional conversion step requires even more energy to produce synthetic diesel which means it actually has a negative impact on the environment (RAMESOHL et al., 2003). One advantage of synthetic diesel over direct use of natural gas for fuel is that there is no longer a need for a new filling station infrastructure or for vehicle conversion. Compared with conventional diesel, synthetic diesel offers improved quality with better ignition and emissions free from sulphur, nitrogen and aromatics.

29. With regard to emissions of other atmospheric pollutants, combustion engines fuelled with natural gas are more advantageous compared with petrol-driven engines. This is mostly due to improved natural gas combustion. Fuel is prevented from condensing on cold engine parts, which significantly reduces cold-start emissions (BACH, 2002). Compared with a petrol-driven engine, emissions of carbon monoxide and hydrocarbons are significantly lower; there are no particle and benzole emissions at all (PEHNT, 2001). In terms of nitrogen oxide emissions, natural gas has the advantage over diesel. While, for example, a diesel bus (Euro III) puts out sixty times as much nitrogen oxides as a passenger car with a petrol engine, a bus running on natural gas only puts out eight times as much (FEISST, 2002).

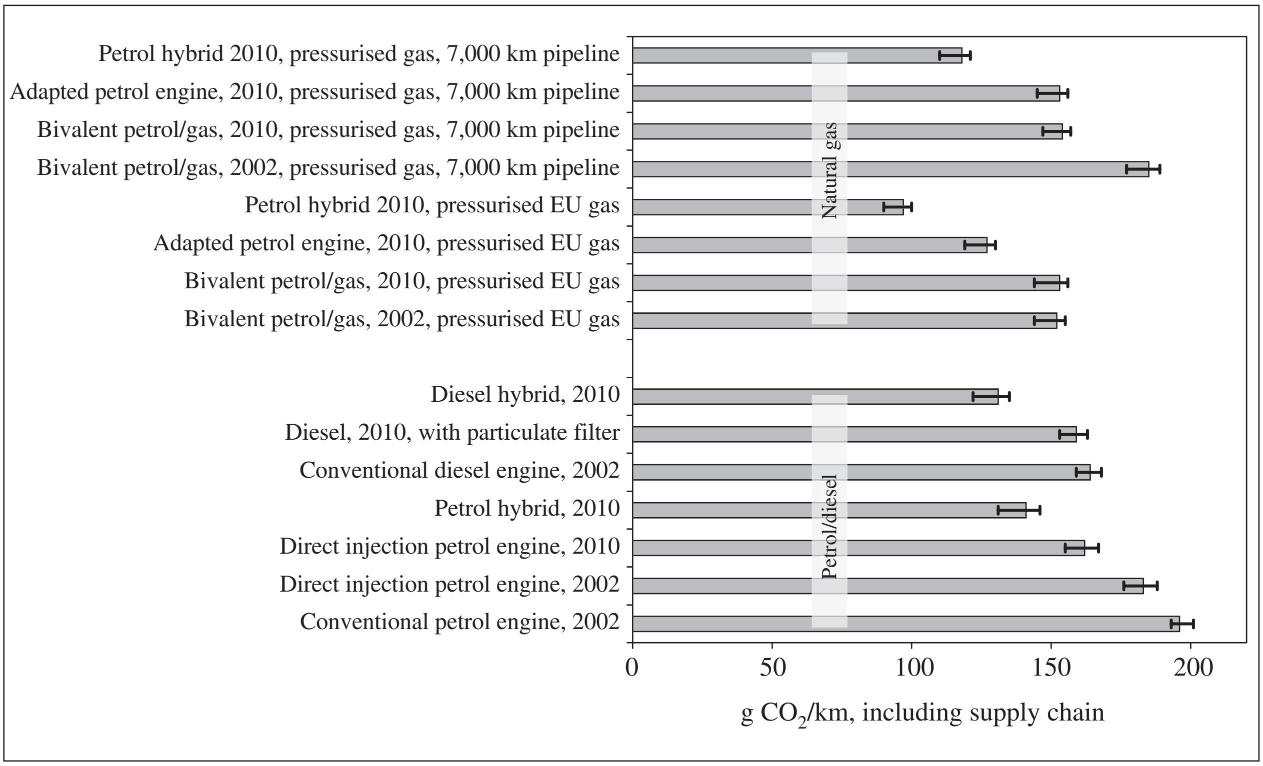
All of these benefits become significantly reduced, however, when Euro 4 standards are complied with, and with the broad introduction of advanced exhaust gas treatment technologies in cars (particle filters and NO_x storage catalytic converters). Then again, if the technological advancements in engine control and exhaust gas treatment already achieved with petrol-driven vehicles could be effected for natural gas-powered vehicles, then their already low emissions could be further reduced by a significant amount (BACH, 2002).

30. The use of natural gas in transportation stands in direct competition with its use in the electricity generation sector, which is set to grow significantly in the future. If the coal used for electricity production is replaced by natural gas, up to ten times more GHG equivalents can be saved per energy equivalent used than by replacing petrol with natural gas for road transport (CONCAWE et al., 2004). Wide use of natural gas for road transport, on the other hand, comes up against the high costs of creating a nation-wide infrastructure.

Based on the above, vehicles powered by natural gas would appear to make sense where concentrated emissions can result in direct local harm due to high volumes of traffic, especially in inner-city areas. It would make particular sense to convert public transport fleets and taxis, as this would quickly effect a significant reduction

Figure 12

Well-to-Wheel Analysis of Total GHG Emissions from Vehicles Fuelled by Natural Gas or Conventional Fuels



Source: CONCAWE et al., 2004, modified

in emissions and would not require cost-intensive development of a nation-wide filling station infrastructure. The use of processed natural gas as synthetic diesel could lead to dramatic reductions in traditional air pollutants, especially in heavy transport (EYRE et al., 2002), but not to a decline in greenhouse gas emissions.

31. Along with natural gas, methanol is also under discussion as a potential energy source in an interim strategy for hydrogen fuel cell vehicles (VES, 2001). The advantage of methanol lies in its comparably simple production from fossil fuels and biomass, and in the fact that it can be easily stored as a liquid fuel. From a greenhouse gas perspective, methanol offers the greatest reduction potential when produced from biomass. Its potential in this regard is limited, however (see Para. 21).

3.2.3 Hydrogen Technology and Transport

32. A combination of hydrogen and fuel cell technology could help to reduce environmental problems in both the mobile and stationary sectors – a zero emissions car powered by hydrogen obtained without releasing CO_2 has been promoted for some considerable time. With the President's Hydrogen Initiative, the American government plans to initiate a research campaign in this sector which it will fund to the tune of $1.2 billion over the next five years (US Department of Energy, 2004). The Organisation for Economic Cooperation and Development (OECD) also sees great potential in the use of hydrogen in the mobile sector (see IEA, 2003). There is also a strong lobby for a hydrogen strategy at European level: the President of the EU Commission and the EU's Transport, Energy and Research commissioners have presented a communication on an EU Roadmap Towards a European Partnership for a Sustainable Hydrogen Economy (Press Release IP/03/1229). The High Level Group on Hydrogen and Fuel Cells was established in October 2002 and presented its vision for a European hydrogen economy in June 2003 (HLG, 2003).

The German Advisory Council on the Environment also believes that hydrogen technology will play a key role in the future. Any assessment of the technology, however, depends on the emissions associated with hydrogen production. If, for example, production switched to hydrogen derived from fossil fuels, the energy and climate balance would no longer be acceptable because the amount of primary energy used to produce hydrogen would at best be three times as high as in the production of petrol (WALLENTOWITZ and NEUNZIG, 2001, p. 38). Integration of nuclear energy into the hydrogen technology system, as proposed in some quarters, as a component of hydrogen production cannot be considered due to the risks and unresolved disposal problems.

33. The use of hydrogen as a long-term technological fix for emissions reduction is currently being researched in two different areas: production of engine power using fuel cells (e.g. Daimler-Chrysler: NECAR 5) and combustion of hydrogen in a combustion engine (e.g. BMW: 745h, 750hL). Fuel cells, which achieve better levels of efficiency compared to the combustion engine, are however regarded as the longer term solution for mobile use of hydrogen (WB BMVBW, 2002).

If in place of hydrogen, whose use due to its low energy density is only feasible when it is stored in liquid form under extremely high pressure or at very low temperatures, a fuel-cell vehicle is powered by natural gas, petrol or methanol, then these must be converted on-board into hydrogen. In turn, the hydrogen must be cleaned before being fed to the fuel cell. A fuel cell that can be powered directly with methanol is currently under development, although it is not yet suited to use in the mobile sector (Enquete Commission, 2002, p. 219; OERTEL and FLEISCHER, 2001, p. 91).

34. The key benefits of fuel cell technology are its mechanical simplicity, low maintenance, independence from oil and high-performance on-board energy supply (STOLTEN et al., 2002, p. 488). In-vehicle storage of hydrogen remains one of the key problems, however. Storage of hydrogen in pressurised containers requires extreme pressures of 350 bar and more. Another problem is that due to the gas's high diffusion rate, a tank filled with hydrogen would be empty after just a few months and also poses a potential hazard. Alternative storage options such as chemical storage in metal hydride batteries might well be safer and more compact than pressurised containers, but their storage capacities per unit weight are rather low. This makes mass production of fuel cells at affordable prices unrealistic, especially as there is as yet no substitute for platinum as a catalyst. Another barrier that should not be underestimated is the need for a new infrastructure in order to supply the nation's vehicles with hydrogen (see also VES, 2001; WALLENTOWITZ and NEUNZIG, 2001, p. 35).

Energy balance and climate impact of (mobile) hydrogen technology

35. Hydrogen-powered vehicles produce no or few direct emissions and are CO_2-free. However, any assessment of the energy balance and environmental impact depends not only on the efficiency of energy use in powering the vehicle, but on the upstream process chain and, first and foremost, the primary energy carriers used in hydrogen production.

A number of processes exist for producing hydrogen. These include steam reforming of natural gas, oil gasification, methanol reforming, the Kværner process (breakdown of hydrocarbons in an electric arc into pure hydrogen and pure carbon), gasification or fermentation of biomass and electrolytic water-splitting. CO_2 emissions could thus occur during production of hydrogen: during direct conversion of fossil and biogenic energy carriers and in the production of electricity needed for electrolysis or the Kværner process. Significantly more energy is needed to produce hydrogen than for petrol. At between 100 g CO_2eq/MJ (natural gas reforming from an EU mix) and 190 CO_2eq/MJ (gasification of coal plus CO shift), greenhouse gas emissions from fossil-generated hydrogen are considerably higher than those from generic fuels which lie in the range of 14.2 g CO_2eq/MJ (diesel) and 12.5 g CO_2eq/MJ (petrol) (CONCAWE et al., 2003a). In electrolysis, the use of coal-generated electricity produces the poorest results, with greenhouse gas emissions of 420 g CO_2eq/MJ. Electricity generated from nuclear energy produces around 7 g CO_2eq/MJ, while electricity from renewable energy sources produces 9.1 g CO_2eq/MJ (offshore wind energy; see Figure 13). Full conversion of all passenger vehicles in Germany would result in a hydrogen demand of 700 PJ and take some 290 TWh of electricity to produce it. This amounts to about half of the gross electricity generated in Germany today (AGEB, 2004).

Due to the sometimes high greenhouse gas emissions occurring in hydrogen production, fuel cell vehicles can in some cases effect no primary energy savings compared with optimised, low-consumption combustion engines (OERTEL and FLEISCHER, 2001, p. 295; KOLKE, 1999; SRU, 2002, Para. 1397). As opposed to its use in the stationary sector, the effectiveness of a fuel cell is reduced in mobile use although it still reaches between 40 and 50 per cent or more (KOLKE, 1999, p. 46; also CONCAWE et al., 2003b). Taking account of the entire energy chain, including the complex processes of hydrogen production and liquefication, current effectiveness is estimated at between 20 and 30 per cent (STOLTEN et al., 2002, p. 467).

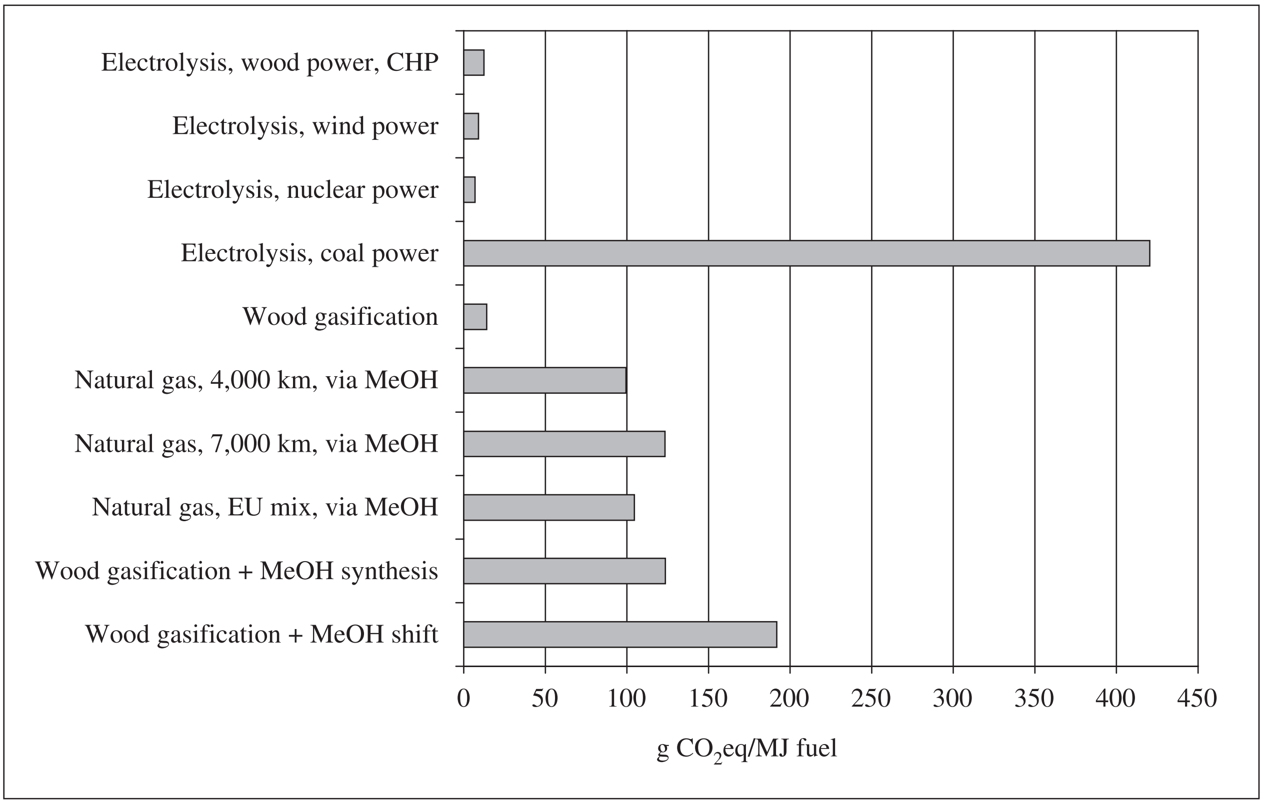
36. On the whole, the use of hydrogen technology can effect significant greenhouse gas savings if hydrogen is produced from renewable energy carriers and is used in fuel cell vehicles. Total emissions would then amount to around 10 g CO_2eq/km. Fuel cell vehicles powered with hydrogen produced from natural gas reforming put out between 93 and 116 g CO_2eq/km depending on the origin of the gas itself. This lies in the range of emissions achieved with a consumption-optimised combustion engine powered by conventional fuels.

Looking beyond the transport sector, the use of renewables-generated hydrogen as a fuel is questionable both from an environmental and an economic standpoint. At present, it would make more sense to use renewable energy carriers in stationary electricity production and to use that renewables-generated electricity directly (RAMESOHL et al., 2003; NITSCH et al., 2001; KOLKE, 1999, p. 13; EYRE et al., 2002; see also competing uses for biomass, Para. 21).

From a purely economic perspective, it would also make sense to increase the share of renewable energy in the electricity sector before doing the same in the transport sector. The reason being that the costs of replacing fossil fuels with renewable energy carriers in the electricity sector are significantly lower than those in the fuel sector (NITSCH et al., 2001, p. 366 f).

Figure 13

Greenhouse Gas Emissions in Hydrogen Production



Source: CONCAWE et al., 2004, modified

3.3 Evaluation

37. Although alternative fuels like biomass and hydrogen offer significant reduction potential, at least in the longer term, the German Advisory Council on the Environment believes that given the as yet limited potential and comparably high abatement costs, it would make more sense to place greater priority on further exploitation of the technical options for CO_2 reduction in vehicles with conventional engines. Available technology already allows savings of over 40 per cent compared with the current average fuel consumption of newly registered passenger cars fuelled with petrol and up to 40 per cent with diesel. This brings average specific CO_2 emissions from newly registered passenger cars down to around 100 g/km. The main options for emission reduction include improved engine technologies, ensuring that engines run in the optimum performance range through downsizing and improved gearbox spacing, optimum energy management, hybridisation, and reduced vehicle weight and rolling resistance.

4 Implementation

38. No direct regulatory provisions exist at present on reducing specific CO_2 emissions and thus fuel consumption. While direct regulation might be possible in principle, economic instruments offer a range of uncontested benefits for CO_2 emissions in terms of overall economic efficiency. For this reason, the German Advisory Council on the Environment would prefer to see a source-focused strategy towards reducing transport-related CO_2 emissions based on the use of economic instruments. At first glance, the ideal solution might be to regulate CO_2 emissions from transport by using a single pricing policy instrument that places its main focus on fuel consumption. However, a policy of this kind would appear difficult to implement due to prevailing price elasticities. According to HANLY et al. (2002, p. 11), a 10 per cent increase in fuel prices in passenger transport would effect only about a 3 per cent drop in demand in the shorter term. Looking at the longer term outcome, and taking account of further adjustment options, the drop in demand would still only be 6 per cent. These figures are largely consistent with numerous other studies on price elasticity of fuel demand in passenger transport (Victoria Transport Policy Institute, 2004; KNIESTEDT, 1999). The slow response to fuel prices is also highlighted in a survey commissioned by the German Federal Environmental Agency, where some 60 per cent of car owners questioned said they did not intend to change their driving habits until such time as petrol prices doubled those in 2002 (KUCKARTZ and GRUNENBERG, 2002, p. 73). Based on the findings of earlier surveys, it must also be borne in mind that a phased price increase would have a normalising effect and make actual changes in driving habits less pronounced – as the various surveys confirm (DAT, 2002).

Fuel prices are even less elastic in the freight transport sector than in passenger transport because fuel costs make up only an average 6 per cent of transport costs across all freight groups in short-distance freight and 19 per cent in long-distance freight. Added to that is the fact that in freight transport the substitution options as regards modal splitting are considerably less than those in passenger transport.

39. The stated elasticities imply that fuel demand does vary in line with changes in price, but not at anything like the same rate. Any attempt to reduce CO_2 emissions in the transport sector by raising fuel prices would thus fail due to the high price level required and, in consequence, on the issue of political acceptability. This can be illustrated by reference to the Enquete Commission (2002) report on Sustainable Energy Supply in Times of Globalisation and Liberalisation, which identified a need to cut transport-related CO_2 emissions by up to 55 per cent by 2050. Based on a long-term price elasticity of –0.6 and a 10-year adjustment period, a 55 per cent reduction target would require fuel prices to rise, adjusted for inflation, to 1.9 times today's prices by 2040. At an average 2 per cent inflation rate, this would mean that fuel prices would need to rise by almost 10 ct/l each year to reach a nominal price of around €4.70/l in 2040. These figures make it clear that any attempt to achieve the required leverage with higher fuel prices is destined to failure from the outset purely on the grounds that it would be politically unacceptable. This is why regulation of transport-related CO_2 emissions requires a combination of economic instruments that allow its management to address different actors and behavioural changes. This would, however, result in a target-setting conflict: the wider the range of instruments used, the lesser the impact each individual instrument can have in order to increase its chances of being implemented in policy. Depending on the number of instruments used, however, the risk of overlapping or even contradictions becomes greater and can thus affect acceptance and implementability of the policy mix overall (as reported by the Scientific Advisory Council to the Federal Ministry of Transport, Building and Housing, 1992). What is needed is a combination of economic instruments that concentrate on the key reference points and place both carmakers and car owners under obligation. This would involve:

- A switch from self-regulation under the European car industry's voluntary agreement to an emissions trading system that targets fuel consumption in vehicles
- A vehicle taxation system that places greater focus on CO_2 emissions than it has so far
- Further phased increases in the ecotax levied on petrol and diesel fuels
- Further development of Germany's commercial vehicle toll system introduced on 2 January 2005
- Where appropriate, introduction of localised road tolls for passenger vehicles to ease congestion in built-up areas, and/or larger-scale parking space management measures.

The following sections are restricted to the emissions trading model and CO_2-based vehicle taxation, as these recommendations come under the 'measures at source' impact category. It must be pointed out, however, that emissions trading and CO_2-based vehicle taxation can only reach their true potential when combined with the other measures outlined earlier. With regard to those measures, which fall into the 'transport management measures' category, reference is made to the original text of the German-language Special Report (SRU, 2005).

4.1 The Car Industry and Voluntary Agreements

Background

40. Along with fiscal incentives (CO_2-based vehicle taxation) and an obligation to inform consumers (Labelling Directive), the commitments made under the European car industry's voluntary agreement provide the third pillar of the Community strategy to reduce carbon dioxide (CO_2) emissions from cars (EU Commission, 1995). The voluntary agreement is designed to ensure that emissions drop to a level of 140 g CO_2/km by 2008, the remaining 20 g CO_2/km reduction to be achieved with the other two pillars of the Community strategy.

41. In 1998, following several years of negotiation, the European Automobile Manufacturers Association (ACEA – see box) voluntarily agreed to reduce average CO_2 emissions from new passenger cars to between 165 and 170 g CO_2/km by 2003 and to 140 g CO_2/km by 2008 (the latter representing a 25 per cent drop in fuel consumption compared with 1995). European carmakers also want to look at the potential for further CO_2 emission reductions to achieve a target of 120 g CO_2/km by 2012 (representing fuel consumption of 5.16 l/100 km for petrol and 4.56 l/100 km for diesel). All stated reductions are based on the average for M1 category passenger cars (defined in Annex I of Council Regulation 70/156/EEC) sold in the EU by ACEA member companies.

Automobile Associations

ACEA (Association des Constructeurs Européens d'Automobiles): BMW AG, DaimlerChrysler AG, Fiat S. p. A., Ford of Europe Inc., General Motors Europe AG, Porsche AG, PSA Peugeot Citroën, Renault SA, AB Volvo und Volkswagen AG.

KAMA (Korea Automobile Manufacturers Association): Daewoo Motor Co. Ltd., Hyundai Motor Company und Kia Motors Corporation.

JAMA (Japan Automobile Manufacturers Association): Daihatsu Motor Corporation Ltd., Fuji Heavy Industries Ltd. (Subaru), Honda Motor Corporation Ltd., Isuzu Motors Ltd., Mazda Motor Corporation, Nissan Motor Corporation Ltd., Mitsubishi Corporation, Suzuki Motor Corporation und Toyota Motor Corporation.

42. The ACEA made its commitments under the voluntary agreement subject to the following conditions:

- Availability of sufficiently high quality fuel to allow further advancements in engine technology. In response, the EU Commission in 2001 presented its proposal to amend Directive 98/70 (COM(2001)241), which resulted in 2003 in Directive 2003/17/EC amending Directive 98/70/EC relating to the quality of petrol and diesel fuels.
- Non-ACEA members, particularly those in Japan and Korea, should agree to the same commitments to avoid the European car industry being placed at a competitive disadvantage by imports. The EU Commission responded in 1998 by initiating similar voluntary agreements with the Korea Automobile Manufacturers Association and Japan Automobile Manufacturers Association (KAMA and JAMA – see box). As an interim target, JAMA agreed to average CO_2 emissions of between 165 and 170 g CO_2/km by 2003. Korean automobile manufacturers agreed to the same interim target for 2004. Both associations aim to reach a target of 140 g CO_2/km in 2009.
- EU-wide distribution of new vehicle technologies should be obstructed neither by fiscal nor other policy measures. Also, the ACEA retained the right to monitor economic trends and to adapt the reduction target should employment conditions become unfavourable or a distortion of competition occur.

The EU Commission responded by reserving the right to impose a binding legal framework should the ACEA fail to meet the 2008 emissions target or make no adequate progress towards achieving it. Details of the legal framework have not yet been announced.

43. To monitor trends involving both the commitments made under the voluntary agreement and the underlying assumptions, especially as regards economic trends, the EU Commission and the ACEA agreed that the findings of monitoring activities should be included in regular reports issued by the EU Commission. The key findings of the fourth annual report on the effectiveness of the Community strategy to reduce CO_2 emissions from cars (EU Commission, 2004b) for the period 1995 to 2002 include:

- Taking account of *all* measures adopted by the EU and its Member States, average specific CO_2 emissions from passenger cars in the EU dropped from 186 g CO_2/km to 166 g CO_2/km during the period 1995 to 2002. According to official data supplied by the Member States, average specific CO_2 emissions from passenger cars in 2002 amounted to 165 g CO_2/km among ACEA, 176 g CO_2/km among JAMA and 183 g CO_2/km among KAMA. According to ACEA's statistics, its members achieved specific CO_2 emissions of 163 g CO_2/km (see Table 3 for more details).
- Both JAMA and ACEA have made good progress, although ACEA's performance in 2002 was poorer than that in previous years. ACEA did, however, meet the interim target for 2003 back in 2000 (EU Commission, 2002a) and at 165 g CO_2/km is now at the lower end of the target range. JAMA achieved the interim target in 2002. KAMA's progress remains unsatisfactory despite it having caught up slightly in the past two years.
- To achieve the voluntary agreement target of 140 g CO_2/km, additional efforts are necessary as all three associations need to increase their average reductions. An average annual reduction of around 2 per cent or 3.5 g CO_2/km is needed over the period 1995 to 2008/9. As previous annual reduction rates have been significantly lower, abatement efforts must be stepped up throughout the remaining years if the 140 g CO_2/km target is to be achieved by 2008/9. Thus, in each of the remaining years up to 2008/9, ACEA needs to achieve an annual 2.5 per cent reduction, JAMA 2.8 per cent and KAMA 3.4 per cent (EU Commission, 2004b).
- Meeting the Community's more ambitious target of reducing specific CO_2 emissions to 120 g CO_2/km for newly registered passenger cars in the EU by 2010 would require achieving an average annual reduction of 3.5 per cent at EU level. This is significantly higher than what has been achieved on average between 1995 and 2002 (about 1.5 per cent). Both the ACEA and the EU Commission had anticipated that the reduction rate would increase over time but the EU Commission now believes that additional efforts have to be made in order to meet the target by 2010.

Evaluation

44. The German Advisory Council on the Environment has taken up the problems of voluntary agreements on a number of occasions, recommending a careful, if anything restrictive use of the instrument (SRU, 2004, Section 13; SRU, 2002a, Para. 446 ff; SRU, 1998, Para. 276 ff). In particular, the Council criticised the fact that an association's inability to place its members under obligation, and the ensuing free-rider problems, means that self-regulation at industry association level only allows the pursuit of very unambitious targets that rarely extend beyond business-as-usual. Further, the Council called for voluntary agreements to be supported by an effective sanctioning mechanism which would kick in if targets are not met. The European car industry's voluntary agreement contains serious weaknesses on both counts.

45. Although the ACEA is highly organised and has a comparably small number of members, this by no means eliminates the free-rider problem and its negative impacts on target achievement. On 30 April 2002, for example, the ACEA notified the EU Commission that Rover had left the association. While Rover then only had about a one per cent share of the passenger car market in the European Union (VDA, 2002), its departure from the ACEA could incite other carmakers to leave the association if they were to experience financial difficulties. Also, there is no explicit means of distributing the burden between ACEA members, meaning that each member company

Table 3

Average Specific CO_2 Emissions for Newly Registered Passenger Cars between 1995 and 2002 (CO_2 emissions in g/km)

ACEA	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001(3)**	**2002(3)**	**Change 95/02 (%)(4)**
Petrol vehicles	188	186	183	182	180	177	172	172/ 171(5)	– 8.5/ *– 9.0 %*(6)
Diesel vehicles	176	174	172	167	161	157	153	155/ 152(5)	– 11.9/ *– 13.6 %*(6)
All fuels(1)	**185**	**183**	**180**	**178**	**174**	**169**	**165**	**165/ 163(5)**	**– 10.8/ *– 12.1*(6)**
JAMA(2)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001(3)**	**2002(3)**	**Change 95/02 (%)(4)**
Petrol vehicles	191	187	184	184	181	177	174	172	*– 9.9 %*
Diesel vehicles	239	235	222	221	221	213	198	180	*– 24.7 %*
All fuels(1)	**196**	**193**	**188**	**189**	**187**	**183**	**178**	**174**	***– 11.2 %***
KAMA(2)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001(3)**	**2002(3)**	**Change 95/02 (%)(4)**
Petrol vehicles	195	197	201	198	189	185	179	178	*– 8.7 %*
Diesel vehicles	309	274	246	248	253	245	234	203	*– 34.3 %*
All fuels(1)	**197**	**199**	**203**	**202**	**194**	**191**	**187**	**183**	***– 7.1 %***
EU-15(2*)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001(3)**	**2002(3)**	**Change 95/02 (%)(4)**
Petrol vehicles	189	186	184	182	180	178	173	172	*– 9.0 %*
Diesel vehicles	179	178	175	171	165	163	156	157	*– 12.3 %*
All fuels(1)	**186**	**184**	**182**	**180**	**176**	**172**	**167**	**166**	***– 10.8 %***

(1) Petrol and diesel-fuelled vehicles only, other fuels and statistically unidentified vehicles are not expected to affect these averages significantly.
(2) Data for 2002 based on that from Member States. Data under Change 95/02: the 95 data came from the associations and the 2002 data from the Member States.
(2*) New passenger cars put on the EU market by manufacturers not covered by the commitments would not influence the EU average significantly.
(3) The figures for 2001 and 2002 are corrected by 0.7 per cent for the change in driving cycle.
(4) Percentages are calculated from unrounded CO_2 figures; data for 2002 from Member States.
(5) The first figure is based on data from Member States; the second figure is based on data from ACEA.
(6) The first figure is based on 2002 data from Member States and 1995 data from ACEA; the second figure is based solely on data from ACEA.
Source: after EU Commission, 2004b, p. 6

remains free to decide how much it contributes to achieving the commitment targets. What is essentially an entirely unguided process can hardly balance marginal abatement costs between the various carmakers and achieve the reduction at minimal cost. This would not seem an efficient solution (ZERLE, 2004, p. 76 ff). In this regard, criticism is also made of the fact that in their monitoring activities, neither the ACEA nor the EU Commission (contrary to its original announcement (EU Commission, 1998)) publish the reductions achieved by individual carmakers (KÅGESON, 2005). This conscious lack of transparency means that the environmental awareness shown by individual carmakers, and thus the reductions they achieve, cannot flow into consumers' purchasing decisions when choosing a new vehicle.

46. The voluntary agreement target falls far short of what is technically possible. From a technological perspective, it would be possible by 2010 to halve the average consumption levels of new vehicles registered in 1990. According to a study on fleet consumption in 2010, this halving could be achieved by saving some 60 per cent through purely technological measures and 40 per cent through a shift in market segments (passenger cars, off-road vehicles, vans, etc.) (MEHLIN et al., 2002). Other studies show that, using available technology, average fuel consumption could be reduced by between 40 and 50 per cent between the mid-1990s and 2010 (KEAY-BRIGHT, 2000).

The ACEA's voluntary agreement target lies somewhere in the range of the general consumption trends in the VDA fleet during the 1990s (ZERLE, 2004, p. 76 ff). It must be assumed, therefore, that the achieved reduction was sparked by existing incentives and that self-regulation effected no further reduction in fuel consumption. This means the voluntary agreement target set in 1998 was in the business-as-usual range. Even so, its attainment is by no means guaranteed. Achievement of the target is obstructed by recent trends towards vehicles with bigger engines and high-performance auxiliary equipment, which increase both vehicle weight and fuel consumption (ACEA and the Commission Services, 2003, p. 6; Arthur D. Little, 2003, see also Para. 12). While the ACEA itself acknowledges that technology is available to reduce CO_2, it points to the fact that carmakers are trying to serve the demand for bigger vehicles with higher fuel consumption. The number of European carmakers who produce high-consumption sport utility vehicles (SUVs) rose from two in 1995 to seven in 2004 (KÅGESON, 2005, p. 20 f). The underlying error in the voluntary agreement structure is that the very organisation required to fulfil the agreement – the ACEA – has only limited influence on how the 140 g CO_2/km target is achieved (ZERLE, 2004, p. 81 f). Firstly, the ACEA cannot dictate CO_2 emissions levels for vehicles produced by individual manufacturers. Secondly, it is ultimately the consumer who decides the average CO_2 output for passenger cars *sold* in the EU. Thus, compliance with the standards for passenger cars falls to the consumer – whereas the standards actually target the ACEA by virtue of its commitments under the voluntary agreement. Even if carmakers place a suitable passenger car fleet on the market, there would be no guarantee that consumers would actually buy only those vehicles that, in the aggregate, comply with the standards. Although technological practicability poses no problem and, from a technology perspective, the target lies within the business-as-usual range, significant reductions must still be achieved by 2008. Today's average annual reductions of 3 g CO_2/km (1.7 per cent) must be increased to 4 g CO_2/km (2.5 per cent) (EU Commission, 2004b). The voluntary agreement would, however, appear an unsuitable instrument to initiate such further reductions in fuel consumption. This is all the more so considering that self-regulation has only an indirect impact on consumer behaviour and thus on the composition of the passenger car fleet actually sold. Greater reductions to achieve the 2012 target of 120 g CO_2/km can therefore only be made using alternative instruments that eliminate the mismatch between those who the standards target and those who comply with them.

47. The voluntary agreement provided that in 2003 the situation would be reviewed as regards setting a more ambitious CO_2 reduction target of 120 g CO_2/km by 2012. In 2003, therefore, a study commissioned by the ACEA was published which looked at the impacts of a more ambitious CO_2 reduction target of 120 g CO_2/km by 2012 (Arthur D. Little, 2003). The study showed that a further 20 g CO_2/km reduction across the entire vehicle fleet to achieve 120 g CO_2/km emissions would incur average additional costs of €4,000 per vehicle. ACEA fears that additional per vehicle costs of that magnitude would lead to significant deterioration in European carmakers' competitiveness and thus to the loss of jobs and factory closures.

The German Advisory Council on the Environment believes that the obstacles to further CO_2 reduction cited by ACEA are inconclusive. The threat of competitive disadvantage brought about by more expensive vehicles with lower CO_2 emissions and thus lower fuel consumption levels would appear negligible for two main reasons. Firstly, as a result of their commitments, neither JAMA nor KAMA have any competitive advantage in the European market. In other markets such as the US, the engine capacities of the vehicles on sale are tailored to local demand. If the ACEA still sees a risk of unfair advantage being gained by specific carmakers engaging in free-rider tactics, then it should logically distance itself from the voluntary agreement and call instead for binding rules that apply to all carmakers. Secondly, in times of continuously high fuel prices, fuel-efficient vehicles with low CO_2 emissions actually have a competitive advantage over high consumption vehicles.

The calculations used in the Arthur D. Little (2003) study, which identified additional average costs of €4,000 per vehicle to achieve the 120 g CO_2/km target, assumed abatement costs of initially €50/t CO_2 rising to €900/t CO_2. In the joint study conducted by EUCAR (European Council for Automotive Research and Development), CONCAWE (Conservation of Clear Air and Water in Western Europe) and the Joint Research Centre of the EU Commission, abatement costs of between €200/t CO_2 and

€400/t CO_2 were identified for conventional technologies (CONCAWE et al., 2004). Thus, the additional costs probably lie far below the €4,000 per vehicle cited by ACEA. To allow for these differing abatement costs, including from an efficiency standpoint compared with other CO_2-emitting sectors, CO_2 emissions from motorised personal transport should be regulated in a uniform, Europe-wide CO_2 emissions trading scheme (MICHAELIS, 2004).

4.2 Emissions Trading

48. Given that road transport causes more than 20 per cent of CO_2 emissions in the European Union and has the greatest growth rates among all emitting sectors (EU Commission, 2002b), it would seem wise in terms of both efficiency and effectiveness to integrate it either directly or indirectly into emissions trading. Literature published since the early 1980s has contained numerous suggestions along these lines (for an overview see JUNKERNHEINRICH, 1998) which can be broken down into three categories: systems targeting car owners, the fuel trade and carmakers.

49. An emissions trading scheme that targets car owners directly would award them an annual fuel contingent or CO_2 emission allowance and permit them to freely trade their excess quantities. However, with around 30 million car owners in Germany, considerable transaction costs would be incurred (DEUBER, 2002, p. 53; KNIESTEDT, 1999, p. 156 ff) and finding the right allocation format would prove highly difficult. Furthermore, detractors would find it easy to discredit the scheme by drawing similarities with war-time rationing, which would severely affect public acceptance. Emissions trading schemes that directly target car owners are therefore excluded from the subsequent appraisal.

50. The choice between the two remaining approaches – the fuel trade and carmakers – must first consider that CO_2 emissions from road transport are largely dependent on two factors: driving habits and the energy efficiency of the vehicles in use. Any strategy to reduce CO_2 emissions in road transport should ideally take account of both factors to achieve a holistic management approach. It is thus necessary to use a combination of instruments that influence the behaviour of car users and that of carmakers.

51. An emissions trading scheme that targets the first tier of the fuel market (fuel-based approach), as recently recommended by BERGMANN et al. (2005), would be beneficial in terms of transaction costs but would only result in higher fuel prices because the costs would be passed on to the consumer (car owners). Policymakers could neither justify dual taxation on fuel that results from ecotax legislation on the one hand and an emissions trading scheme on the other, nor would it be accepted by the consumer. An emissions trading scheme that targets the fuel trade would not, therefore, supplement ecotax levied on fuel but actually replace it – although its impact would be no greater than that already achieved with ecotax. The only benefit compared with the existing ecotax system would be that a fuel-based emissions trading scheme would ensure more accurate achievement of the emissions target proposed for road transport. There would, however, be no direct incentive for carmakers to improve energy efficiency in their vehicles. All that would happen is that, as with the ecotax system, higher fuel prices would entice car owners to switch to low-consumption vehicles – although an indirect impact of this nature would not provide sufficient incentive for carmakers to enhance energy efficiency in the vehicles they produce (HOHENSTEIN et al., 2002, p. 31; DEUBER, 2002, p. 53). This is due both to the comparably low price elasticity in fuel sales (see Para. 38 f) and the fact that specific fuel consumption is only one of many factors that influence consumers' purchasing decisions. A number of these other factors, like safety and prestige, actually make for heavier vehicles and more powerful engines, which in turn mean higher fuel consumption. This is supported by a recent survey conducted by Deutsche Automobil Treuhand (2004, p. 42) which shows that despite strong increases in fuel prices, only 10 per cent of car owners say their next car will have a smaller engine while 29 per cent say they want a more powerful car next time around. In consequence, an emissions trading scheme that takes a fuel-based approach would not be sufficient to fully exploit the potential for enhanced energy efficiency offered by available vehicle technology. Compared with the existing ecotax system, a fuel-based emissions trading scheme would offer no real advantage aside from target accuracy.

52. A third possibility for emissions trading in the transport sector, and one the Dutch environment ministry recently brought into the political debate at EU level (Ends Daily, 17.09.2004), involves targeting carmakers. The 'carmaker approach' entails approving CO_2 emissions for vehicles placed on the EU market within a given trading period. This would guarantee a prescribed percentage reduction in aggregate annual fleet emissions across all carmakers – and the tradability of emissions rights would ensure that emissions and consumption are cut by those carmakers who can effect a reduction at the lowest cost.

In contrast to the fuel-based approach outlined above, the carmaker approach is not an alternative but rather a supplement to the ecotax system. In a combination of the two instruments, the ecotax would directly target drivers and influence their driving habits, while the emissions trading scheme would target carmakers and influence specific fuel consumption or specific CO_2 emissions from vehicles. Given its broad effectiveness, the German Advisory Council on the Environment sees this combination of instruments as preferable to replacing (or supplementing) the ecotax system with an emissions trading scheme along the lines of the fuel-based approach. The Council is aware, however, that when matched against the fuel-based approach, the carmaker approach provides for less accurate target achievement in terms of the actual emissions produced (Para. 58) and could result in higher transaction costs. These disadvantages would appear acceptable, however, given that the carmaker approach would provide direct incentives to develop low-consumption cars and thus offer greater innovative potential, while the fuel-based approach would merely replicate the effects achieved with the existing ecotax system. Added to this is the fact that the criterion of accuracy in target attainment should not be over-valued, especially in the light of experience with EU-wide emissions trading between large emitters in the stationary sector (SRU, 2004). Accurate achievement of an emissions target that was anyway set in a somewhat questionable manner at policy level can hardly be considered as the key criterion for selection of an environmental policy instrument.

53. Compared with the car industry's existing voluntary agreement, an emissions trading scheme that targets CO_2 emissions from cars has two key advantages when it comes to environmental effectiveness and economic efficiency:

- As outlined in Section 4.1, the car industry's commitments under the voluntary agreement are linked to numerous clauses and conditions so that a softening or withdrawal of the agreed targets is certainly possible. In contrast, the strict quantity limits laid down in an emissions trading scheme would provide more transparency and greater stability in the longer term, and thus foster innovation among the carmakers involved.
- Section 4.1 also points out that under the current voluntary agreement, distribution of the burden among individual carmakers goes largely unaddressed. This provides little hope of the agreement being an efficient solution. By way of contrast, emissions trading would ensure that the required reduction in specific CO_2 emissions is distributed across the various carmakers in such a way as to minimise the costs overall.

54. Apart from obtaining emissions credits, the car industry can essentially choose between three main adaptation strategies that can be used either individually or in combination (with regard to the following, see DEUBER, 2002, p. 84 ff): development of new technologies to reduce specific CO_2 emissions, restructuring of available product ranges towards smaller and thus low-emission vehicles (downsizing), and marketing activities to promote the sale of such low-emission vehicles. Contrary to what might be assumed at first glance, the latter of these three strategies actually promises greater impact over time. This is because current consumer attitudes towards motorised personal transport are largely shaped by carmakers' marketing strategies. If carmakers were to change their strategies to place greater importance on environmental needs they could, especially when combined with the introduction of speed limits on German motorways as called for by the German Advisory Council on the Environment (see SRU, 2005, Section 9.3), make a significant contribution towards discouraging the obsession with horsepower so predominant among sections of the population.

55. A large number of detail issues would need to be addressed before introducing an emissions trading scheme that targets CO_2 emissions from the car industry's fleet. Nevertheless, the groundwork already done – which in some areas is already substantial – can be used as a base on which to build future activities (particularly DEUBER, 2002; HOHENSTEIN et al., 2002; KNIESTEDT, 1999). The main issues involved relate to the type of vehicles to be included in the emissions trading scheme, the choice of measurement base, setting fleet emissions standards for individual carmakers (including the tightening of those standards over time), the possibility of linking up with sectoralised emissions trading between large stationary emitters under the EU directive, and interactions with other environmental policy instruments. Given the experience gained in implementing the EU directive on emissions trading, attention must also be paid to whether such a system is politically feasible.

Vehicle types

56. With regard to vehicle types, it must be decided whether the emissions trading scheme should cover not just passenger cars but also commercial vehicles. Other than in the passenger car sector, the purchase of commercial vehicles is dominated by economic considerations such as fuel consumption and the availability of a Europe-wide service network. It can thus be assumed that rising fuel prices alone will trigger a significant response towards greater energy efficiency in the commercial vehicle sector (e.g. ALBRECHT, 2000, p. 397). Also, the commercial vehicle sector has only limited room for improved energy efficiency when compared to the passenger car sector. This is largely due to the fact that, other than with passenger cars, reduced vehicle weight effects only minimal savings because the weight of the freight to be transported is the dominant factor (ALBRECHT, 2000, p. 397). The scope for improved energy efficiency in road-freight transport as reported in the literature (LEONARDI et al., 2004) relates not to consumption characteristics in commercial vehicles but to improvements in logistics. It would thus appear appropriate, for purely practical reasons, to initially restrict emissions trading to passenger cars. The inclusion of commercial vehicles should be considered in the longer term, however.

Choice of measurement base

57. The types of emissions trading schemes reported in the literature provide for a baseline and credit system in which the various carmakers are required to meet a fleet emissions standard (derived from historical data) for CO_2 emissions from vehicles placed on the EU market within a given trading period. If carmakers undercut their fleet emissions standard, they receive emissions credits to match the remaining amount. If carmakers exceed their standards, they must obtain emissions allowances to cover the excess. Either the specific or (estimated) absolute CO_2 emissions from the vehicles could serve as the measurement base. In the first case, a specific g CO_2/km target is set which average emissions of all vehicles placed on the market within the trading period must comply with. If this average target is undercut, the CO_2 savings achieved are calculated based on estimated total mileage and the carmaker is then allocated emissions credits in the respective amount. If they exceed the threshold, carmakers must obtain emission allowances to make up the excess. The critical factor in this approach is that it allows no restriction to be placed on absolute emission quantities which means that, if the number of people with cars or using cars increases, absolute CO_2 emissions could rise despite specific emissions being reduced and the overall distance travelled remaining constant. This could be counteracted by the fact that passenger car markets in Germany and similar EU countries are more or less saturated. This does not apply to the EU as a whole, however, as there is still probably significant pent-up demand both in the new EU Member States and the accession states.

58. Given the problems outlined above, the German Advisory Council on the Environment favours a system in which absolute CO_2 emissions serve as the measurement basis. In this case, individual carmakers would be told when receiving their fleet emissions standards what quantities of CO_2 the vehicles they place on the EU market within the trading period may emit during their projected lifecycle. To calculate the CO_2 emissions put out by a vehicle during its lifecycle, the respective specific g CO_2/km emissions target is multiplied by the estimated total mileage. DEUBER (2002) suggests basing the calculation on a fixed lifetime mileage of 200,000 km. To minimise any deviations between CO_2 emissions calculated in this way and actual CO_2 emissions during a vehicle's lifecycle, it would make sense to establish different size classes with assumed overall mileage because bigger-engined vehicles achieve significantly higher mileage during their lifecycle than those with smaller engines. A distinction would also need to be made between vehicles with petrol engines and those that run on diesel.

When measuring specific emissions, attention must be paid to the fact that both fuel consumption in and CO_2 emissions from passenger cars are currently measured under EU Directive 93/116/EEC by a method that does not take account of the impacts of high-performance auxiliary equipment (e.g. air conditioning) and thus results in specific CO_2 emissions being underestimated. The transaction costs involved in switching to more realistic measuring requirements cannot, however, be apportioned to the proposed emissions trading scheme because, for the reasons outlined above, current measurement requirements are anyway in urgent need of revision.

If absolute CO_2 emissions are taken as the basis in the manner outlined above, the result would be that carmakers who increase their sales must compensate for the increase either through additional reductions in specific CO_2 emissions or by buying extra emission allowances. This could indirectly restrict passenger car sales overall and could be problematical given the economic importance of this sector. As will be explained below (Para. 61), however, even with a system based on absolute CO_2 emissions, a restrictive effect on overall passenger car sales can be avoided if emissions trading between carmakers is linked to the sectoralised emissions trading scheme between large stationary emitters under the EU directive.

59. One particular problem in the choice of measurement base that had not been considered in the groundwork already done (DEUBER, 2002; HOHENSTEIN et al., 2002; KNIESTEDT, 1999) involves the treatment of alternative engine types in which, other than with conventional petrol and diesel engines, CO_2 emissions are either wholly or partly relocated to upstream production phases. This means vehicles that are fuelled by natural gas or run on electric motors and, in the longer term, those powered by a combination of hydrogen and fuel cell technology. If the threshold for such vehicles was based solely on emissions from the engine it would pose an unfair advantage and, to a certain degree, would hinder further development of conventional petrol and diesel engines. To prevent any distortion of this kind, it would appear appropriate for targets to be set by adding a fixed additional amount to the CO_2 emissions put out by the engine itself. The fixed additional amount to be applied in each case would need to be further defined in environmental impact assessments or well-to-tank analyses (see SRU, 2005, Section 7.4).

Setting fleet emissions standards

60. A further choice involves the basis on which to set fleet emissions standards for individual carmakers. This resembles the problem of initial free allocation under a classic trade regime (cap and trade) in which emitters must hold appropriate emissions permits for each type of pollutant emitted (HEISTER et al., 1990, p. 104 ff). As with such a system, a similar problem emerges on the question as to what fleet emission standards to allocate to carmakers as a no-charge baseline. To prevent adjustment problems and rule out the possibility of manipulation when introducing the system of fleet emissions, and to take account of potential annual fluctuations in product ranges and sales, standards should be based on the average fleet emissions from vehicles placed on the market in the last three years prior to the system being introduced (similarly KNIESTEDT, 1999, p. 179). In the case of new carmakers entering the market for whom no historical data is available, fleet emissions standards would need to be based on 'available technology' (DEUBER, 2002, p. 74).

Once the system is in place, fleet emissions standards can be reduced annually by a given percentage and over a prescribed timeline. A percentage reduction would mean carmakers who produce larger vehicles must go to greater lengths to reduce emissions in absolute terms than those who produce smaller vehicles. This would appear justified, however, given that larger vehicles offer the greatest reduction potential (JORDAN-JOERGENSEN et al., 2002, p. 62).

The percentage by which fleet emissions standards are reduced each year should be tangibly above the business-as-usual reduction rate that results from the car industry's current commitments under the voluntary agreement. In light of the reduction potentials outlined in Section 3.1, an annual reduction of 6 per cent would appear both appropriate and acceptable. Assuming that vehicle sales remain stable, an annual six per cent reduction would mean that the average specific CO_2 emissions from the entire fleet placed on the market in a given trading year must be reduced to around 100 g CO_2/km by 2012.

Linking to the EU Emissions Trading Scheme

61. Linking the two systems would allow free transfer of emission allowances between large stationary emitters participating in the EU Emissions Trading Scheme and carmakers. If the marginal costs of CO_2 reduction in the car industry were higher than those in the electricity sector, emission allowances could be transferred from large stationary emitters to carmakers. This would balance the marginal abatement costs under the two trading systems and so achieve the required emissions reduction at minimal cost. This cross-sectoral optimisation of reduction effort would lessen the burden both on market participants and on the economy without requiring concessions on the desired reduction target (HOHENSTEIN et al., 2002, p. 107).

An additional, although less significant, advantage to be had from linking the two emissions trading systems is that, due to the high degree of concentration in the car industry (WEISS, 2000), isolated emissions trading between carmakers alone would make for a comparably 'narrow' market and thus give rise to the (albeit remote) danger that individual carmakers might be prompted to engage in strategic hamstering of emission allowances. If this were to happen, the reduction target would still be achieved but the efficiency of the system would be lost. Linking the two emissions trading systems would make for a sufficiently bigger emission allowances market and dispense with any problems as regards potential market dominance by individual players.

62. Linking the two emissions trading systems also has disadvantages, particularly as regards accurate achievement of the emissions target. CO_2 emissions from the respective vehicle fleets can only be projected based on the levels of specific emissions and expected overall mileage during vehicle lifecycles. There thus appears an urgent need not, as recommended in the literature, to base the calculation on a fixed total mileage across all vehicle groups but, as recommended earlier in this report, to distinguish between size classes and other appropriate vehicle characteristics. Further, the risk of potential deviations from the target should not be overestimated because it can be assumed that in practice, the projected emissions will in some cases be either above and or below actual CO_2 emissions. This means that up to a certain level the deviations will cancel each other out. The remaining negligible deviations from target would appear acceptable given the advantages to be gained from linking the two emissions trading systems.

Interaction with other instruments

63. As already emphasised, the emissions trading system for CO_2 emissions from cars should be embedded in a mix of economic instruments that include changing the vehicle taxation system over to a CO_2-focused tax base and additional phased increases in the ecotax levied on fuels. A range of interactions can be expected which will enhance the effectiveness of this instrument mix.

Of particular importance is the potential rebound effect from increased energy efficiency in vehicles. Where the restriction of fleet emissions results in a drop in specific CO_2 emissions from cars placed on the market, car users would have the incentive to travel greater distances because, assuming constant fuel prices, the price of fuel per kilometre would be reduced. With (long term) price elasticity of –0.6 (see Para. 38), a ten per cent increase in energy efficiency would lead to a six per cent increase in mileage. To prevent this rebound effect, the emissions trading system outlined earlier must be supported by additional phased increases in fuel tax as part of ecotax reforms. To prevent a distortion of competition in the Single Market, such increases should be implemented not at national but at European level (see SRU, 2005, Section 9.3.1).

Consideration must also be given to the fact that energy efficiency in the vehicles placed on the market is not only determined by supply but also by demand. Thus, all efforts within the car industry to produce low-CO_2 vehicles would be negated if consumers were not prepared to buy them. Assuming that costs are passed on in full, emissions trading would tend to result in vehicles with high CO_2 emissions becoming more expensive, but this would not be sufficient in itself to spark the required demand response from consumers (see box below for sample calculation). For this reason, it would appear sensible to support sales of low-CO_2 vehicles with demand-side measures. As outlined earlier, the opportunities for measures that involve increased fuel prices are extremely limited. Thus, an emissions trading scheme that targets carmakers should be supported by a CO_2-based vehicle taxation system as addressed in more detail in the following section.

Sample Calculation
Costs Incurred by a Carmaker in Emissions Trading

The calculation is based on the assumption that to comply with fleet emissions standards, a carmaker must achieve average specific emissions of 120 g CO_2/km across all vehicles it places on the market. This would mean that the carmaker would have a CO_2 deficit of 24 t CO_2 per unit sold for large-engined vehicles in the upper price segment with specific emissions of 240 g CO_2/km and an assumed overall mileage of 200,000 km. Where the deficit cannot be balanced by another vehicle in the product range, the carmaker must purchase emission allowances to cover the difference. At an estimated emissions permit price of around €8/t CO_2, this results in additional costs per vehicle of about €212. In the upper price segment, passing on those costs would not significantly affect demand.

Political acceptability

64. As was made clear by the implementation of the EU Emissions Trading Scheme and particularly the issues surrounding the National Allocation Plan (SRU, 2004), emissions trading schemes by virtue of their complexity run the risk of becoming so disfigured during the policymaking process that, in the end, their effectiveness is called into question. The German Advisory Council on the Environment is, of course, aware that the emissions trading model described above runs the same risk. However, complex problems sometimes call for complex answers, and these should not be blocked from the outset with an eye to the policymaking process. Also, the discussion contained in the previous section makes it very clear that a reduction in transport-related CO_2 emissions to the required level is hardly possible without measures that target the car industry. Unless, of course, a huge increase in real fuel prices – which have to date remained largely stable – is seen as a realistic alternative (SRU, 2005, Section 3.2.1). Because, as already outlined, the European car industry's voluntary agreement is not effective, the only alternative to an emissions trading scheme is to prescribe binding fleet consumption standards like those introduced for climate protection purposes in Japan and California. The top runner approach in Japan prescribes fleet consumption standards for passenger cars in differing weight classes; these are based on the most energy efficient vehicle in each of the weight classes and must be achieved by 2010 (see ECCJ, undated). The approach also sparks competitive innovation among carmakers. However, compared with emissions trading as outlined above, the less-flexible top runner approach involves considerably higher costs, both for businesses and for national economies. In particular, it does not allow carmakers to comply, at least in part, with prescribed emissions standards by purchasing emission allowances from the EU Emissions Trading Scheme for large stationary emitters. The political acceptability of the emissions trading model is thus primarily dependent on how well its benefits compared with the only remaining alternative of non-tradable standards are communicated to the car industry.

4.3 CO_2-Based Vehicle Taxation

65. In the German government's coalition agreement for the electoral period 2002–2006, the governing parties agreed to further environmental reforms of vehicle taxation and to using CO_2 emissions as the basis for those reforms. The existing vehicle tax was restructured on 1 July 1997 to be based on vehicle emissions and has since been adjusted a number of times to accommodate technological advancements. This has resulted in a continuous increase in the share of low-emission passenger cars among new registrations. In 2001, more than 90 per cent of newly registered passenger cars complied with the Euro 3 and Euro 4 standards; by the 1 January 2002 deadline, some 21.9 per cent of vehicles in the entire vehicle fleet complied with the Euro 3/D3 standards and 9.6 per cent with the more stringent Euro 4 standard (KBA, 2003, 2002). Due to the many other factors involved, this trend cannot be apportioned to vehicle taxation alone. Nevertheless, it provides an impressive illustration of the potential that vehicle taxation harbours for independent control – potential that should continue to be tapped in future. Considerations along the lines of abolishing vehicle taxation altogether and transferring it to tax levied on petroleum products, as called for by the German Federal Environment Ministry (BMU, 2003b), are therefore misguided despite the associated simplification in administration. Other than with fuel tax, vehicle tax allows for differentiation according to technical characteristics of the vehicles concerned and for a progressive tax rate structure (JORDAN-JOERGENSEN et al., 2002, p. 113). It is even possible to levy vehicle tax in advance over a substantial time frame, thus enhancing its control effect even further (Para. 69). Given these options, vehicle taxation offers control potential that extends beyond that of fuel taxation and should not be given up without good reason. In any case, transferring vehicle tax to fuel tax would significantly distort the fiscal balance between the federal and Länder governments because vehicle tax is picked up by the Länder while fuel tax goes into the federal government's budget.

66. In a European comparison, significant differences are evident in how passenger cars are taxed. The EU Commission sees a need for harmonisation (see KUHFELD and KUNERT, 2002). Following the EU Commission's Communication of September 2002 on Taxation of Passenger Cars in the European Union (EU Commission, 2002c), harmonisation should also be used under the Community Strategy to Reduce CO_2 Emissions from Passenger Cars (EU Commission, 1995) to standardise the basis on which national vehicle tax is levied and place the focus on specific CO_2 emissions.

For Germany, this would mean that vehicle tax would no longer be based on engine capacity but on specific CO_2 emissions. Provided that vehicle tax can also be based on additional pollutants in the future, this approach is to be welcomed in principle. As shown elsewhere in this report, it cannot be assumed that fuel prices alone will provide consumers with sufficient incentive to switch to more fuel-efficient vehicles.

67. One possible argument against CO_2-based vehicle tax is that the current engine capacity-based system already takes adequate account of CO_2 emissions. This is not the case, however, because specific fuel consumption and thus CO_2 emissions from vehicles are not only determined by engine capacity but to a large extent by engine technology and fuel type, by vehicle weight and by rolling and air resistance (see Section 3). Specific CO_2 emissions can thus differ by as much as 50 per cent in vehicles with the same engine capacity (RAUH et al., 2001, p. 33). For this reason, a simulation study conducted by the Gesellschaft für Wirtschaftliche Strukturforschung (2004) found that a restructuring of the vehicle taxation system would result in greater demand for vehicles with lower average fuel consumption.

68. To enhance the control effect of CO_2-based vehicle tax in reforms calculated to have no net impact on total tax revenue, the German Advisory Council on the Environment recommends use of a progressively increasing tax rate (JORDAN-JOERGENSEN et al., 2002, p. 86 f). The resulting price signal could thus be made appreciably stronger for vehicles with big engines without burdening small or medium-sized vehicles to any great extent; this would significantly increase acceptance of a CO_2-based vehicle tax system. This type of progressive approach can also be justified with reference to the fact that large-engined vehicles usually achieve far greater mileage – an aspect that would be ignored with a linear tax increase.

One argument that might be brought against a progressively increasing tax rate is that company cars would be over-burdened because they usually have much bigger engines than private vehicles (JORDAN-JOERGENSEN et al., 2002, p. 48). What must be considered, however, is that company cars – which are already subject to lower tax rates upon purchase – are usually sold on to the private sector after a period of between two and four years. This means that in the medium-term, business purchasing decisions have a significant impact on the composition of the private vehicle fleet. A correspondingly strong control effect is thus needed in the company car sector.

69. The control effect of CO_2-based vehicle tax could be further enhanced by making vehicle tax payable for several years in advance at the time a new vehicle is registered. Setting the actual prepayment period, however, involves a target-setting conflict. The longer the period, the stronger the price signal and so the lower the level of acceptance by the drivers affected. Also, a longer prepayment period would make it difficult for people in lower income groups to switch to a new (usually more fuel-efficient) vehicle unless carmakers aligned their financing terms to the new conditions. The German Advisory Council on the Environment thus recommends striking the happy medium, making vehicle tax payable in advance for the first four years in which a new vehicle is used. From the fifth year, vehicle tax would be levied annually as is currently the case. If a vehicle is taken off the road permanently before the end of the four-year period, the vehicle owner would receive a tax refund in the respective amount.

70. The German Advisory Council on the Environment also recommends that, as a supporting measure, the Ordinance on Affixing Fuel Consumption Labels to Passenger Cars (PKW-EnVKV, Federal Gazette 2004 Part I, p. 1037) be amended to include a provision whereby car suppliers must not only indicate fuel consumption and CO_2 emissions, but also the applicable vehicle tax rate.

71. Restructuring the current engine capacity-based vehicle taxation system to one that focuses on CO_2 emissions would tend to give diesel vehicles an advantage due to their lower fuel consumption and thus lower emission levels. This would result in an increased number of diesel vehicles in the vehicle fleet overall. In this regard, the German Advisory Council on the Environment sees a need to reiterate its call for an ecotax structure that is based on CO_2 emissions and distinguishes between petrol and diesel fuels (SRU, 2005, Section 9.3.1).

72. As outlined earlier, to continue to provide an incentive to reduce other harmful emissions, it should still be possible even after a CO_2-based vehicle tax system has been put in place to set the tax rate in line with other emissions factors independent of the respective CO_2 emission levels. With regard to motorcycles, the Council recommends using such flexibility to introduce an additional distinction according to a vehicle's noise emissions. Motorcycle inspections would then have to ensure, however, that the vehicle's noise emissions are not manipulated after the fact.

5 Recommendations

73. With improved technology for conventional engines it is already possible to reduce current average fuel consumption by over 40 per cent for newly registered passenger cars with petrol engines and by up to 40 per cent for those with diesel engines. This would cut average specific CO_2 emissions from newly registered passenger cars to around 100 g/km. The main technical options include improved engine technology, engine performance within an optimal range through downsizing and improved gearbox spacing, optimal energy management, hybridisation, and reduced vehicle weight and rolling resistance. Measures to change both consumer behaviour and driving habits also play a key role.

Although alternative fuels like biomass and hydrogen are expected to offer significant scope for reductions, at least in the longer term, their potential remains limited for the time being and their abatement costs are relatively high. The German Advisory Council on the Environment thus considers that the priority should be on further exploiting the technological potential to reduce CO_2 emissions from vehicles with conventional engines. As an interim measure, average specific CO_2 emissions from newly registered passenger vehicles could be reduced by introducing an emissions trading scheme that requires carmakers to cut CO_2 emissions to 100 g CO_2/km by 2012; additional, longer-term targets could be set to achieve even greater reductions. It is foreseeable that even in the medium run, consumption-optimised vehicles with combustion engines will remain both cheaper than fuel cell vehicles and at least level with them in environmental terms. At present, the use of fuel cells for energy in the vehicle sector is neither technologically nor economically ready for the market.

74. While the ACEA's commitments under the voluntary agreement represent an environmental advance in principle, they leave much to be desired in some respects. In particular, the targets fall far short of what is technically possible. One problem as regards self-regulation at industry association level involves the association's inability to place its members under obligation. Up to now, there has been no regulatory framework to allow sanctions to be put in place if targets are not met. This violates the EU Commission's guidelines for the voluntary agreements on the one hand, while on the other the car industry has made its commitments subject to a range of conditions that make unilateral modification or even termination of the agreement a possibility. Nor is there any explicit distribution of the burden among individual carmakers, which makes it impossible to efficiently allocate individual reductions so as to achieve the overall targets.

While these deficits could be partly remedied through modification, some of the problems cannot be resolved because they are inherent in the voluntary agreement itself. The voluntary agreement should not, therefore, be renewed at the end of its current term in 2008. Rather, an EU-wide emissions trading system for carmakers should be introduced. As an alternative, maximum consumption standards could be considered such as those introduced for climate protection purposes in Japan and California.

75. To integrate the transport sector into the emissions trading scheme, an approach should be chosen that sets out for each individual carmaker the levels of CO_2 allowed during the entire lifecycles of vehicles placed on the market in each trading period. If a carmaker undercuts its fleet emissions standard, it can sell its spare or excess emission allowances. If it exceeds it, it must purchase additional emission allowances in the respective amount. In this way, the aggregate annual fleet emissions across all carmakers could be reduced by a prescribed percentage, while tradability of emission allowances would ensure that both emissions and consumption are reduced by those carmakers who can achieve the reductions at the lowest cost. Compared with the current voluntary agreement, this would not only mean increased efficiency but would make for more transparency and a more stable operating environment over time. It would also foster innovation on the part of the carmakers involved. Linking the system to the EU Emissions Trading Scheme would additionally ensure cross-sectoral optimisation of prevention measures.

76. An emissions trading system that focuses on fleet emissions should be supported by demand-side measures, because all efforts made by the car industry to provide low-CO_2 vehicles would be in vain if consumers were not prepared to actually buy them. Simply increasing fuel prices would not provide the necessary incentive due to the low price elasticity of demand. Added to this is the fact that when it comes to passenger cars, consumers' purchasing decisions are not based on fuel consumption alone, but on a range of factors, some of which actually lead to greater vehicle weight, more powerful engines and higher fuel consumption. For this reason – as also pointed out by the EU Commission – a reform of the vehicle taxation structure is recommended to improve take-up of low-CO_2 vehicles.

The restructuring of vehicle taxation in 1997 to a system based, at least in part, on vehicle emissions resulted in continuous growth in the number of low-emission passenger cars on the roads. This trend shows that vehicle tax offers a high degree of control potential compared with fuel tax – this potential should continue to be tapped in future. Transferring vehicle tax to fuel tax would not be the right approach. Instead, and in line with the EU Commission's proposals, engine capacity-based vehicle tax should be restructured to be based on specific CO_2 emissions while retaining the existing distinction between emissions classes. To further enhance the control effect of vehicle tax, it should be levied in advance for a period of four years at the time a new vehicle is registered and be progressively increased thereafter. Vehicle taxation in this form would send out a much stronger price signal, particularly as regards big-engined vehicles, without burdening small or middle-class vehicles to any great extent.

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Ministry of the Environment, Nature Conservation and Nuclear Safety

Charter Establishing an Advisory Council on the Environment at the Ministry of the Environment, Nature Conservation and Nuclear Safety

1 March 2005

Article 1

The Advisory Council on the Environment has been established to periodically assess the environmental situation and environmental conditions in the Federal Republic of Germany and to facilitate opinion formation in all government ministries, departments and offices that have jurisdiction over the environment, and in the general public.

Article 2

(1) The Advisory Council on the Environment shall comprise seven members who have special scientific knowledge and experience with respect to environmental protection.

(2) The members of the Advisory Council on the Environment shall not be members of the government, a legislative body of the government or the civil service of the Federal Government, state governments or of any another public entity, universities and scientific institutes excepted. Further, they shall not represent any trade association, or employers' or employees' association, nor shall they be in the permanent employ of or party to any non-gratuitous contract or agreement with any such association, nor shall they have done so in the 12 months prior to their appointment to the Advisory Council on the Environment.

Article 3

The task with which the Advisory Council on the Environment is charged shall be to describe the current environmental situation and environmental trends, and to point out environmentally related problems and suggest possible ways and means of preventing or correcting them.

Article 4

The Advisory Council on the Environment is charged exclusively with the mission stated in this charter and may determine its activities independently.

Article 5

The Advisory Council on the Environment shall provide the federal ministries whose area of competence is involved, or their representatives, the opportunity to comment on important issues that emerge as a result of the Council's performing its task, and to do so before the Council publishes it reports on these issues.

Article 6

The Advisory Council on the Environment may arrange hearings for federal offices and *Länder* offices concerning particular issues, as well as invite the opinions of non-governmentally affiliated experts, particularly those who represent business and environmental associations.

Article 7

(1) The Advisory Council on the Environment shall draw up a report every four years, to be submitted to the Federal Government in May. The report is to be published by the Council.

(2) The Advisory Council on the Environment may make additional reports or statements on particular issues. The Federal Ministry of the Environment, Nature Conservation and Nuclear Safety may commission the Council to make further reports and statements. The Council is to submit the reports and statements mentioned in clauses (1) and (2) of this article to the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety.

Article 8

(1) Upon approval by the Federal Cabinet, the members of the Advisory Council on the Environment shall be appointed by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety for the period of four years. Equal participation of women and men shall be aimed for as provided for in the law governing appointments to federal bodies (the *Bundesgremienbesetzungsgesetz*). Reappointment shall be possible.

(2) The members of the Council may give written notice to resign from the Council to the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety at any time.

(3) Should a member of the Council resign before serving the full four-year period, a new member shall be appointed for the remaining period. Reappointment shall be possible.

Article 9

(1) The Advisory Council on the Environment shall elect, by secret ballot, a chairperson who shall serve for a period of four years. Re-election shall be possible.

(2) The Advisory Council on the Environment shall set its own agenda, which shall be subject to approval by the Federal Minister of the Environment, Nature Conservation and Nuclear Safety.

(3) Should a minority of the members of the Council be of a different opinion from the majority of the members when preparing a report, they are to be given an opportunity to express this opinion in the report.

Article 10

The Advisory Council on the Environment shall be provided with a secretariat to assist it in the performance of its work.

Article 11

The members of the Advisory Council on the Environment and its secretariat are sworn to secrecy as concerns the Council's advisory activities and any advisory documents that it classifies as confidential, and as concerns any information given to the Council that is classified as confidential.

Article 12

(1) The members of the Advisory Council on the Environment are to be paid a lump-sum compensation and to be reimbursed for their travel expenses. The amount of compensation and reimbursement shall be determined by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, with the consent of the Federal Ministry of the Interior and the Federal Minister of Finances.

(2) The financial funding for the Advisory Council on the Environment shall be provided by the Federal Government.

Article 13

To accommodate the new date of submission to the Federal Government under Article 7 (1), the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety may extend the appointments of the Council members in office when this Charter enters into force to 30 June 2008 without requiring the approval of the Federal Cabinet.

Article 14

The Charter Establishing an Advisory Council on the Environment at the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (GMBl. 1990, no. 32, p. 831), issued on 10 August 1990, is superseded by this charter.

Berlin, 1 March 2005

G I 1 – 46010/2

The Federal Minister of the Environment, Nature Conservation and Nuclear Safety

Jürgen Trittin

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Reports and statements prepared by the German Advisory Council on the Environment

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Bundestag publications (Bundestagsdrucksachen) are available from Bundesanzeiger Verlagsgesellschaft mbH, Postfach 100534, 50445 Köln, Germany (www.bundesanzeiger.de).

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*) = a summary is available in English, **) = a summary is available in French

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