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Reducing CO_2 emissions in the transport sector

A status report by the Federal Environmental Agency

- A description of measures and update of potentials -

September 2003

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Abbreviations

A...G	Energy efficiency bands
ACEA	Association des Constructeurs Européens d' Automobiles, European Automobile Manufacturers Association
ADAC	Allgemeiner Deutscher Automobilclub (German Motoring Association)
BMU	Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BAST	Bundesanstalt für Strassenwesen (Federal Highway Research Institute)
CO_2	Carbon dioxide
CV	Commercial vehicle
ExU	Extra-urban
EU	European Union
EURO 1...5	Range of standards in European legislation on exhaust emissions from cars, light commercial vehicles, heavy-duty vehicles
FC	Fuel cell
HDV	Heavy-duty vehicle
ICAO	International Civil Aviation Organisation
JAMA	Japanese Automobile Manufacturers Association
KAMA	Korean Automobile Manufacturers Association
KBA	Kraftfahrt-Bundesamt (Federal Motor Transport Authority)
LCV	Light commercial vehicle
LV	Low viscosity
LRR	Low rolling resistance
M	Motorway
NOx	Oxides of nitrogen
RME	Rapeseed methyl ester
SAE	Society of Automotives Engineers
TREMOD	Traffic Emission Estimation Model
U	Urban
UBA	Umweltbundesamt (Federal Environmental Agency)
VAT	Value Added Tax
VCD	Verkehrsclub Deutschland (a non governmental organization that lobbies for environmentally friendly mobility)
VMT	Vehicle mileage travelled

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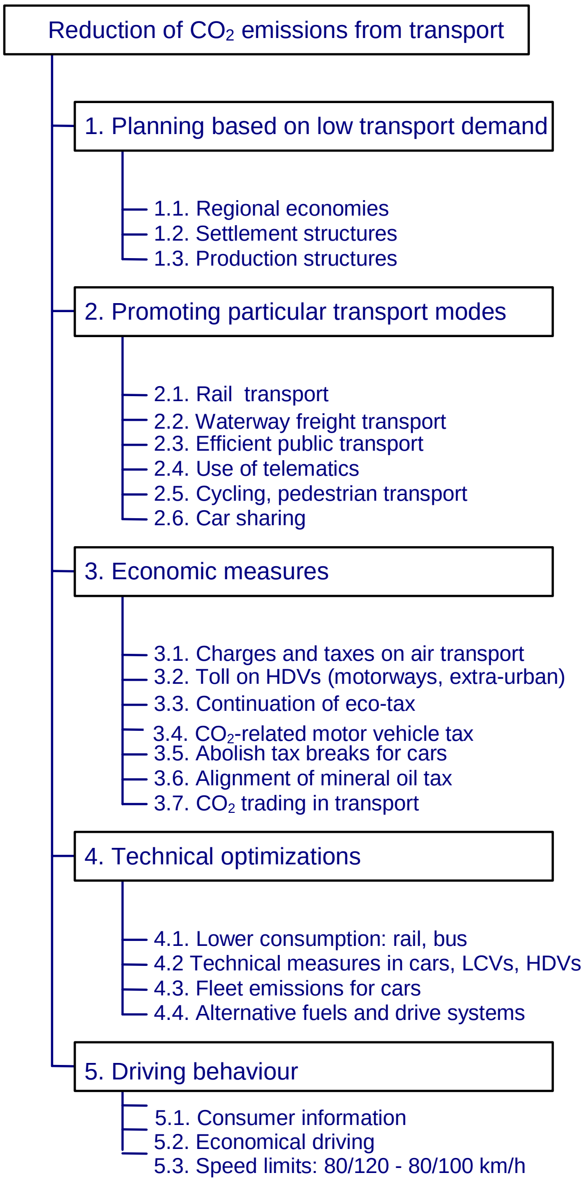
Introduction

Unlike in other sectors, CO_2 emissions from transport rose between 1990 and 2000 by more than 12%. The primary reason is the increased transport volume: between 1990 and 2000, the increase in freight transport alone was around 41%. During the same period, the increase in passenger transport, measured in passenger kilometres, was around 22% *[VIZ, 2001/2002]*. It was not until after 1999 that there was a slight drop in CO_2 emissions from transport, largely due to a drop in vehicle kilometres in passenger transport. However, this cannot yet be seen as a trend reversal, because the revival of economic activity is likely to lead to a renewed increase in vehicle kilometres and therefore of CO_2 emissions in the transport sector.



We must assume that there will be a marked increase in transport volume between now and 2010. Given the current basic conditions and assuming that no additional measures are implemented to curb the growth in transport, vehicle kilometres in road traffic will rise by around 23% compared with 1990. Current trends suggest even higher growth levels for road freight transport. For example, we must expect CO_2 emissions caused by road freight transport to increase by approximately 58% by 2010, measured against 1990 levels *[IFEU, 2002]*.

The steeper the rise in CO_2 emissions caused by transport, the more measures will be needed to reduce emissions in other sectors and the more radical they will have to be, if we are to achieve the German federal government's CO_2 reduction target and thus meet the requirements for averting climate change.

To ensure that the transport sector makes a contribution to climate protection and CO_2 reduction in the long term, we must find a way of achieving a greater degree of mobility combined with lower levels of CO_2 emissions from transport. This can be supported by a package of different instruments and measures.

Apparently immutable laws, such as the link between increase in transport volume and economic growth, or the trend to use improvements in the efficiency of vehicle drive systems mainly to achieve higher engine output or raise standards of comfort and safety, can be adapted with carefully targeted measures to serve the requirements of climate protection.

This report describes the different measures for reducing CO_2 in the transport sector and explains how they interact. Unless stated otherwise, the estimates of reduction potential given are based on model calculations using TREMOD 2.1 *[IFEU, 2002]*.

The expansion of production, settlement and infrastructure that has been promoted over decades must be replaced by a different regional planning strategy that aims to reduce unavoidable transport needs (avoid creating the need for transport in the first place). This is the *sine qua non* of sustainable economic development in which individual mobility and production based on division of labour are possible even with reduced transport volumes (**section 1**). By promoting public transport and non-motorised transport and by creating carefully targeted economic incentives, transport can be shifted to more environmentally friendly and energy-efficient modes (**sections 2 and 3**). Organising existing transport in a more eco-friendly way using both technical and non-technical measures is already bringing about a reduction in specific CO_2 emissions in the short term (**sections 3.7 and 5**).

1 Promoting environmental transport planning

Integrated transport planning means that spatial planning, regional planning, urban design, environmental planning and regional economic development have to be coordinated and closely tailored to environmental and climate-policy targets. The amendment of the Regional Planning Act has already improved the basis for implementing a sustainable policy of regional and settlement development. Any expansion of infrastructure, designation of land for commerce and light industry and production locations, as well as the development of residential areas and urban structures must be designed in a way that will avoid long distances and thus traffic volume and will increase the provision of environmentally friendly alternatives to motor vehicle traffic.

For the first time, the current revision of the 1992 Federal Transport Infrastructure Plan includes expected CO_2 emissions in the macroeconomic assessment procedure for transport routes. If the 2003 Federal Transport Infrastructure Plan is to represent a step closer to the goal of sustainable mobility, it is essential not only that environmental components are incorporated into the cost-benefit analysis but that the possibility of exploring alternatives to the project originally assessed are also created, if they are to be able to fulfil the transport functions more efficiently (least cost transport planning). In the long term, the Federal Transport Infrastructure Plan should be developed into an environmentally based concept for long-distance transport, capable of ensuring that stated environmental goals relating to transport can be achieved.

Reduction potential

Environmental transport planning is the essential framework for the implementation of numerous individual measures such as promoting public transport or cycling. The total potential for cutting CO_2 offered by environmental transport planning is thus the sum of all these individual potentials. To avoid counting them twice over, it makes more sense to list these potentials only in connection with the measures that go with them.

1.1 Regional economies

Regional economies help to avoid the need for long-distance transport and should be further boosted. This would entail providing backing for a great depth of production within a region and promoting regional marketing of products. Regional development must take into account the effects on traffic volumes and CO_2 emissions of companies setting up business. To do this, the effect on transport and the environment have to be added to the existing criteria for the promotion of regional development and, where necessary, existing criteria will have to be replaced by neutral development measures. This applies in particular to the criterion of supraregional sales markets on which location assistance in structurally weak regions depends: it is counter to the goal of avoiding generating traffic and promoting low-traffic settlement and economic structures.

EU subsidies that are granted for defined regions, not EU wide, play a special role. They lead to transport-intensive “bandwagon effects” and thus to freight being transported over long distances.

Reduction potential

Due to the complexity of the situation, it has to date not been possible to estimate the potential for cutting CO_2 offered by promoting regional economies.

1.2 Settlement structures

The process of suburbanisation that has been noticeable for a long time now as a result of residential and commercial areas being located decentrally, i.e. in the areas surrounding settlements and cities, has a dual effect on the increase in motorised traffic. First, the distances to numerous destinations (work, shopping, recreational facilities) have become longer, with the result that although the number of journeys has not increased the overall volume of traffic has. Secondly, longer distances reduce the attractiveness of non-motorised transport; consequently, shifts in the modal split mean that additional journeys are made by motor vehicle. Today’s dispersed settlement structures are not conceivable without the motor vehicle: it is the only way of achieving such low-density development of land.

In the transport statistics of former West Germany the traffic-generating effect of these settlement patterns is reflected in the increase of average distance travelled per journey, which, depending on the purpose of the trip, increased by 10% to 20% between 1976 and 1994. These increases seem relatively small, which is due to the fact that they are averaged across all modes of transport, in other words they include the short trips made on foot or by bicycle. Related to motorised transport, this means for shopping traffic, for example, a growth in the volume of traffic of 46.7 billion passenger kilometres to 79.2 billion passenger kilometres, which is an increase of approx. 70%. The high levels of pollution caused by retail parks on greenfield sites, which provide excellent car access, and indeed are sometimes accessible only by car, were illustrated in an exemplary fashion in a study carried out in Leipzig: a visitor to the Saale Park, which is situated at a motorway junction, generates on average around 7 kg/d CO_2 as compared to 0.4 kg/d by a visitor to a local shopping venue in town.

Settlement structures set a course in a way that takes effect in the very long term both for traffic generation and also for opportunities for environmentally friendly modes of transport. Low-traffic settlement structures are often characterised by the catchword “town of short distances.” The aim of this kind of planning policy is to create compact settlement structures with a good mix of functions, provision of shopping, services and recreational facilities and work opportunities close to where people live, so that daily trips are kept short. For longer journeys it is also important to plan good (i.e. close) access to public transport by ensuring that regional development closely follows public transport corridors.

In this way regional and urban planning policies can set important accents to counter generation of traffic at source.

Since the amendment of the Regional Planning Act of 1992, the principle of sustainable development has been a binding guideline for regional planning and has to be implemented by programmes of action in the statutory regional plans of the states and local authorities. The goals they set are binding on the local authorities and may also trigger obligations to adapt. This means that they offer in principle an effective instrument at individual state and regional level for promoting low-traffic settlement structures. However, with a view to practising "sustainable development," regional planning policy often concentrates on preserving ecologically valuable land and creating green corridors, while factors that generate traffic are often not adequately taken into account.

The most important instruments for promoting low-traffic settlement structures are:

- Local authority reorganisation to strengthen regional power structures. This would make it easier for concepts concerning settlement structures and transport for the entire region to be asserted over the particular interests of individual local authorities,

- Replace land tax by a combined tax on land value and land area as an incentive to design buildings with low land take,

- Promote construction of new housing that centres on existing infrastructure, or infrastructure that still has to be created, for environmentally sound modes of transport (structure-based approaches).

In practice, the implementation of the "town of short distances" is fraught with numerous obstacles, such as:

- Land prices in central locations or locations with good public transport connections are much higher than those in surrounding areas,

- A lack of available land, particularly in view of the number of restitution claims that have still not been resolved in the German states that formerly belonged to East Germany, and

- The problem of contaminated sites.

Reduction potential

It has proven very difficult to quantify potential because hardly any surveys have looked at reduction of vehicle kilometres or reduction in the growth of vehicle kilometres. One reason for this is certainly the complexity of the interactions and the influence of factors that are not within the jurisdiction of planning and transport policy. This applies particularly to estimating effects in rush-hour traffic, which is highly influenced by the labour market.

To calculate potential up to 2005 or 2010, future developments at local level will have to be modelled in the form of scenarios in order to obtain realistic estimates of the possible changes to length of journey.

When comparing several regional planning scenarios, the state of Brandenburg's *Ausschuss für Immissionsschutz* or Pollution Control Committee *[BRB, 2000]* calculated that the best planning concept permitted a 3% saving in vehicle kilometres by comparison with the worst concept. The same study calculated for the town of Oranienburg that locating residential areas with access to public transport in mind would bring about a potential for cutting private motor traffic of approximately 27% of vehicle kilometres as compared to a similar scenario without access to public transport.

It would also be possible to tap a certain potential by targeted allocation of social housing to commuters who travel into the cities from surrounding areas (incoming commuters). In Albertslund (Denmark, the Greater Copenhagen area) 0.5% of publicly funded housing was allocated to incoming commuters. The average reduction in vehicle kilometres in these households amounted to just less than 70 km per household and working day *[*UBA, 2000*]*. If we assume that approximately 1 million homes have been funded in the last ten years as part of social housing schemes in Germany and if we further assume that 1% of these homes were allocated on transport-related criteria, approximately 1.5 million t CO_2 could be saved (given the same reductions in vehicle kilometres per household as in Albertslund). Due to the currently uncertain position regarding whether funding of social housing is to be continued, no special mention has been made of this potential in the summary to this report.

1.3 Location of businesses

Businesses are both a source of and destination for traffic, both passenger transport and freight transport. It is therefore vital that all the possibilities of the Regional Planning Act and the legislation on building planning are exploited to the full to ensure that the way businesses set up in new locations is optimised – and that includes transport criteria. Businesses with a high volume of freight transport, for example, should be located near railway lines and should have their own branch line.

A planning approach that permits the transport intensity of a company to be taken into account in the choice of location is provided by "ABC planning," which has been used for some time now, above all in the Netherlands. In this system, the accessibility requirements of companies are matched to the accessibility profiles of different locations. ABC concepts follow the principle that companies with high use intensity (A companies: high number of employees, high visitor numbers, little freight transport) should set up at locations that are easily reached by environmentally friendly modes of transport, which are mostly in town centres (A locations). By contrast, companies that tend to have low use intensity and high dependence on (road) freight transport should be allocated to sites that are easily reached by car and are difficult to reach by environmentally friendly modes of transport (C locations).

Reduction potential

Attempts are being made in the Netherlands to reduce the share of motorised private transport on all roads in rush-hour traffic to less than 20% at A locations and less than 35% at B locations.

A study in Oranienburg has shown that integrated locational planning using the ABC method for companies in the service, crafts and industrial sectors was able to achieve a saving of approx. 19% of car trips on weekdays and approx. 31% of car trips in the case of retail outlets. These saving potentials apply initially only to companies newly arriving at a location. However, new set-ups at A and B locations could have a positive effect on provision of environmentally friendly modes of transport and thus lead to other switches in transport mode.

2 Promoting environmentally sound modes of transport

2.1 Rail transport

2.1.1 Improving the competitive conditions for freight and passenger rail transport

Putting the railways in a better competitive position is crucial to the environmental and transport policy goal of transferring more transport onto rail. To that end, the railways themselves – backed by national and European standards and financing – must improve their performance. Furthermore, equal underlying conditions must be created for the competing modes of transport: road, air and water. In the EU acceding countries, rail transport still has a high share in overall traffic volume. Here massive efforts on the part of the EU, the acceding states and the railways themselves are necessary to ensure that they do not lose market share. The existing Member States would also benefit from any stabilisation and improvement in the quality of rail transport in the acceding states.

Rail transport's service deficits are primarily in the area of international passenger and freight transport; they are caused by the continued existence of national barriers and the lack of adaptation to industry's changing needs (increase in freight haulage where the time factor is critical, "just-in-time" etc.). Rail transport operators have to pay to use the infrastructure, whereas that is not the case for large sections of the road network. The forthcoming introduction in Germany of a toll system for heavy-duty vehicles is therefore an important move towards equal treatment of road and rail. A comparison of modes of transport shows that, along with waterways, rail has the lowest external costs; if these costs were actually charged rail's competitive position would be significantly improved. Taxation law is also different for the different modes of transport; here air transport enjoys particular privileges (exemption from value added tax on international transport, no tax on kerosene). Safety and social regulations for road transport should also be adjusted to the high level that applies to rail transport.

The principal measures that could be taken to improve the efficiency of regional, national and international rail transport are:

- *Expansion of infrastructure*
  - Eliminate bottlenecks
  - Expand rail coverage, for example, by reactivating unused or only partially used lines and increasing the density of private sidings in the freight transport network
  - Expand the European high-speed network for passenger transport
  - Separate the networks for freight and passenger transport
  - Improve the technology for intermodal transport

- *Remove restrictions on network access*
  - Prerequisite: organisational separation of infrastructure and operations
  - Open up national networks to international traffic
  - Transparency of decision-making regarding access to infrastructure (rail network, shunting yards, stations, workshops)

- *Remove market and border obstacles through operational and technical interoperability*
  - Power supply
  - Signalling technology
  - Uniform European information technology
  - Cross-border accreditation for train staff, harmonisation of employment law
  - Uniform European licensing procedure for rail vehicles
  - Comprehensible national and international charging systems

- *Improve provision of services by tailoring them more closely to customers' needs*
  - Uniform timetable information system
  - Varied range of customized transport and logistics services from a single provider
  - Greater flexibility
  - Guaranteed transport times and immediate provision of information to customers in the case of delays
  - Attractive pricing system

- *Adapt vehicle technology to the changing requirements of industry:*
  - Expand high-speed freight transportation using small container systems
  - Improve loading and unloading facilities, including those for intermodal transport

Similarly, significant improvements to competitiveness are also possible in local passenger rail transport by introducing measures such as:

- *Creation of denser networks with higher service frequency and integration into larger-scale rail transport systems (for example using multi-system vehicles such as those in operation in Karlsruhe)*

- *Increase comfort and improve fare systems*

- *Increase utilization during times of low transport demand*

- *Shorter journey times by improved vehicle technology and creation of regulations that give priority to rail over road traffic*

- *Restrictions and additional charges (as justified above) for motorised private transport*

Urban and regional planning can also contribute to modal shifts by making public transport stations and stops focal points for future settlements.

Reduction potential

Implementing the above-mentioned measures can bring about a significant transfer of road and air traffic onto the railways. The effects this would have on CO_2 emissions will be estimated in the following sections.

2.1.2 Increasing rail transport's share in overall transport volume

Transferring road and air transport to the railways brings about a reduction in CO_2 emissions simply as a result of lower specific emissions. In the case of passenger transport, domestic air traffic generates three times the volume of specific CO_2 emissions of rail passenger transport, road traffic almost twice the volume *[DB, 2000]*. The trend scenario calculated by TREMOD for 2010 assumes similar ratios. In urban transport, petrol and diesel cars generate 2.7 and 2.2 times the volume of specific emissions as trams, taking an average value of 190 g/passenger kilometres for cars. This value includes the average CO_2 emissions from petrol and diesel cars, taking into account the upstream processes involved in producing the fuel.

Domestic air freight transport generates 25 times the volume of specific CO_2 emissions of rail freight transport *[DB, 2000]*, road freight transport 6.2 times the volume (TREMOD for the trend scenario for 2010).

Reduction potential

Potential for reductions can be derived from the above-mentioned background conditions[1] (net effects). The trend for transport volumes and specific CO_2 emissions in 2010 is established on the basis of TREMOD's calculations; the transport volumes for the transfer scenario are selected on the basis of the integration scenario (SCENARIO 1) in the "Transport Report 2000" *[BMVBW, 2000]* (linear conversion from 2015 to 2010). This is summarised in Table 1. In addition, estimated transport volumes for a complementary scenario (SCENARIO 2), which includes further switches to rail transport, are given in the Transport Report 2000 *[BMVBW, 2000]*.

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[1] Given a transport volume in private motor transport in 2000 of 740 billion passenger kilometres *[VIZ, 2001/2002]* and an estimated 25%share of total private transport corresponding to urban areas, a 1% reduction corresponds to 1.75 billion passenger kilometres in urban areas and 5.25 billion passenger kilometres extra-urban.

Table 1: Transport volumes 2010 in long-distance freight and passenger rail transport *[according to BMVBW, 2000]*

	Long-distance freight transport in billions tkm		**Long-distance passenger transport in billions passenger kilometres**	
	Road[1)]	**Rail**	**Road[1)]**	**Rail**
TREND	409	86	596	81.7
SCENARIO 1	336	127	586	91
SCENARIO 2	320	142	534	109

[1)] Effect on transport volumes extra-urban and on motorways

The estimations of the potential for CO_2 reduction in rail transport take into account the entire emissions from the upstream processes. This ensures, for example, that electric traction is not seen as producing zero emissions because the displaced emissions are counted as well. At the same time, the existing categorisation of emissions can be retained. Currently, the boundaries for drawing up a balance sheet for road transport are set in such a way that the emissions from the upstream processes, which can add around 13-17% to the total emissions, have not yet been taken into consideration in reduction targets and emission scenarios. The following emission factors have been taken into account in this study (Table 2).

Table 2: CO_2 emission factors 2010 in long-distance freight and passenger transport

	Long-distance freight transport in g/tkm		**Long-distance passenger transport g/passenger kilometres**	
	Road	**Rail**	**Road**	**Rail**
TREND counting upstream processes	143	23	117	66
TREND[1)] not counting upstream processes for road transport	126	-	100	-

[1)] In order to retain the familiar categorisation of emissions by mode of transport, road transport emissions have also been calculated without counting emissions from fuel processing.

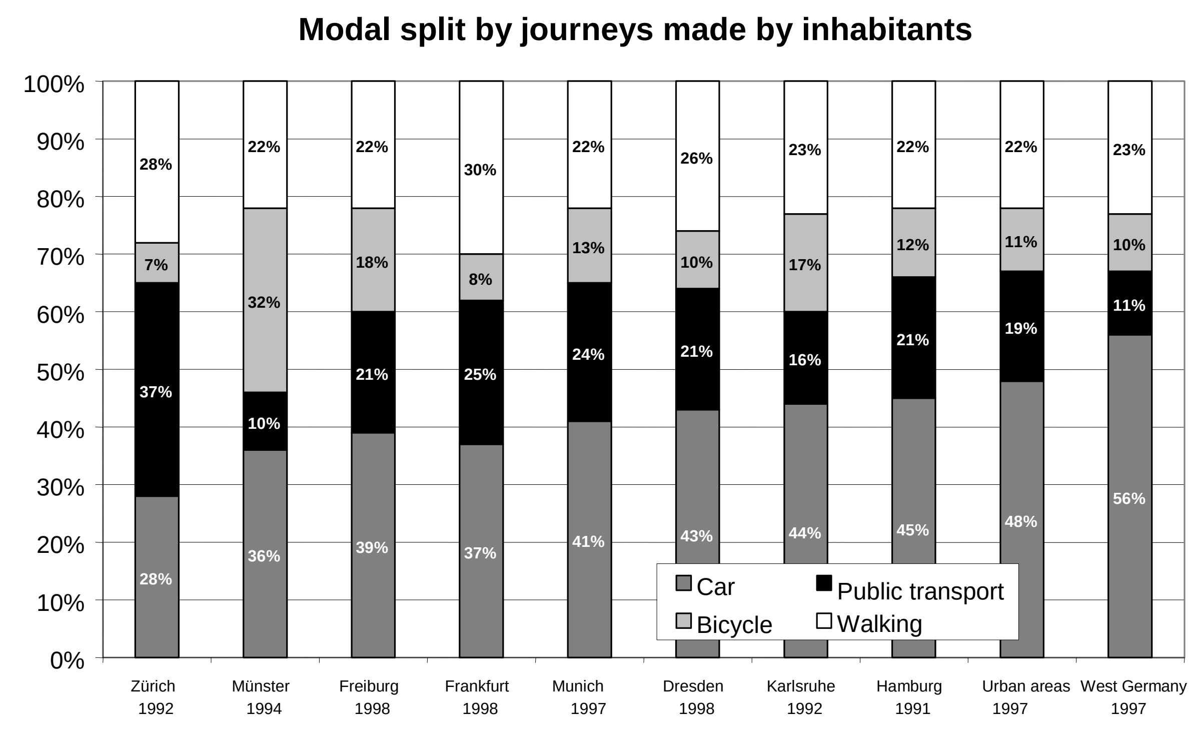
This shows that a transfer to rail as assumed in SCENARIO 1 would bring about reductions of 8.4 (not counting upstream processes) or 9.6 million t CO_2 for long-distance freight transport and 0.4 (not counting upstream processes) or 0.6 million t CO_2 for long-distance passenger transport in 2010. The relatively small reduction for long-distance passenger transport is largely due to the fact that SCENARIO 1 estimates a low level of transfer of not even 2%. For local rail passenger transport, potential reductions of approx. 0.3 (not counting upstream processes) or 0.4 million t CO_2 are calculated for 2010.

The transfers of transport assumed in SCENARIO 2 produce 10.0 and 11.2 million t CO_2 for freight transport (not including/including upstream processes in road transport) and 4.4 and 5.6 million t CO_2 for long-distance passenger transport (not including/including upstream processes).

2.2 More efficient public transport

Public transport has an outstanding role in any scheme designed to promote mobility. Public transport ensures that all sections of society have access to transport that does not depend on the car and generates on average only about a third of the CO_2 emissions of a car per passenger kilometre.

Public transport's share in urban traffic volume varies enormously depending on the underlying conditions. The average value for urban areas in Germany is 15% and peak values are achieved, for example, in Frankfurt a.M. with 25%, in Munich with 24%, and in Hamburg, Dresden and Freiburg with 21%. By comparison, public transport's share in Zurich is as high as 37%. Figure 1 gives an overview according to *[SCHLEY, 2002]*.



Source: SCHLEY, 2002

Figure 1: Comparison of modal split in different cities

The prerequisite for increasing public transport's share in urban transport is an extensive network, modern and efficient vehicles and provision of services that are tailored to customers' needs. Equally, if not more, important are restrictions on urban car traffic, particularly carefully targeted parking management that includes reductions in the number of parking spaces. The internalisation of the external costs of car traffic also contributes to a modal shift in favour of public transport.

The federal government, states and local authorities fund public transport to the tune of some 15 billion euros per annum. The funding system is not very transparent and is based more on expenditure (anyone who invests a lot receives a lot) than performance (e.g. customer numbers). To achieve larger scale modal shifts it is necessary to reorganise public transport financing in a way that creates incentives for the highest possible transport volumes, customer satisfaction and cost efficiency.

Reduction potential

Each per cent that is transferred from urban car transport to public transport brings about a reduction in CO_2 emissions of 260,000 tonnes compared with the current trend (calculated for 2010). A transfer of 5% of urban car transport would mean a 24% growth in public passenger transport (bus, tram, suburban and underground railways). Taking public transport's fuel consumption into account, that would bring about a reduction in CO_2 of 1.3 to 1.5 million tonnes in 2010, depending on the occupancy rate of public modes of transport.

2.3 Use of telematics

The use of telematics can also bring about a reduction in CO_2 emissions, because, for example, they increase efficiency in freight transportation (increased capacity utilisation, avoidance of empty trips, transfer to rail or ship). Companies are increasingly using systems of that kind for economic reasons. Attractive public transport provision is also dependent on the use of telematics. Guidance systems, priority at traffic lights and dedicated lanes within towns and cities can reduce journey times, avoid delays and reduce not only costs but also CO_2 emissions. Increased use should be made of traffic control systems in order to improve parking management and make it easier for people to change from their cars to public transport by constant provision of up-to-the-minute traffic and travel information. This can avert traffic searching for a parking space, ease the burden of car traffic in city centres and thus reduce CO_2 emissions. Living environments are improved this way and urban living becomes a more attractive option.

Reduction potential

A study carried out in 1999 by Prognos AG estimates that some 0.6% of urban CO_2 emissions could be cut if dynamic information boards were installed on the approach roads to all P&R facilities, signposting the facility and providing information about the number of free parking spaces and public transport services. Fitting all tram stops, suburban and underground railway stations and principal bus stops with a dynamic travel information system would reduce CO_2 emissions from urban traffic as a result of the transfer by approx. 2%. Overall the potential reduction in emissions for urban traffic (cars/commercial vehicles) for 2010 would be around 2.3% or 1.2 million tonnes CO_2. On extra-urban roads, telematics combined with various technical measures could reduce CO_2 emissions from freight transport as a result of improved logistics by about 2.6% (1.4 million tonnes CO_2) by 2010; for the car sector the reduction potential is negligibly small *[PROGNOS, 1999]*. Overall, the potential for reductions in CO_2 emissions as a result of traffic information and guidance systems in road transport is approximately 2.6 million tonnes. Of that total, it would be possible to achieve roughly a third by 2005, taking into consideration financial and procedural constraints (0.9 million tonnes).

Often, markedly greater potential for reducing CO_2 emissions is ascribed to telematics. This is because they make it possible to introduce and apply economic control instruments, such as road charges and parking management systems. In other words, telematics primarily create the technical conditions necessary to implement other measures.

2.4 Bicycle and pedestrian transport

Promoting bicycle transport can also contribute to the goal of cutting CO_2 emissions from traffic. The potential offered by cycling as a means of transport is often underestimated because the bicycle is primarily a mode of transport for short distances. However, half of all journeys made by car are less than 6 km *[BREG, 2000b]*, a distance over which use of the car normally brings no time advantage. Vehicle emissions are particularly high over short journeys because fuel consumption is disproportionately high due to the cold engine and because the catalyst is not yet working at full efficiency. For these reasons, the pollution-reduction effect when journeys otherwise made by car are made by bicycle is particularly high.

In order to be able to estimate the reduction in emissions for air pollutants and CO_2 that would result from increased promotion of bicycle transport, the potential shift from motorised private transport to bicycle transport in terms of vehicle kilometres and journeys has to be known. With the aid of the emission factors used in the TREND scenario of the TREMOD model, the car kilometres and journeys saved can then be used to calculate the reduction in CO_2 and other pollutants.

Reduction potential

It is difficult to estimate the potential for modal switch because no reliable procedure is currently available. On the basis of the little data that is available, four hypothetical switch potentials were set up. However, only the potential for a switch from the car to the bicycle was considered, so that it was not possible to take into account the additional effects of better links between cycle transport and local public transport or long-distance rail.

Table 3: Possible potentials for modal switch and the resulting savings in CO_2 and annual bicycle kilometres for 2010

Scenario	**Assumed shift**	**CO_2 savings** [million t/year]	**Resulting bicycle kilometres** [km/year and inhabitant]
Car-W6	30% reduction in car journeys under 6 km	6.63	998
Car-W10	30% reduction in car journeys under 10 km	11.93	1320
Cycle+32	32% increase in bicycle journeys	3.52	824
Cycle+102	102% increase in bicycle journeys	8.61	1071

The assumed shifts from motorised passenger transport to bicycle transport would result in the CO_2 savings shown in Table 3. They are between 3.5 and 12 million t/a and would be feasible if cycle transport were consistently promoted between now and 2010. The bicycle kilometres per inhabitant and year (as a statistical mean) that would result from the increase in cycle transport are also given. The current figure for annual bicycle kilometres is around 300 km, whereas in the Netherlands and Denmark statistically each inhabitant cycles around 1000 km. This indicates that the modal shift scenarios are realistic.

To actually realise these potentials, a comprehensive long-term promotion of cycle transport as part of an overall integrated transport policy is necessary. A first step was taken with the "National Bicycle Transport Plan" *[BMVBW, 2002]*, which identifies all the possibilities for systematically promoting bicycle transport and calls upon all actors involved, and indeed every member of the general public, to join in.

2.5 Car sharing

Acquiring a car is an important decision that predetermines an individual's mobility behaviour. Any subsequent choice of mode of transport is not made on a level playing field. In principle, car sharing is a viable alternative that takes advantage of all the benefits of the car, but without biasing the individual choice of mode of transport in the long term against more environmentally friendly alternatives. At the same time, the choice of vehicle can be far better matched to the particular transport need, enabling a more efficient use of the transport capacities of the fleet than if each person owns their own "all-purpose car." Car sharing can also encourage a more rational attitude to the car and facilitate societal acceptance of environmentally justified restrictions to car traffic (e.g. traffic calming schemes, speed limits etc.).

In order to promote car sharing and increase its acceptance, it is vital to ensure that sufficient parking places are allocated to vehicles belonging to car sharing groups to enable a dense network of car sharing schemes to develop. Priority spaces could be reserved on public car parks, private underground car parks and multi-storey car parks and could be made exempt from parking charges. If a close link were established between pricing systems and user information and public transport, it would be possible to plan a journey thoroughly in terms of both time and cost. Furthermore, acceptance of shared use of vehicles must be increased by professional marketing instruments to ensure that people have adequate information and understanding. The service provider "Mobility CarSharing" of Switzerland, which already has over 50,000 customers, has demonstrated how well this kind of scheme can work.

However, it is important to take into consideration that the car sharing industry in Germany is currently undergoing a process of change *[WILKE, 2002]*. In the hope of increasing the market chances of car sharing, we are aiming for a centralisation of the provider structure and more flexible use possibilities, i.e. something that is as close to individual car ownership as possible. This can bring about changes in use patterns and consequently in the ecological effects. After all, car sharing does not automatically lead to a reduction in CO_2; this is true only under certain conditions. If, for example, companies or public agencies make use of the services of car-sharing organisations instead of or as a back-up to their own fleet, or if the majority of users want to use car sharing as a means to additional car mobility, it is no longer guaranteed that car sharing would help reduce CO_2.

Reduction potential

On the basis of a study commissioned by the German Federal Transport Ministry and published in 1994, the potential reduction in vehicle kilometres can be estimated to be around 7 billion km. This means that a reduction in CO_2 emissions by a maximum of 1.2% of car traffic emissions, or just less than 1.2 million t, by the year 2010 can be assumed. It will be possible to achieve about one third of that in 2005 if the above-mentioned underlying conditions are fulfilled.

3 Economic measures

3.1 Charges and taxes on air transport

Air transport is becoming an increasingly serious problem in terms of its impact on climate change. The main reason is the sharp increase in air traffic. Added to that is the particular significance of the emission of CO_2 and NO_x at high altitude and the emission of water vapour, which has a warming effect due to the formation of contrails. The impact on the climate of emissions from air transport is 2 to 4 times greater due to the altitude of the emissions than if the same amount were emitted close to the ground *[IPCC, 1999]*. For that reason, it is important to introduce measures to reduce climate-relevant emissions from aviation as soon as possible, although they do not make any contribution to fulfilling the Kyoto commitment because climate-critical gases from aviation are exempt from the Kyoto Protocol. They come under the jurisdiction of the ICAO (International Civil Aviation Organisation).

Various measures for reducing emissions from aviation have been under discussion for many years now. Due to the growth rates in the volume of traffic, it is unlikely that technical progress in engines will be sufficient to reduce overall emissions or even keep them at today's levels. For that reason, the focus is increasingly shifting to market-driven instruments, which, apart from creating incentives to develop and use low-emission technologies, can also reduce the demand for air travel. There are a great many situations, both nationally and internationally, that amount to subsidies in the broadest sense and which, in the context of an ecologically oriented aviation policy, would have to be reviewed very critically. The grounds originally cited to back the introduction of these subsidies are no longer justified. The first measure to consider would be to revoke the exemption from Value Added Tax (VAT) on international flights. The introduction of a VAT rate of 16% could bring about a slight drop in demand for the flights affected. However, 40% of flights are for business purposes; making them subject to VAT would have no effect, since businesses can reclaim VAT anyway. In addition, there are plans to introduce tax on mineral oil for aviation on the same lines as for motorised road transport. However, fuel costs account for only about 12% of an airline's overall costs. A quantitative analysis has shown that if a tax on kerosene were introduced, which in the final stage would be the same level as the tax on diesel fuel, the volume of air traffic would grow by 5% less than the standard scenario predicts *[UBA, 2001]*. Airlines would then use larger and more efficient aeroplanes with higher capacities and emissions per passenger kilometre would drop. However, one of the principal effects of a tax on kerosene would be that the increased costs would lead to a fall in demand.

In addition, distance-related emission charges can also help reduce CO_2. Planes with above-average emissions could be subjected to higher charges and taxes in order to encourage the introduction of aeroplanes with lower emissions as well as the demand for new technologies and the research and development that entails. This measure thus has a high potential for exercising ecological control and creates incentives for the aviation industry to make both technical and operational improvements. The levy would be based on CO_2 and NOx emissions for the entire route including landing and could be charged through the air traffic control charge using a modelling system. An emission charge of 0.06 € per kg CO_2 and 13.7 € per kg NO_x from 2010 onwards would produce more or less the same cost burden and effect as a moderate tax on kerosene, i.e. a reduction of approx. 5% as compared with the standard scenario *[UBA, 2001]*.

Today's flight service management is inefficient in a number of different ways that to some extent cancel out the success of technical and economic measures. By improving the way air transport is organised, which would include deregulating air routes and improving landing and take-off patterns, as well as airspace control, savings of approx. 8% of CO_2 emissions generated by air transport could be made in 2010 as a result of operational measures.

Reduction potential

The sum of the measures described above could bring about reductions in the CO_2 emissions expected to be generated by air traffic by some 11% by 2010. This is equivalent to 3.5 million tonnes CO_2.

3.2 Toll system for heavy-duty vehicles on German motorways and trunk roads

The "Act on the Introduction of Distance-Related Charges for the Use of Federal Motorways by Heavy-Duty Vehicles" lays the foundation for a toll system for based on distance to begin in 2003. For HDVs over 12 t, an average charge of 12,4 cents for every kilometre driven on German motorways is planned. There will be a sliding scale of charges ranging from 9 to 14 cents/km, depending on axle weight and emission class. The Eurovignette system will no longer apply in Germany.

It is thought that the toll system will bring revenue of 3.4 billion € per annum into the state coffers. Set against that are the costs of running the system, calculated to be 560-620 million € per annum, and the loss of revenue from the Eurovignette of 428 million €. That leaves net revenue for the federal government of approx. 2.2 billion € per annum. The costs for an average HDV will be around 15,000 € per annum. Set against that is a saving of approx. 1,250 € per annum from the cancellation of the Eurovignette. HDV operating costs will rise by 8-10%. However, the rise in the cost of goods will be negligible, e.g. it will add 1.4 cents to a kilo of bananas, 0.5 cents to a pot of yoghurt, and 1-1.5 cents to a pair of shoes.

According to an estimate by Rothengatter & Doll *[ROTHENGATTER, DOLL, 2001]*, the HDV toll system, at the level planned (without compensation payments or new road building), will have a positive effect on emissions of pollutants, but not on gases relevant to the climate. Due to the fact that the toll is emissions-related, compliance with EURO 4 and EURO 5 exhaust standards will occur significantly sooner than legally required. Road freight transport will not drop noticeably. *[ROTHENGATTER, DOLL, 2001]* come to the conclusion that "[...

the] negative effects of traffic choosing the trunk road network over motorways and the positive effect of the higher proportion of low-pollutant vehicles [more or less cancel each other out].” The expected CO_2 savings will be in the order of 50 thousand tonnes per year.

The introduction of the HDV toll in 2003 is thus a step in the right direction. If the charges were higher, the effect on climate protection would be of real significance. According to *[ROTHENGATTER, DOLL, 2001]* an extension of the toll system to the entire road network, a 5 cent higher charge for HDVs over 18 t and a second stage as of 2010 at 20 cents (30 cents for HDVs over 18 t) would bring about a 2.5% reduction in vehicle kilometres in road freight transport and a 7% increase in the volume of freight transported by rail. Assuming that the railways cope with the additional volume transported without additional train kilometres, this would produce a reduction in CO_2 of some 1 million t for 2010 as compared with the current trend. If, at the same time, the rail improves its haulage services, the increase in the volume of freight transported by rail could amount to up to 14% and the drop in vehicle kilometres on road freight transport 3.3%. However, there will not be a greater reduction in CO_2 because the railways are developing additional services that in all probability will lead to an increase in train kilometres. A toll system modelled on that in Switzerland would have a markedly greater effect. It would apply to the entire road network for HDVs of 3.5 t or over and would rise from 69 cents per kilometre in 2005 to 1.05 €/km in 2010. The drop in vehicle kilometres in road freight transport would be 12% and the increase in the volume of freight transported by rail 60%. However, a shift to the railways of this magnitude is not possible without an improvement in the provision of transportation services. The CO_2 reduction would be between 1.5 and 3.2 million t. The exact amount would depend on how many additional train kilometres the railways would need to deal with this volume of freight (not taking into account pre-carriage and on-carriage). With this model too, a shift to the trunk road network would also be expected because hauliers would choose the shortest routes for cost reasons. A proportion of the costs would be cushioned by increased capacity utilisation and improved logistics. Overall, use of a toll system based on the Swiss model would add 30% to transportation costs.

In the long term, we can expect adjustment responses in warehousing and distribution patterns for production locations, which will further enhance the positive effects.

Reduction potential

A summary of the reduction potentials shows that, based on current underlying conditions, only minimal reductions in CO_2 emissions and vehicle kilometres can be expected. Only if toll charges were increased markedly could a positive impact on CO_2 reduction be expected (Table 4).

Table 4: Potentials for modal switch and the resultant CO_2 savings brought about by introducing a toll system for HDVs

Scenario	Details of HDV toll system		CO_2 savings[1)] and change in vehicle kilometres in freight transport in 2010	
	2005	2010	[million t/year]	[%]
I	12 t and over: 0.13 €/km motorways		0.05	-0.5% road freight - rail freight
II	12 t and over: 0.13 €/km entire network 18 t and over: + 0.05 €/km	12 t and over: 0.20 €/km entire network 18 t and over: + 0.10 €/km	0.5-1.0	-2.3% road freight +7% rail freight
III[2)]	0.69 €/km entire network	1.05 €/km entire network	1.5-3.25	-12% road freight +60% rail freight

1) All figures calculated without taking into account pre-/on-carriage for transfer to rail
2) Swiss model

3.3 Eco-tax

As a result of legislation introducing ecological tax reform, tax on mineral oil was raised by 3.07 cents per litre on 1 April 1999. The Act on the Continuation of the Ecological Tax Reform regulates the rise in taxation by 3.07 cents per litre on 1 January each year until 2003. Public transport paid the full increase in 1999; from 2000 it will pay half the increase.

The Panta Rhei model estimates the volume for 2010 to be 10.5 billion € *[FROHN, et al., 2002].* By far the greatest part of this revenue will be used to gradually reduce pension fund contributions by both employers and employees from 20.3% in 1998 to 19.1 percentage points in 2003. Without eco-tax they would have been at 20.6% in 2002.

Eco-tax adds 15% to the price of petrol and 18% to the price of diesel. This means additional costs of 156 € per year for the average motorist. For a low-consumption vehicle the extra costs are lower (5-l car: 92 €/year). The reduction in social insurance contributions as a rule more than compensates this extra expenditure. For example, someone in paid employment with a gross annual income of 40,000 € will pay 240 € per annum less in social insurance contributions. Someone with an annual income of 30,000 € will still save 180 €. Those sections of the population who are not employed in a job where social insurance contributions are mandatory – the self-employed, retired people, students and recipients of unemployment benefit – will suffer the extra expenditure without compensation.

Eco-tax boosts the demand for vehicles with low consumption and accelerates the replacement of vehicles with high consumption. It provides an incentive to drive in a way that saves fuel and to use fuel-saving tyres and oil. More environmentally sound modes of transport, such as public transport, cycling or walking, become more attractive.

Eco-tax also influences residential and business settlement patterns, encouraging low-traffic structures. With the current tax levels, however, this effect is relatively weak.

Reduction potential

Simulation modelling using the Panta Rhei model has shown that the current eco-tax bands on fuels that are valid until 2003 will bring about a reduction of 9.44 million t of CO_2 emissions in 2010 and create 90,000 more jobs than would be the case without the tax. *[UBA, 2002]*. This potential has already been taken into consideration in the TREND scenarios. If the eco-tax were continued for another 5 years (2008), initial estimates indicate that we could expect a further reduction potential of 4 million tonnes CO_2 per year.

3.4 CO_2-related vehicle tax for cars and light commercial vehicles

Vehicle tax with different bandings depending on exhaust values proved useful in the past for promoting low-emission vehicles and made a decisive contribution to accelerating the development and use of more environmentally sound vehicles. Now that requirements concerning pollutant emissions for newly registered vehicles have been tightened up significantly throughout Europe, it would be possible to use vehicle tax to promote sales of low-fuel cars. To do this, tax levels should be set according to the CO_2 emissions and progressively graded, i.e. the lower the specific fuel consumption and CO_2 emissions of a vehicle, the lower the amount of vehicle tax the owner has to pay. This measure has an impact both on people’s decisions when purchasing cars and on faster replacement of old vehicles. A study carried out for the EU Environment Commission shows that had a vehicle tax graded to reflect CO_2 emissions been introduced in Germany in 2000, it would have produced a reduction of 6% in 2008 *[COWI, 2002]*. That indicates that the pollutant emission categories currently used for the tax should be retained and the cubic capacity of the engine, which is actually not a concrete yardstick for consumption, should be replaced by CO_2 emissions per kilometre.

Reduction potential

The potential of this measure for cars and light commercial vehicles is in the order of 6% within 8 years *[COWI, 2002]*. The possibilities of a CO_2-related vehicle tax reducing the fuel consumption of heavy-duty vehicles are much more limited, since the necessity of keeping operating costs as low as possible means that consumption values for these vehicles have already been optimised far more than is the case for cars and light commercial vehicles. For that reason this measure has not been applied to commercial vehicles. The currently valid vehicle tax is fixed until 2005, so that the introduction of a CO_2-related element would be possible from 2006. The resulting reduction in CO_2 emissions would then amount to around 6.5 million tonnes for cars and light commercial vehicles in 2013 (2010: 3.8 million t CO_2). The costs of this measure are very low in relation to the reduction in emissions that can be achieved, since, if it is organised in a volume-neutral way, only the basis of assessment for the vehicle tax would change.

3.5 Phasing out tax breaks for cars

Under existing income tax laws, flat-rate allowances are stipulated for expenditure incurred in reaching the workplace (up to 10 km 0.36 €/km, 10 km or over 0.40 €/km). These tax allowances cover some of the running costs of a small car. This means that – intensified by public transport services that are often perceived as inadequate – the decision to purchase a car is influenced in the most unfavourable way in terms of the environment. Furthermore, the scale of standard allowances based on distance to the workplace is neither justified nor acceptable from the point of view of climate change. Current regulations encourage long journeys to work and influence people's decisions on where to live. In this way they promote urban sprawl and contribute to a significant increase in the number of commuters and the CO_2 emissions that go with that.

In the past, private use of company cars has been taxed at 1% per month of the list price of the vehicle as a benefit in kind to the user (e.g. the employee). This figure is too low. The rise in this flat-rate taxation envisaged in the coalition agreement in 2002 to at least 1.5% of the list price will create an incentive to use cheaper – and therefore as a rule smaller – cars with fewer additional features as company cars.

Provision of free parking for employees' cars is not taxed as a benefit in kind under income tax legislation. Taxing free parking would encourage the use of public transport and the formation of car pools.

Reduction potential

It is not possible to quantify directly the reductions in CO_2 emissions achievable with this measure. Phasing out tax breaks for cars would primarily encourage a shift to more environmentally sound modes of transport and settlement structures with shorter distances between home and work.

3.6 Alignment of the mineral oil tax on petrol and diesel fuel

The low tax on diesel is primarily an instrument to encourage road freight transport. Due to the high proportion of diesel consumed for non-commercial purposes, at 48% accounting for almost half in Germany, this argument is becoming increasingly questionable. At the end of the 1980s, the share in diesel consumption held by cars in the EU was around 10%, by 2001 it had risen to 22%, 43% of newly registered vehicles in 2001 being diesel vehicles. Bringing the tax on diesel into line with that on mineral oil therefore seems necessary in Germany and indeed in all EU Member States.

Furthermore, the 0.18 € difference in the mineral oil tax on petrol and diesel fuel is not justified in terms of climate policy. Diesel fuel has a higher energy content per litre than petrol and during combustion generates approximately 13% higher CO_2 emissions. To achieve equal treatment of equal “offences” in terms of climate change, the tax on mineral oil would have to be related to the carbon content of the fuel. In the past, this instrument was used to give a tax advantage to road freight transport and compensated in the car sector by a higher vehicle tax for diesel vehicles. The higher fuel costs for commercial vehicles arising from aligning the tax rates on mineral oil could be compensated for in the HDV toll system. The vehicle tax would also have to be the same level for both diesel and petrol vehicles.

The diesel vehicle share in new registrations in 2002 was as high as 37.5%. An alignment of mineral oil tax on petrol and diesel would counter this trend. Aligning the tax on mineral oil for petrol and diesel fuels would create a fair taxation system for both petrol and diesel cars. In the case of diesel cars, the compensation for tax on mineral oil that is built into the vehicle tax could be phased out. Technically speaking, cost efficient measures such as optimising petrol engines (direct-injection petrol engines) would then become significantly more attractive.

Reduction potential

It is difficult to quantify the reduction potential. A rise in the price of diesel would lead to a drop in vehicle kilometres for diesel vehicles. At the same time, it would become more attractive for car manufacturers to introduce measures to reduce consumption not simply by selling diesel engines but by carrying out technical measures on petrol engines. It is not possible to quantify the potential connected with this measure with an adequate degree of accuracy. However, to achieve equal treatment of equal “offences” in terms of climate change and to promote awareness of energy consumption and the resultant CO_2 emissions, tax rates on mineral oil should, despite the low potential for direct reduction, nevertheless be related to the carbon content of the fuel.

3.7 CO_2 trading in the transport sector

The system of environmental allowances is a market-driven instrument for reducing emissions that is based on the issue or sale of emission allowances to economic actors affected by the legislation. The instrument is being introduced with the aim of reaching a prescribed level of emissions at minimal cost to the economy within a certain period of time. On introduction of the system, the number of allowances issued will be based on current emission levels and then constantly adjusted to the reduction goal within a defined period of time. The advantage of this instrument lies in its encouragement of innovation. It creates a dynamic incentive to look for the most economical reduction possibilities. For example, in a cross-sector system, reductions in emissions can be achieved at those points in the economic system at which the avoidance costs involved are minimal – in other words low for the economy as a whole. After all, it is of no importance for the climate in which sectors the desired savings are made. Sector-specific targets can, however, be used to ensure that reductions are guaranteed to be achieved in certain sectors of the economy. Since they have no alternative opportunities for evasion, the actors are placed under greater pressure. However, the question of cost efficiency does arise here. The targets can be set in absolute terms (in tonnes of CO_2 equivalents) or specifically (e.g. in kg of CO_2 equivalent/vehicle km). The cap-and-trade system is based on absolute emission allowances, such as those stipulated in the Kyoto Protocol. Specific targets, by contrast, are not dependent on production volumes. Generally speaking, however, there is a risk with specific targets that compliance with an absolute emission reduction target can be undermined by vigorous growth during dynamic production trends (for example, growth in traffic volumes).

There are three possible points at which the energy system can be regulated – the upstream, midstream and downstream approach (upper, middle and lower sections in the value chain of a national economy) *[DEUBER, 2001; IFEU, ZEW, 2001]*. In the downstream approach, it is the emitter who must obtain allowances, in other words the road user (e.g. the customer at a petrol station). The attraction of this approach is that emissions are directly recorded and monitored where they are actually generated and there is a high degree of certainty that the reduction target will be achieved. However, it entails considerable administrative problems and high transaction costs. The midstream approach tackles vehicle manufacturers and transport service providers (the railways, for example). In other words, allowances are issued to those economic actors whose products or services contribute to CO_2 emission levels while they are being used by the consumer. However, with this approach on its own it is not possible to guarantee that CO_2 reduction targets will be achieved with absolute precision because it is neither possible to influence the total number of vehicle kilometres nor driving behaviour. The approach that can most easily be integrated into a general trading system is the upstream approach, in which it is the fuel manufacturers (refineries) who are required to obtain allowances. The allowances would be based on the carbon content of the fuels, which generate CO_2 when subsequently combusted. The advantage here is that the number of actors and therefore transaction costs are low and that all energy-related CO_2 emissions can easily be covered by the trading system. The incentives to actually reduce emissions are created by tax-like mechanisms for passing on price increases. This kind of measure would have a similar effect to raising the rate of tax on mineral oil. Nevertheless, the fact that fuel manufacturers are given an absolute overall emissions target guarantees that targets will be met.

Reduction potential

In October 2001, the European Commission presented a draft Directive on trading of greenhouse gases within the EU, which was last amended in November 2002 *[COM 2002/ 680(01)]*. This legislation aims to launch an emissions trading system within the EU by 2005. It applies directly to emitters. The model includes the most energy-intensive industries (production and processing of ferrous metals, mineral industry, pulp and paper) and the energy sector. The approach used in the Draft Directive cannot be applied wholesale to transport. Firstly, the number of mobile emission sources (particularly motor vehicles) would probably generate excessively high transaction costs for an emissions trading system based on the downstream approach. Secondly, the relevance of transport to climate policy and society in general, particularly road transport, justifies special regulations that reflect the complexity and intensity of regulation of transport. Against this backdrop, the question arises as to how emissions trading can limit CO_2 emissions caused by transport in the most effective and cost efficient way. A research project within UFOPLAN 2003 (Environmental Research Plan 2003) will develop concrete and scientifically sound recommendations on how to organise and possibly implement an emissions trading system in the transport sector. The idea is to clarify how an emissions trading system for road, rail and inland shipping could best be designed. It is thus not possible to state any concrete reduction targets before this project has been completed.

4 Technical optimisation of modes of transport

4.1 Reduction of consumption for rail and bus transport

Apart from transferring road and air kilometres to the railways, technical improvements to rail vehicles – particularly those belonging to the Deutsche Bahn, but also tram, suburban and underground railways – also helps reduce CO_2 emissions. Deutsche Bahn AG has set itself the target of reducing the specific energy consumption of its trains related to volume of traffic by 25% by 2005 as compared with 1990 levels.

The following reductions were achieved by the year 2000 *[DB, 2000]*:

- *19% in freight transport,*
- *15% in local passenger transport*
- *only 2% in long-distance passenger transport*

Clearly, considerable efforts will be required in long-distance passenger transport in order to achieve the target set; an increase in occupancy rate could, of course, make a significant contribution.

CO_2 reductions can be achieved by means of vehicle engineering (e.g. lightweight design) and increasing operational efficiency. Operational measures include energy-saving driving behaviour, recovery or flywheel storage of braking energy (as seen, for example, in the diesel-electric prototype LIREX, with savings of up to 25%), as well as a separation of fast and slow trains.

Apart from technical measures, improved driving behaviour is another way to achieve reduction in consumption by rail transport: for example, anticipatory driving on the Metropolitan train on the Ruhrgebiet to Hamburg route brought about a 30% reduction in consumption compared with average driving behaviour *[DB, 2000]*. Driver training thus holds great reduction potential.

Technical measures on urban bus fleets, including reducing vehicle weight or using tyres with lower rolling resistance, low-viscosity oils and low-consumption design of the drive line can lead to cuts in consumption. The total potential for cutting CO_2 emissions is between 20 and 25%.

Reduction potential

The reduction potential for rail vehicles is included in the transfer potential described in **section 2.1.2**, since the TREMOD model's TREND scenario assumed considerable reductions in specific CO_2 emissions between the year 2000 and 2010 – related to traffic volumes and taking into account upstream processes for rail transport - 27% in freight transport and 19% in passenger transport.

Related to the entire fleet, the technical potential for CO_2 reductions from urban buses is approx. 0.2-0.3 million t by 2010. At least a further 10% reduction could potentially be achieved through appropriate driver training, so that the total potential for urban buses is 0.3-0.5 million tonnes CO_2.

4.2 Technical measures for cars, light commercial vehicles and heavy-duty vehicles

By technical measures for reducing CO_2 emissions from cars and light commercial vehicles we mean measures that go beyond the technical measures that car manufacturers are already pursuing as part of the voluntary agreements concluded with the European Commission *[ACEA, 1999; JAMA, 2000; KAMA, 2000]*. These agreements aim for average CO_2 emissions of 140 g/km from cars sold in 2008 (ACEA) or 2009 (JAMA, KAMA). The main measures being implemented at present are increased use of diesel engines and the optimisation of petrol engines, such as charging engines, the use of variable valve timing or direct petrol injection.

If we take into consideration all the measures put in place so far, the average specific CO_2 emissions from new passenger cars in the Community as a whole in the period 1995-2001 dropped from 186 g CO_2/km to 167-170 g CO_2/km. The Community's strategy for reducing both fuel consumption and CO_2 emissions from motor vehicles aims to achieve an average specific CO_2 emission of 120 g CO_2/km by 2005 for passenger cars newly registered in the EU (2010 at the latest). It is highly unlikely that the Community's target of 120 CO_2/km will be achieved by 2005. However, we can realistically assume that it will be achieved by 2010 if the necessary measures are taken and the necessary effort is made. *[COM 2002/693]*

Analyses by the Federal Motor Transport Authority (Figure 2) show that average CO_2 emissions from newly registered cars in Germany (type testing values as prescribed in 1999/100/EC) are continuing to drop. For 2002, an average CO_2 value of 177 g CO_2/km was forecast for Germany. The German Federal Motor Transport Authority has pointed out that there will probably be no drop in the number of cars with diesel engines in 2002 *[KBA, 2002]*.

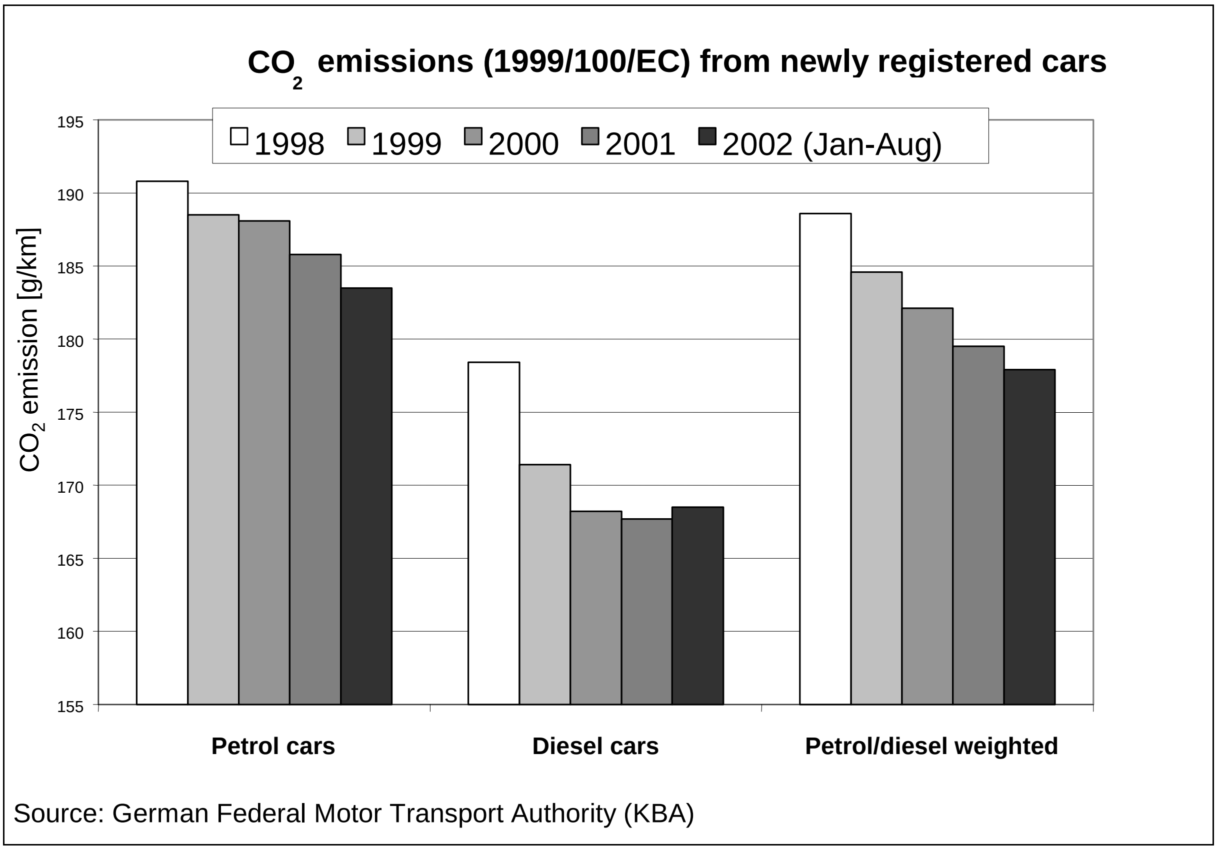


Figure 2: Trends in the average specific CO_2 emissions according to 1999/100/EC from newly registered cars in Germany between 1998 and August 2002

Reduction potential

Since reductions in CO_2 emissions are already part of the TREMOD-TREND emission scenario due to the voluntary agreements, a quantification of this potential will not be given here. The potential for reducing CO_2 by technical methods is summarised in the following sections.

4.2.1 Use of low-viscosity oils

The most important function of a low-viscosity oil in an engine is to reduce internal friction, in other words its lubricating function. The influence of friction on the overall energy conversion within the engine is particularly important. Modern engine oils have to be able to perform both at high temperatures (full load) and very low temperatures (cold-weather starts). The property that characterises a lubricant is its viscosity (flow property).

Engine oils are classified by their viscosity. There are a number of different systems of classification. The most common is the SAE system (Society of Automotive Engineers). This grades engine oils by their viscosity during a cold-weather start-up and at high engine temperatures. Oils in the SAE grades 0W30 and 5W30 guarantee the best lubrication function due to their viscosity; they are classified as low-viscosity oils. They consist of synthetic base oils and additives. Conventional engine oils (15W40, 10W40) are not able to achieve viscosity levels of that kind because of the blending properties of their mineral base oils.

In 2001, low-viscosity oils of grades 0W30 and 5W30 accounted for only 10% of the mix of engine oils sold in Germany. These figures initially appear to contradict statements issued by the Germany car industry, which, in the declaration on climate protection issued jointly with the Ministry of Transport on 24.07.2002, stated that low-viscosity oil was used for the first fill in over 98% of cars with *[VDA, 2002]*. Since the term "low-viscosity oil" is not clearly defined, oils of different qualities are currently being marketed as low-viscosity oil. For example, 10W40 engine oils are sold as low-viscosity oils, although the flow properties of these oils are by no means ideal.

Defining a quality standard (e.g. using the "Blue Angel"[2]) could facilitate the widespread use of low-viscosity oils. Legislation defining a uniform quality standard could then be introduced in the Member States of the European Community.

Reduction potential

Based on specific reduction factors and an introductory period of 5-6 years to achieve implementation in 90% of cars and commercial vehicles, reductions of 2.5 million tonnes CO_2 in 2005, 5.2 million tonnes in 2010, and 4.8 million tonnes CO_2 in 2020 could be achieved. The technical reduction potential connected with using low-viscosity oils and low rolling resistance tyres is summarised in Figure 3.

4.2.2 Use of tyres with low rolling resistance and low-noise tyres

Vehicle tyres that have reduced rolling resistance generate less noise and contribute to lower fuel consumption. Rolling resistance occurs as a result of the tyre being deformed under load. The extent of the power loss depends on the weight of the vehicle and the friction between the road and the tyre.

One of the aims of tyre development over recent years has been to optimise rolling resistance, i.e. to retain important properties of the tyre, such as grip on wet surfaces and braking performance, while at the same time lowering the rolling resistance. The use of new compounds in treads have made it possible to develop fuel-saving, low-noise tyres, known as low rolling resistance tyres. In 1997, eco-label RAL-UZ 89 ("Blue Angel") was introduced for low-noise, fuel-saving tyres *[RAL-UZ89]*.

The German tyre market already has a wide range of tyres with low rolling resistance. Studies by the Federal Environmental Agency have shown that low rolling resistance tyres can be purchased from various suppliers in all sizes tested (summer and winter tyres) and in

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[2] http://www.blauer-engel.de

virtually all categories of tyre. It must be said that tyre manufacturers tend to use their own individual system of labelling, so that low rolling resistance tyres are not always called that, but are sold under the name of “Economy,” “Energy,” “Fuel-saver” or similar terms. The eco-label (“Blue Angel”) is used by manufacturers to a very low extent. A price comparison of low rolling resistance tyres with conventional tyres showed that there is little or no price difference. A limit value for the rolling resistance coefficient of tyres could facilitate the blanket use of low rolling resistance tyres. Standard Europe-wide labelling of rolling resistance and noise values on the sidewall of the tyre could support prompt implementation.

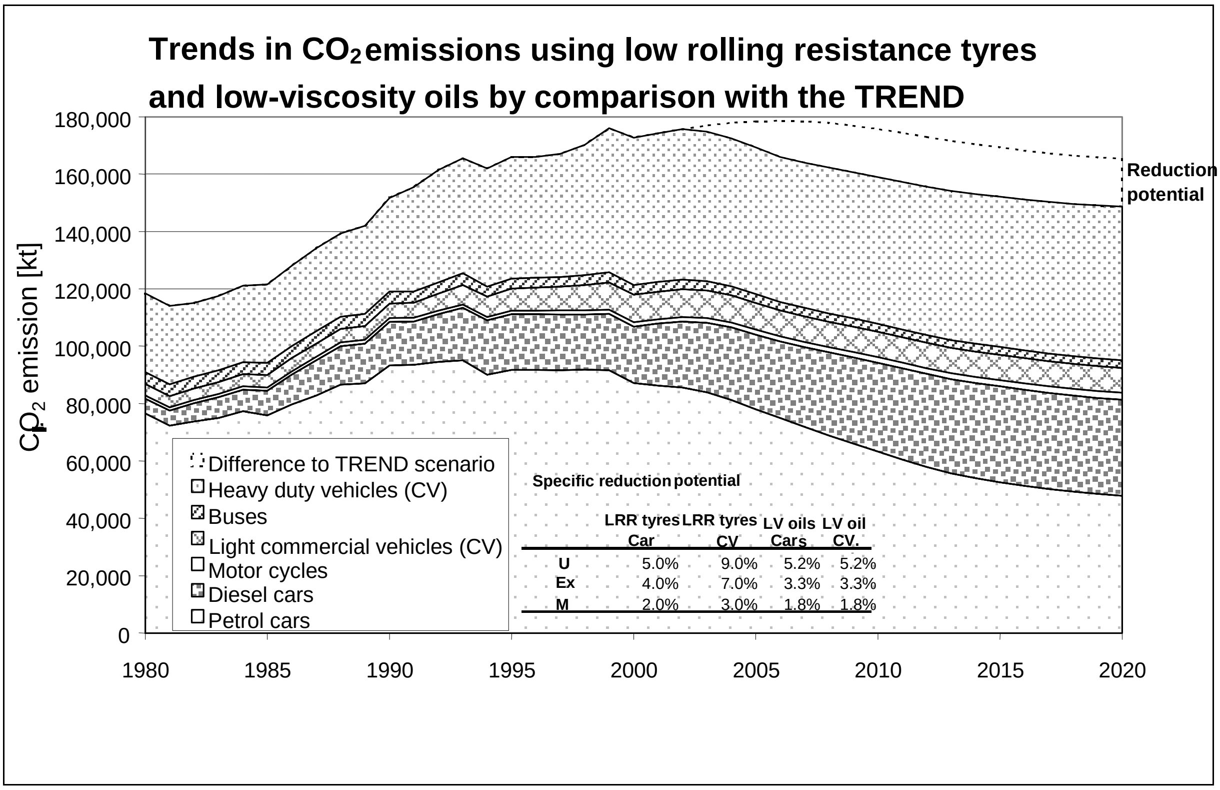

Figure 3: Trends in CO_2 emissions if low-viscosity oils and low rolling resistance tyres were used, by comparison with the TREND scenario

Reduction potential

The influence of different levels of road resistance on energy conversion depends to a great degree on driving patterns. A 20% reduction in rolling resistance reduces fuel consumption by up to 5%, depending on driving speed. The greatest potential is achieved in urban traffic and at average speeds on trunk roads *[SCHEDEL, 2002]*. An even greater potential is assumed for commercial vehicles. Depending on the composition of the route, speed and wind conditions, tyres with optimised rolling resistance can lower fuel consumption in HDV freight transport by 4-12% per vehicle. Based on the specific reduction factors and an introduction period of 4 years to achieve implementation in 90% of cars and 60% of commercial vehicles, reductions of 4.4 million tonnes CO_2 could be achieved in 2005, 5.8 million tonnes in 2010 and 5.4 million tonnes CO_2 in 2020.

The technical reduction potential achievable by using low-viscosity oils and low rolling resistance tyres is summarised in Figure 3.

4.3 Limiting fleet emissions from newly registered cars

In December 2002, the European Commission presented its third annual report on the effectiveness of the Community strategy to reduce CO_2 emissions from cars *[COM 2002/693]*. The results for the reporting period between 1995 and 2001 show that all three associations have achieved reductions in average specific CO_2 emissions. ACEA and JAMA have made greater progress than KAMA. Additional efforts must be made if the final target is to be met, because a reduction rate of 2 % per year on average, or approx. 4 g CO_2/km throughout the entire monitoring period, has not been achieved (actual average for 1995-2001: ACEA: 1.9 %, JAMA: 1.5 %, KAMA: 0.9 %).

The EU Commission declared in *[COM 2002/693]*: “KAMA’s progress is unsatisfactory, although in 2001 it achieved the highest reduction rate so far. There is a real risk that KAMA will not meet its 2004 intermediate target range. This could put the whole approach in danger.” Council conclusions of 16 October 1999 state that the Council invited the Commission “...to present immediately proposals, including legislative proposals, for consideration, should it become clear, on the basis of the monitoring and after consultation with the associations, that one or more of the associations would not honour the commitments made.”

From 2005 it should be possible to estimate whether the target of 140 g/km in 2008/2009 can be achieved in the European Community. At present it is not yet possible to predict whether it will be sufficient from 2008/2009 to continue the existing voluntary agreement or whether it will be necessary to introduce a limit value for CO_2. In order to examine the existing challenges of lowering specific CO_2 emissions from cars and the possible consequences of the conclusions of the Council of 16 October 1999, section 4.3.1 describes a continuation of the existing voluntary agreement on CO_2 and section 4.3.2 the introduction of limit values for CO_2 to be applied to newly registered cars as measures to reduce CO_2.

4.3.1 *Continuation of the car industry’s voluntary agreement on CO_2*

If the existing voluntary agreement (section 4.2) is successful by 2008/2009, the emission targets will gradually be made more stringent. For example, a target of 120 g/km has been proposed for the new car fleet for 2012.

This measure makes it possible to have a direct influence on total car kilometres, driving behaviour and demand orientation. The car manufacturers can use marketing and product ranges to influence the purchasing behaviour of motorists and, through research and development, can create the technical prerequisites for energy saving. A gradual increase of the tax on mineral oil can be used as an additional instrument to influence driving behaviour and vehicle kilometres.

Reduction potential

Since the TREMOD-TREND emission scenario already includes annual tightening of the reduction rates for CO_2 emissions down to an average value of 120 g/km, a quantification of this potential will not be given here.

4.3.2 *CO_2 limit values for new car registrations*

If the target is not achieved by 2008/2009 (section 4.2), a legally binding CO_2 limit value related to an average distribution of consumption rates should be introduced from 2010. In a similar way to the emission limit values for air pollutants, the limit values on these emissions should gradually become more stringent. For example, for 2010 a limit value of 120 g/km has been proposed for the new car fleet and for 2015 of 100 g/km (Figure 4). CO_2 limit values for commercial vehicles and rail transport should be set in the same way.

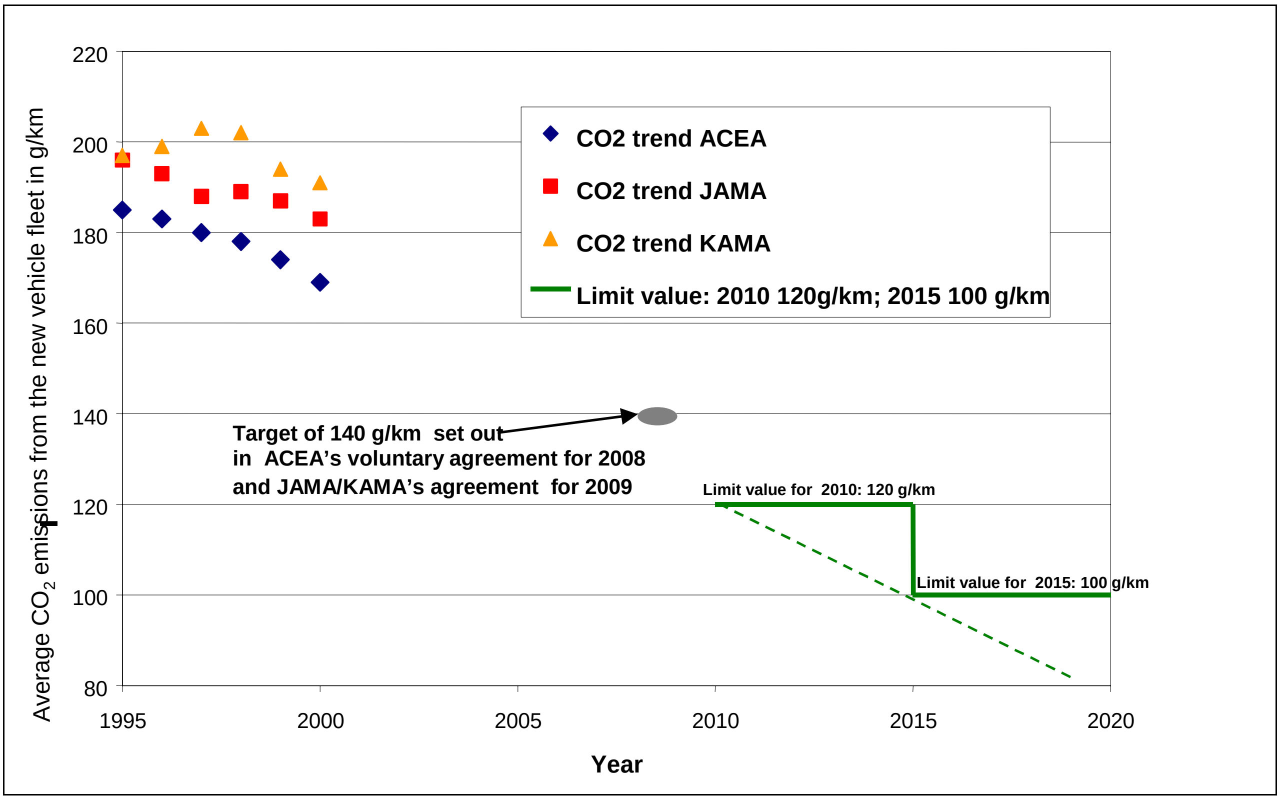

Figure 4: Trends in CO_2 emissions from the new car fleet von ACEA, JAMA and KAMA from 1995 to 2000 *[COM 2001/643]* and assuming introduction of a CO_2 limit value of 120 g/km in 2010 and of 100 g/km in 2015

Reduction potential

The costs entailed in this measure are minimal, since the conditions required to put a monitoring system in place were already created under the voluntary agreements. Working on the basis of the standard scenario and given no change in the sales figures for new cars, introducing limit values in two stages (120 g/km from 2010 and 100 g/km from 2015) would reduce the CO_2 emissions from cars by around 10 million t by the year 2020, which means a reduction of some 6% for road transport as a whole measured against the baseline of the TREND scenario. An introduction of CO_2 limit values should be accompanied by a consumption-related vehicle tax to ensure that the entire vehicle stock develops in the direction envisaged. This would increase the potential CO_2 reduction connected with the introduction of a limit value. Higher vehicle taxes on vehicles with fuel consumption well in excess of the limit values would create incentives for motorists to get rid of old vehicles with high fuel consumption. They would be able to take advantage of the range of lower consumption vehicles in their new purchase.

4.4 Alternative fuels and drive systems

The discussion on use of alternative drive systems and fuels to reduce CO_2 emissions is currently focussing on natural gas, biofuels and hydrogen.

The advantage of natural gas is that it is readily available and technically established; biofuels have – at least theoretically – a high potential for CO_2 reduction, and hydrogen has been identified in the “Verkehrswirtschaftliche Energiestrategie” or Transport Energy Strategy (a government/industry joint project) as the “fuel of the future.” Apart from these three options, many other avenues for alternative fuels could be explored, but, according to our current level of knowledge, none of them offer any fundamental advantages over these three.

We shall confine our consideration of alternative drive systems to electric and fuel cell vehicles.

Concepts such as hybrid drive technologies are to some extent classified as “alternative.” Ultimately, these systems are the refinement of conventional drive systems with the aim – as with other technical measures – of lowering emissions and consumption. Measured against current levels, consumption could be reduced by about half. Above all, these vehicles can be operated using the existing supply network and infrastructure. The same applies to other energy converters such as steam turbines or Stirling engines.

Natural gas has a 20% lower CO_2 emission factor by comparison with petrol and diesel fuel. However, this advantage is offset to some extent by the lower energy efficiency in the engine compared with modern direct injection petrol and diesel vehicles.

Furthermore, the average distances over which natural gas has to be transported will rise in the medium term because most of the deposits that are likely to last longer are in Russia.

This leads to higher losses during transportation and through leakage. Natural gas or methane has a 21 times greater impact on climate than CO_2 seen over a period of 100 years.

Overall the use of natural gas in transport has virtually no potential for reducing climate gases compared with diesel and petrol fuel.

Biomass can be processed in gasification and other plants into gaseous or liquid fuels. Currently **biodiesel** is the only biofuel used in Germany in any significant quantity. To be more specific, this biodiesel is rapeseed methyl ester (RME).

At the conference on biofuels organised by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Environmental Agency on 26/27 June 2003 *[BMU/UBA, 2003]*, the conclusion was reached that using biomass for energy generation was expedient on climate protection grounds. Biofuels such as RME help to achieve the federal government's climate targets and increase public acceptance of the use of renewable resources. In the medium to long term, other biofuels (e.g. synthetic fuels) have additional potential. However, in future the use of biomass in the fuel market will be facing tougher competition from heat and electricity generation because ambitious goals are also being pursued in this sector. The political framework should therefore be designed in such a way that ecologically and economically efficient options for using biomass for energy purposes are enhanced and the competition between the areas of application is developed.

For biofuels based on vegetable oil and bioalcohols (from fermentation), sound life cycle analyses are available for current cultivation conditions by comparison with fossil fuels. They come to the following conclusions *[BMU/UBA, 2003]*:

- *Energy and climate gas balances are positive,*
  N_2O emissions have been taken into account
- *When looking at acidification and eutrophication,*
  biofuels almost always have a negative overall impact.
- *For photochemical smog, ozone depletion and toxicity*
  there is no clear direction.
- *If conservation of resources and climate protection are a high priority,*
  biofuels always compare positively with fossil fuels.
- *Life cycle analyses point up fields of political action*
  involved in the manufacture and use of biofuels.

With regard to the fundamental aspects of the biofuel options RME, bioethanol and Fischer-Tropsch fuels, *[BMU/UBA, 2003]* stated that:

- *RME has no far-reaching development potential,*

- *In the case of ethanol, Germany has a problem in supplying feedstock, and*
- *Fischer-Tropsch fuels from biomass have great potential in terms of quantities but are not available in the short term and require further research.*

Battery electric road vehicles have repeatedly received backing in the past – including for environmental reasons. Apart from their undisputed benefits of being emission-free at point of use, they did not fulfil other expectations.

Above all, it has clearly emerged that, due to the high CO_2 emissions from the generation of electricity, no reductions in CO_2 can be expected in the current situation compared with conventional drive systems. However, ultimately the practical introduction of these "pure" electric vehicles failed because the problem of energy storage could not be satisfactorily resolved. Here there are no technological "breakthroughs" in sight, particularly in terms of weight, price and battery lifetime.

The problem of energy storage in electric vehicles can be solved by the **fuel cell (FC)**. Fuel cells generate the required energy directly in the vehicle from chemical energy sources such as methanol or hydrogen. The outstanding features of this concept are its high-energy efficiency (particular when hydrogen is used), zero emissions at point of use and acceptable ranges.

However, when considering the entire energy chain, there are no clear CO_2 savings compared with efficient conventional drive systems if primary energy is supplied from fossil sources. In the meantime there is a broad-based consensus that FC drive systems are beneficial in terms of climate protection only if the fuel supply is regenerative.

The use of **regenerative energy** in transport must be analysed in the context of the overall energy system. Particularly for regenerative sources of energy that are available in the form of useful electrical energy,[3] the result is unequivocal:

[DLR, WI, 2002] explains comprehensively why replacing conventional electricity in the "electricity mix" by regeneratively produced electricity reduces CO_2 2-3 times more than replacing fossil fuels in transport by hydrogen electrolysis, for example, by the same proportion of regenerative electricity.

[EST, IEEP, NSCA, 2002] gives more detailed explanations: regenerative sources of energy that do not necessarily produce electricity in the energy conversion chain are to be regarded differently, biomass being primarily to be mentioned here. This makes the situation more complex due to the diverse range of possible uses. However, from the point of view of climate protection, stationary use should be given preference over use for fuel production for transport.

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[3] As is very clearly the case for photovoltaics, for example. However, in practice wind and solar-thermal power plants generate almost exclusively useful electrical energy.

The advantage of stationary use over fuel production will be cancelled out both for regenerative electricity and for use of biomass only when a high level of penetration of the stationary sector by regenerative sources of energy is achieved (>50%). Even in the most optimistic and ambitious energy scenarios *[DLR, WI, 2002; EST, IEEP, NSCA, 2002]* this is not expected before 2030.

Reduction potential

The regenerative production of fuels naturally offers a high potential for reducing CO_2 emissions. In favourable scenarios based on regenerative electricity production and hydrogen electrolysis, virtually CO_2-free fuel supply is possible. But, even with fuel production from biomass, new concepts such as thermochemical gasification of whole plants, make reductions in climate gases conceivable.

Directives from Brussels requiring Member States to make greater use of biofuels and other regenerative fuels will lead to an increased use of these sources of energy in the transport sector. The potential for reducing greenhouse gases that can be quantified today for German cultivation conditions using fuels based on vegetable oil (biodiesel) is, as explained above, very low and not sufficient to achieve the EU target of 5.75% biofuel share set for 2010. For conditions in Europe as a whole (eastern enlargement of the EU) and new technologies (use of whole plants, thermochemical biomass gasification), considerable potential is conceivable, but it is not currently possible to quantify it.

An analysis of the overall energy system in *[DLR, WI, 2002]* comes to the following conclusion: “However, today and in the foreseeable future, it seems to make more sense to use regeneratively produced electricity directly, since in this way a significantly greater reduction of CO_2 can be achieved in the foreseeable future (...). Similarly, this also applies to the greater efficiency of using biomass for energy generation rather than as fuel. (...) Under conditions that move towards developing a system that is generally sustainable, the use of hydrogen in transport [will] not be ecologically competitive until 2040.”

This assessment is confirmed by *[EST, IEEP, NSCA, 2002]*: “Even if electricity from renewable sources of electricity were contractually committed to hydrogen supply, there would be a requirement for more electricity from fossil sources for other uses. Similarly biomass can be used for heat and power as well as transport fuels and so a similar issue regarding optimum use arises. (…) Owing to the expected level of penetration of renewables into the electricity system, production of electrolytic hydrogen for transport is not likely to be an effective way of using renewables to save carbon until at least 2030.”

5 Consumer behaviour

Choice of mode of transport, vehicle purchasing and vehicle usage all have potential for reducing CO_2 that should not be ignored. For example, the consumer can be encouraged to use public transport through individual marketing techniques. The financial investment involved, which is about 10 € per individual consultation, can be offset by the higher revenue enjoyed by public transport. Motorists can also make significant contributions to lowering CO_2 emissions. New vehicle technologies that allow driving in higher gears, combined with the rise in the number of vehicles on the road, justify using measures to promote fuel-saving driving behaviour.

5.1 Providing consumer information

Fundamentally, it makes sense to support the consumer in the choice of a vehicle that is as environmentally sound as possible. The consumer should give preference to small, light vehicles that are tailored to their particular needs. Ratings lists are updated annually and published by the Verkehrsclub Deutschland *[VCD, 2003]*.

To facilitate easy understanding of the consumption values of different vehicles, the federal government was obliged to implement into national law by 18.01.2001 EC Directive 1999/94/EC relating to the availability of consumer information on fuel economy and CO_2 emissions in respect to the marketing of new passenger cars. This information must be presented in a way that is easily legible and simple for all consumers to understand, with the aim of encouraging sales of models of vehicle that have better consumption.

As a basis for introducing a labelling system to enable fuel consumption for cars to be compared, a consumption or CO_2 index is to be introduced, which will relate to the surface area of the vehicle (litre/[100km*m²] or g CO_2/[km*m²]). This value will be placed in relation to the average index, a linear moving average, for the vehicles on sale in Germany in the previous baseline year.

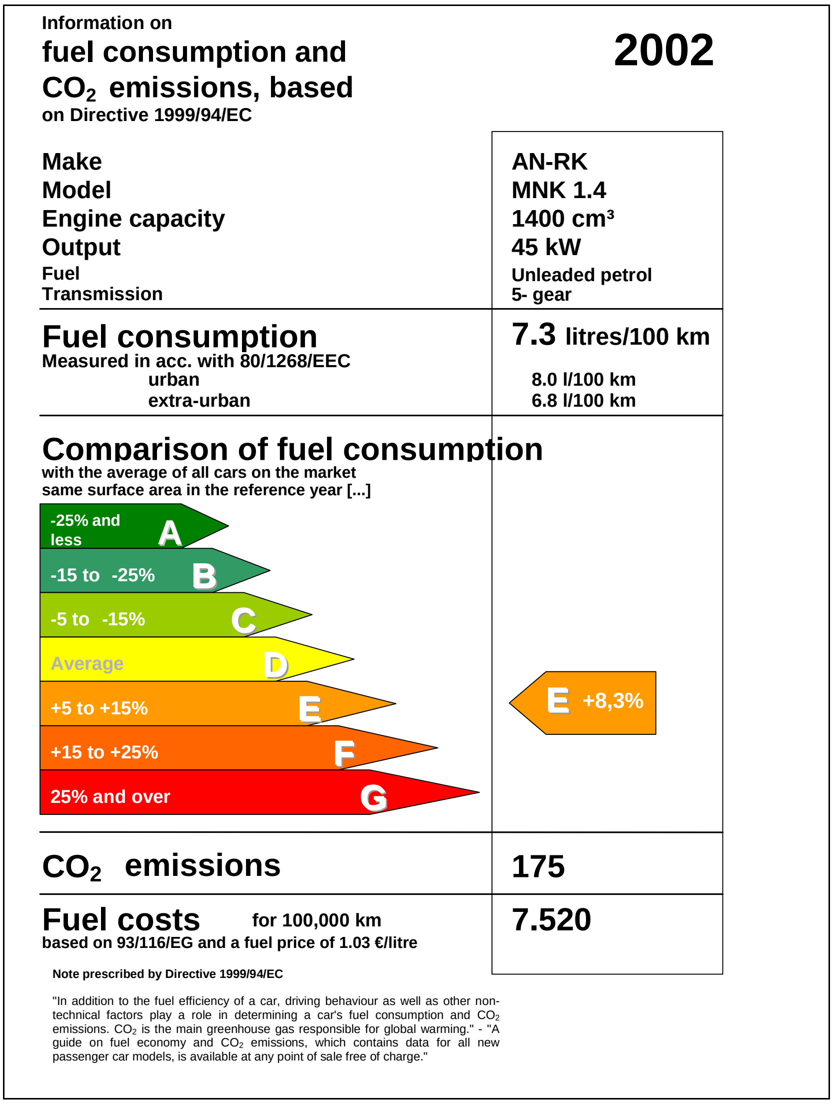

Figure 5: Draft CO_2 label

The relative deviations from the average value will be categorised into 7 efficiency bands (A, B, C, D, E, F, G), ranging from "-25% and less" and "average" through to "+25% and over" (Figure 5). At yearly intervals the average index of all vehicles on sale in Germany in a baseline year should be adjusted, which will automatically mean adjusting the efficiency bands. The public is already familiar with labelling procedures of this kind used in the system of rating white goods (e.g. refrigerator) into energy efficiency bands A-G that are already in use in some Member States. Furthermore, petrol cars and diesel cars must be separately evaluated taking into account differing average indexes. The Motor Transport Authority should be responsible for the processing, the automobile industry for printing and publishing the labels.

Reduction potential

Within 10 years the introduction of energy efficiency bands A-G for cars could bring about a four to five per cent reduction in fuel consumption and CO_2 emissions for the entire car fleet *[EVA, 2000]*. This is equivalent to a reduction of some 4 to 5 million tonnes CO_2 in 2013 (2010: 2.9-3.6 million t). The Allgemeiner Deutscher Automobilclub (ADAC – German motoring association) currently provides information on the efficiency bands *[ADAC, 2003].*

5.2 Promoting fuel saving through economical driving

Changing the technical characteristics of a vehicle is not the only way to influence energy consumption in the transport sector; individual use behaviour and driving style are also important. For example, an economical driving style can bring about fuel savings of up to 25% per vehicle. The fact that fuel consumption can be influenced by economical driving is not widely communicated to the general public. Vehicle owners' knowledge about their car's actual fuel consumption and its dependence on individual use behaviour is relatively meagre. The public should be given better information about low-emission driving style that is adapted to new engine technologies and should focus on improving the image of low-consumption driving behaviour. Not only would it help save fuel but accident figures would also be improved and noise pollution reduced.

An immediate course of action could be to agree a programme with companies that operate a fleet of vehicles that would include both driver training and ongoing encouragement of low-consumption driving behaviour through bonuses or ways in which the driver would share the economic benefits. To promote driver training for private individuals as well as companies, funding programmes should be developed, which would provide, amongst other things, financial subsidies for training schemes. Technical features in the vehicle, such as standard fitting of consumption displays, would help the driver to save energy. Making fuel more expensive through the tax on mineral oil, or as an effect of emissions trading based on a downstream approach, would encourage widespread adoption of a fuel-efficient driving style. Issuing a voucher for training in economical driving to people buying new vehicles or a reduction in insurance premiums for drivers who have completed this kind of training course would have a positive effect on propagating this style of driving.

Reduction potential

The long-term potential for individual reductions in consumption and CO_2 is 12.0% on average in urban conditions. Extra-urban, the savings potential per car is roughly 6% or 4% for heavy-duty vehicles and buses. On motorways a figure of around 2% is assumed for each category of vehicle. The take-up rate for 2005 for vehicles used commercially is put at 30–40% - markedly higher than for private car use at roughly 10%. This would signify a reduction totalling 2.2 million t CO_2 in 2005. If low-consumption driving behaviour continues to be promoted, a figure of 80-90% for commercial use and 35% for private car use can be expected in 2010. That corresponds to a savings potential of some 5.9 million t CO_2. This could rise to 6.5 million t CO_2 by 2020 (Figure 6).

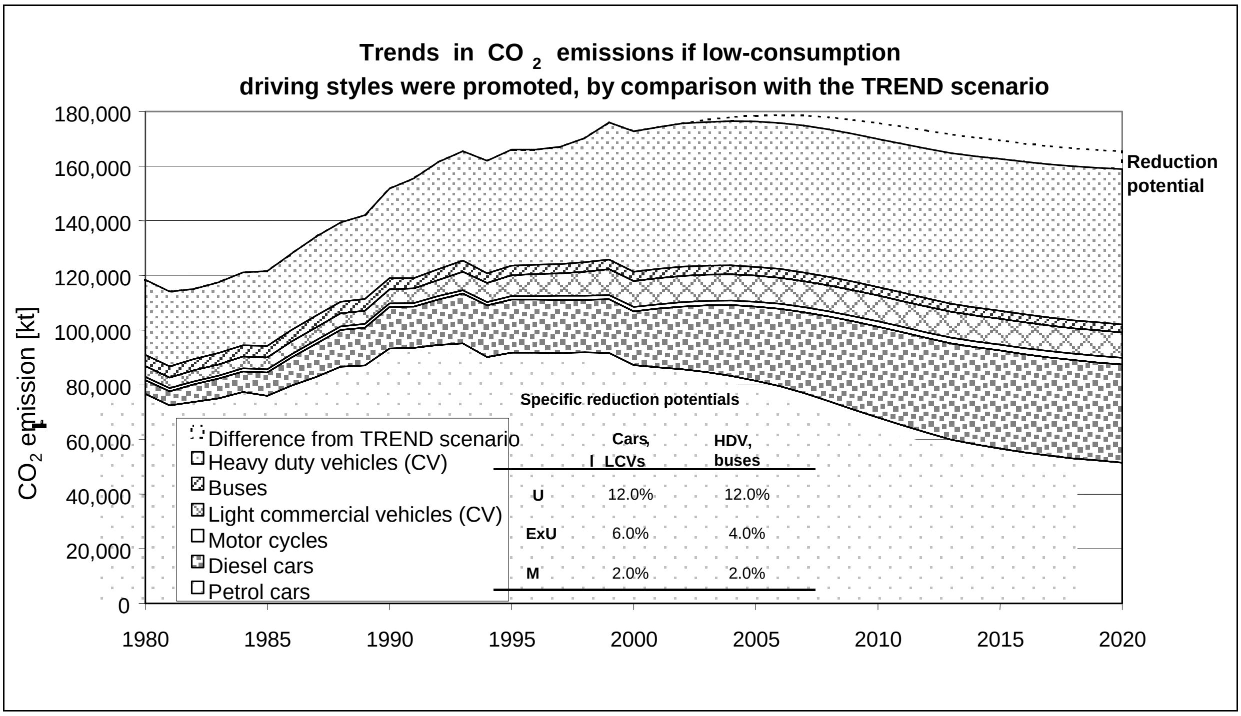

Figure 6: Trends in CO_2 emissions if low-consumption driving styles were promoted

5.3 Speed limits: 80/120 and 80/100 km/h

Approximately 33% of vehicle kilometres would be affected by the introduction of a speed limit. If a speed limit of 120 km/h were introduced, the reductions in fuel consumption for cars on motorways would be around 10% and would lead to a total reduction in fuel consumption of 2%. If the speed limit were set at 100 km/h, reductions would amount to 20% on motorways and 3% for total road traffic.

We shall briefly outline the positive effects of a speed limit *[UBA, 1999]*. Analyses of effects on road safety are readily available in the literature. In terms of practical experience with a speed limit in Germany, we must point out that the number of people killed and severely injured on motorways dropped by around 50% when a speed limit of 100 km/h was imposed on all German motorways between November 1973 and March 1974 due to the oil crisis. These figures were confirmed by the accident trends on a number of motorways in the state of Hessen, on which a speed limit of 100 km/h was enforced between November 1984 and May 1987. The number of accidents involving fatalities or serious injuries per billion vehicle kilometres dropped by between 25% and 50% on the sections of motorway affected *[DURTH, et al., 1989]*. Positive effects on traffic flow and road safety were also demonstrated as a result of speed limits introduced on the A 2 motorway as part of a pilot scheme that ran between 1992 and 1994 (Strassenverkehrstechnik, no. 4/1995). The accident rate (accidents per million vehicle kilometres) dropped by about half in the period under study. In 1984, the Federal Highway Research Institute quantified a speed limit's positive effect on safety. Related to the entire motorway network, if a speed limit of 130 km/h were introduced, a 20% drop in the number of fatalities could be expected, rising to 37% if the limit were set at 100 km/h *[BAST, 1984]*. Since both traffic volume and speeds have increased markedly since then, the relative reduction effects would no doubt be even higher today. More recent studies are not available.

The introduction of a blanket speed limit would also make it possible to reduce the noise pollution caused by cars. With a speed limit of 120 km/h, a reduction of ½ dB (A) can be expected on weekdays and of 1 dB (A) on Sundays. Given a speed limit of 100 km/h, the figures would be 1½ (weekdays) to 3 dB (A) (Sundays). Further effects of a speed limit would arise from the possible reduction in the amount of land used for roads. However, this is not currently quantifiable. Furthermore, it would be possible to use smaller or lower power vehicles and apply the idea of “downsizing” to cars. A 30% reduction in engine output can bring about a 13 to 19% reduction in CO_2 emissions from petrol cars and a 5 to 15% reduction from diesel cars. A 50% reduction in output can reduce CO_2 emissions by 25 to 32%. In addition, narrower tyres could be used, which would contribute to further reductions in CO_2 and a reduction in noise. Tyres for speeds over 200 km/h are up to 3 dB (A) noisier at speeds of 100 to 120 km/h than tyres that are approved for a maximum speed of 150 km/h. That means that a speed limit of 100 to 120 km/h would halve noise emissions. Furthermore, the speed limit would increase the railways’ competitive position, since the arguments of the time advantage for car travel over public transport would only partially apply.

The use of telematics in connection with a speed limit, enforced through control technology, would require additional investment of between 150,000 and 0.5 million € per kilometre. These costs do not take account the operation and maintenance of the traffic control technology. The advantages of technology of this kind are that it enjoys broad-based acceptance. However, it only has an influence on safety aspects but does not lead to any lasting positive environmental effects.

The positive effects on the environment that can be achieved through the introduction of a general speed limit depend essentially on the extent to which drivers adhere to it. The results of calculations presented here are based on a relatively high compliance rate of 80%. To achieve this, past experience has shown that increased efforts would be required (public information and motivation campaigns, monitoring expenditure). Individual drivers would enjoy direct benefits from a speed limit in the form of lower fuel costs due to lower consumption and less wear and tear on the vehicle.

Reduction potential

The average reduction potential has been ascertained as being 10% assuming a speed limit of 80 km/h on trunk roads and 11 to 24% at a speed limit of 120 km/h or 100 km/h on the basis of emission factors given in the “Handbuch für Emissionsfaktoren” (Handbook of Emission Factors).

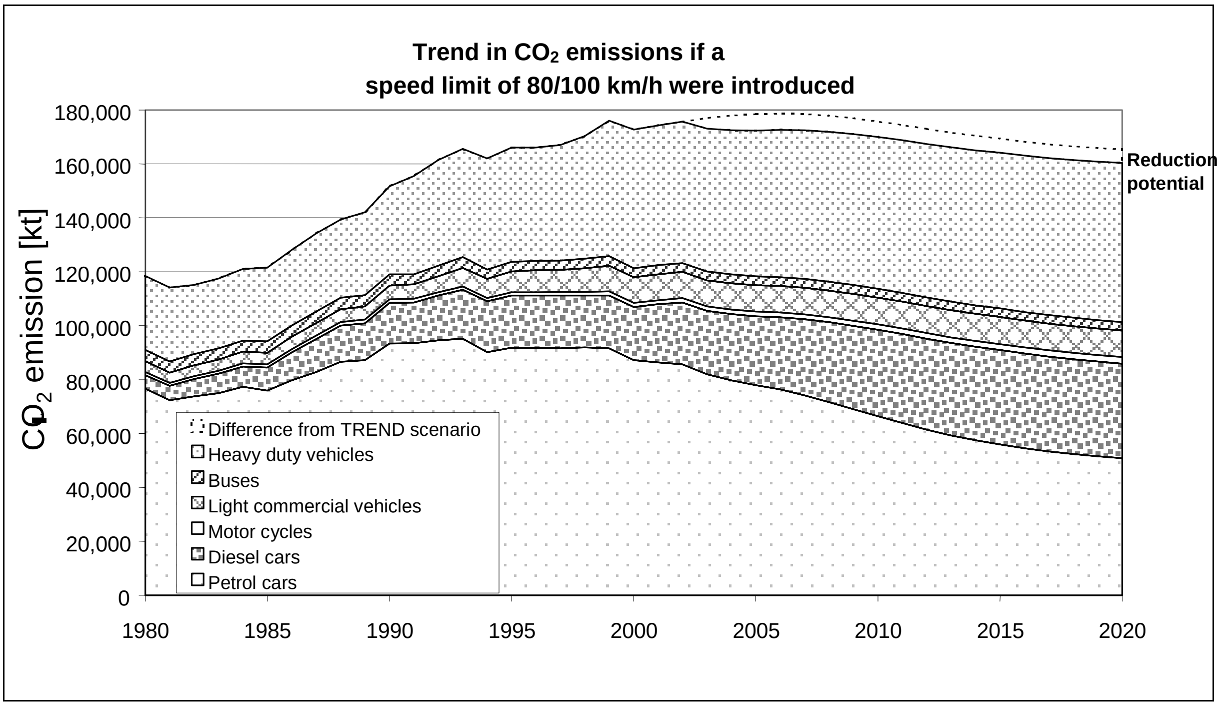

Figure 7: Trend in CO_2 emissions if a blanket speed limit of 80/100 km/h were introduced

Taking into account the fact that the compliance rate has been set relatively high at up to 80%, the extra-urban CO_2 emissions can be reduced by 8% and emissions from cars on motorway journeys by 9% (speed limit of 120 km/h) or 19% (speed limit of 100 km/h). Based on the specific reduction factors and an introduction period of 3 years until implementation in 80% of cars is achieved, reductions of 2.8 (80/120) to 6.1 (80/100) million tonnes CO_2 for 2005, of 2.7 (80/120) to 5.7 (80/100) million tonnes for 2010 and of 2.3 (80/120) to 5.0 (80/100) million tonnes CO_2 for 2020 can be expected (Figure 7).

6 Summary and conclusions

In the following sections, the specific potentials of the measures described are summarised and presented in overall scenarios. Recommendations for action are then developed from that.

6.1 Summary of the individual potentials

Table 5 shows the reduction targets for CO_2 emissions in Germany set in the climate protection programme 2000 *[BREG, 2000a]*. They are supplemented by transport-related emissions from 1990 (baseline) and 2005 (target year), broken down by mode of transport.

The table below also includes the CO_2 emissions expected in Germany in 2010 in the TREND scenario, which are compared with the potentials that are achievable in the medium term.

Table 5: Summary of CO_2 emission reduction targets (2005) and CO_2 emissions (1990, 2005, 2010) in the TREND scenario in Germany

Emission reduction targets for 2005 as compared with 1990 *[BREG, 2000a]*			
CO_2 emissions reduction target set by federal government		25%	
CO_2 reduction shortfall overall		50-70 million t	
CO_2 reduction shortfall for the transport sector		15-20 million t	
Emissions based on TREND scenario (all figures in million tonnes CO_2)			
	1990	**2005**	**2010**
Road transport	**151.8**	**175.0**	**174.8**
private motor transport	109.8	110.0	106.7
bus	4.1	3.3	3.2
light commercial vehicles	5.1	9.5	9.8
heavy-duty vehicles	32.7	52.1	55.1
Rail transport[1)]	**13.1**	**9.2**	**8.4**
rail passenger transport	8.3	6.8	6.3
rail freight transport	4.8	2.4	2.1
Inland shipping	**2.1**	**0.9**	**1.0**
Air transport	**14.2**	**26.4**	**31.8**
Overall	**181.2**	**211.4**	**215.9**

1) Rail transport including upstream processes (power supply)

Table 6 shows an overview of the individual measures for reducing CO_2 emissions. A final categorisation and evaluation of the results on the basis of a defined overall scenario can be found in section 6.2.

Table 6: Summary of individual measures and their potential for reducing CO_2 emissions (2010) in Germany. (It is not possible to arbitrarily add together individual potentials)

Reduction of emissions by measures 2010 (all figures in million tonnes CO_2)		
Environmental transport planning		
Promotion of regional economies	No data	No data set
Low-transport settlement structures	No data	Complex interactions
Low-transport production structures	No data	Local examples not transferable
Promotion of environmentally sound modes of transport		
Rail freight transport	8.4	Switch: rail: +48%, road -18%
Long-distance rail passenger transport	0.6	Switch: rail: +11%, road -2%
Local rail passenger transport	0.4	As for long-distance rail pas. transport
Efficient public transport	1.3	5% urban car journeys transferred, 24% increase in rail pas. transport
Use of telematics, urban	1.2	
Use of telematics, extra-urban	1.4	Freight logistics management
Cycling and pedestrian traffic	1.8	5% urban car journeys
	3.5	10% urban car journeys
Car sharing	1.2	Reduction in VMT of 7 billion km
Monetary measures		
Charges and taxes on air transport	3.5	
Toll for heavy-duty vehicles on motorways and	0.1	15 cents/km on motorways
trunk roads	3.3	Toll based on Swiss model
Eco-tax (continuation 2004-2008)	4.0	Initial estimate
CO_2-related vehicle tax		
for cars, light commercial vehicles	3.8	
Phase out tax breaks for cars	No data	Not possible to quantify
Adjustment of taxes on mineral oil (petrol, diesel)	+/- 0.0	Different effects balance out
CO_2 trading in the transport sector	No data	Cannot be quantified at present
Technical optimisation of modes of transport		
Reduction in consumption for railways	No data	Specific emissions reduction of 19-27% already in TREND scenario
Reduction in consumption for buses	0.3-0.5	Engineering, tyres, oil, driver
Reduction in consumption for cars, LCVs, HDVs		
use of low rolling resistance tyres	5.8	
use of low-viscosity oils	5.2	
Continuation of voluntary agreement	No data	Specific emissions of 120 g/km (2012) already in TREND scenario
CO_2 limit value from 2010 (newly registered cars)	0.0	Potential 2020 approx. 10 million t
Alternative fuels and drive systems	<0.1	No effect on CO_2 before 2030
Consumer behaviour		
Provision of consumer information	2.9-3.6	A-G energy rating system only
Promoting fuel-efficient driving style	5.9	
Speed limits		
Extra-urban/motorway 80/120 km/h	2.7	
Extra-urban/motorway 80/100 km/h	5.7	

6.2 Overall CO_2 scenario for 2010

The summary of the measures package is intended not only to take into account the quantified potentials, but also to emphasise those measures that have the best cost/benefit ratio. The cost/benefit ratio can be described as follows:

- The benefit is described by the potential for reducing CO_2 emissions. The monetary benefit consists in the contribution a measure can make to avoiding damage to the world economy by climate change.
- Since a reduction in CO_2 emissions is normally connected to a reduction in consumption and fuel costs, it also brings about financial gains (Table 7). On the basis of current fuel costs, *[OILBULLETIN, 2003]* has calculated that a reduction in CO_2 of one million tonnes would for car users bring about a pre-tax cost saving of 130-150 million €. Depending on tax rates, reducing CO_2 by one million tonnes could cut costs for car users by 360-500 million €.
- A quantification of the transaction costs of the measures has not yet been carried out. However, many measures can be put in place without any additional costs (e.g. low rolling resistance tyres) or at only minimal extra cost (e.g. driver training, speed limits).

Table 7: Description of the avoidance gains resulting from reducing CO_2 emissions *[OILBULLETIN, 2003]*

Price basis		**Basis: taxed fuels**		**Basis: non-taxed fuels**	
		Petrol Eurosuper	Diesel	Petrol Eurosuper	Diesel
Price per litre	€/litre	1.16	0.95	0.34	0.35
CO_2 emission per litre	kg/litre	2.33	2.62	2.33	2.62
Saving a million tonnes of CO_2 saves fuel costing		**496.05 million €**	**362.19 million €**	**146.85 million €**	**132.42 million €**

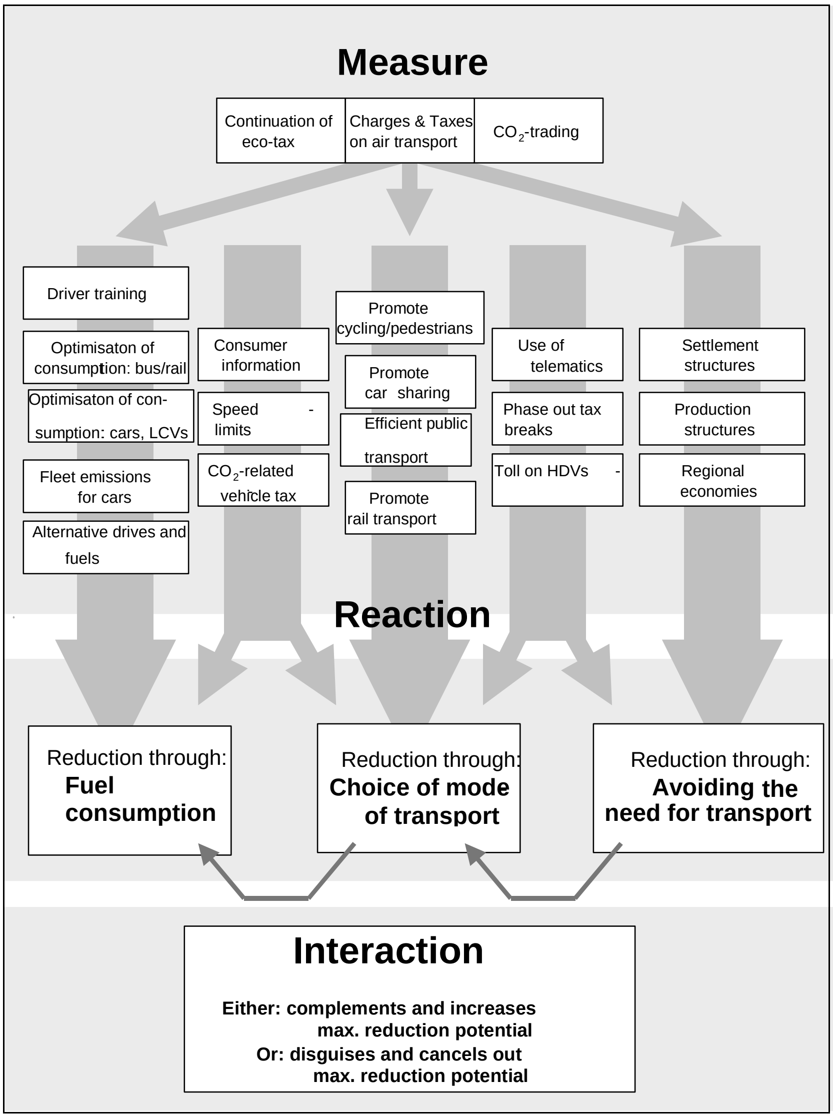

Figure 8: Overview of possible measures for reducing CO_2 emissions and categorisation of the key reactions

Possible measures for reducing CO_2 emissions in the transport sector are once more summarised in Figure 8. In response to the measures described in this report, a reduction can be brought about by avoiding generation of transport needs and by influencing choice of transport mode – resulting in a reduction in the volume of traffic in road transport – and by cutting fuel consumption. When evaluating the individual measures in the overall scenario, it is important to take their interaction into account because the measures can either complement each other and increase the reduction effect, or cancel each other out.

On the basis of the individual measures for reducing CO_2 emissions from transport described in this report, an effective overall scenario will now be drawn up, taking interactions into account.

Summary of the package of measures

In putting together the package of measures, we first of all:

1. Identified the measures with the highest reduction potential. These were then divided into:
   a) Cross-cutting basic measures, and
   b) Follow-up measures for reducing CO_2 emissions.

The basic measures are essential, because without them it would either not be possible to implement the follow-up measures to the required degree, or they would not be as effective.

2. Furthermore, it is necessary to put the follow-up measures into a logical order in order to be able to take possible interactions into account.
   a) First, a balance sheet was drawn up for those measures that are related to reducing the number of vehicle kilometres in the road transport sector.
   b) The remaining measures that have the effect of reducing consumption were then successively incorporated into the model and quantified taking possible interactions into consideration.

The scenario is divided into sub-packages. It is not possible to arbitrarily omit or substitute sub-packages, since that would necessitate recalculating the overall scenario. The following paragraph describes the modelling approach in more specific detail. The results are compiled in Table 8.

Basic package

The basic package comprises the cross-cutting measures that will trigger a reaction. They act as an incentive for implementing the packages of follow-up measures (1-6):

I) Continuation of eco-tax
II) Toll system for heavy-duty vehicles

The basic package also includes measures that create the structural conditions required to avoid generating transport demand and have a particular impact on measures package 1 below.

III) Promotion of settlement and production structures that do not generate demands for transport
IV) Regional economies

The potentials for reducing CO_2 emissions are not separately mentioned for the measures in the basic package, because their main effect is to support the measures packages through their interaction. This avoids counting the reductions in CO_2 emissions twice over.

Package 1

First of all those measures are identified that,
a) Lead to a reduction in vehicle kilometres in road transport,
b) Have a high reduction potential, and
c) Can be connected additively.

→ The reduction in the total vehicle kilometres from road transport and the reduction in CO_2 emissions are quantified.

Package 2

The reduction in vehicle kilometres brought about by modal shifts and in CO_2 emissions from road transport form the basis for further fundamental technical measures that can be introduced at the same time, such as low rolling resistance tyres and low-viscosity oils.

→ The reduction in CO_2 emissions is quantified
and forms the basis for further measures.

Package 3

Based on this, the effect of imposing a speed limit is quantified. The measure chosen is a speed limit with the maximum potential for reducing CO_2 emissions (80/100 km/h).

→ The reduction in CO_2 emissions is quantified
and forms the basis for further measures.

Package 4

Based on this, the potential connected with promoting fuel-efficient driving is estimated in a way that ensures that multiple quantification in connection with the measure in the previous package 3 is ruled out.

→ The reduction in CO_2 emissions is quantified
and forms the basis for further measures.

Package 5

CO_2-related vehicle tax (cars) is now evaluated as a measure that has a cross-cutting effect on the vehicle stock and on resulting CO_2 emissions.

→ The reduction in CO_2 emissions is quantified.

Package 6

Finally, those measures are evaluated for which a balance sheet can be drawn up independently from the interactions described. These include
a) Technical optimisations on buses that are simple to carry out
b) Charges and taxes on air transport

→ The reduction in CO_2 emissions is quantified.

The CO_2 overall scenario shows that through an effective combination of different measures for reducing CO_2 emissions a total of 40.5 million tonnes CO_2 can be saved in Germany by 2010.

Table 8: Results of the overall scenario for CO_2 for 2010

Overall scenario for CO_2 for 2010 (all figures in million tonnes CO_2)		
Measure	***Reduction in CO_2 emissions***	***Proportional contribution of individual package to the overall scenario***
Basic package:		
Continue eco-tax	Prerequisite for packages 1-6	
Toll system for heavy-duty vehicles	Prerequisite for packages 1-6	
Promotion of low-transport settlement and production structures	Prerequisite for package 1	
regional economies	Prerequisite for package 1	
Package 1:		
Promote rail freight transport	8.4	21%
Promote rail passenger transport[1)]	0.7	2%
Efficient public transport[1)]	1.3	3%
Bicycle and pedestrian transport[1)]	3.5	9%
Package 2:		
Low rolling resistance tyres	5.1	13%
Low-viscosity oils	4.6	11%
Package 3:		
Speed limit 80/100	5.4	13%
Package 4:		
Promote economical driving[2)]	4.7	12%
Package 5:		
CO_2-related vehicle tax (cars)	3.2	8%
Package 6:		
Technical optimisations to buses[3)]	0.1	0%
Charges and taxes on air transport	3.5	9%
CO_2-overall scenario	***40.5***	***100%***

1) Measures to promote environmentally friendly modes of transport
2) Cars, commercial vehicles, buses including regular buses
3) Training for bus drivers (0.2 million t CO_2) are included in measures package 4; low rolling resistance tyres, low-viscosity oils (0.1-0.15 million t CO_2) are included in measures package 2

6.3 Conclusions

It has been demonstrated that implementation of various measures can lead to a 19% drop in the level of emissions expected in the TREND scenario for 2010. This would mean that the starting level of 1990 could be achieved or even bettered by 3%.

It will scarcely be possible to close the deficit of 15-20 million tonnes CO_2 in 2005 *[BREG, 2000]* (Table 5). Nevertheless, reductions in emissions of around 40.5 million tonnes CO_2 can be achieved in the medium term, provided that the following essential measures are put in place without delay:

- Continue eco-tax
- Bring the toll on heavy-duty vehicles up to the level of Switzerland
- Promote low-transport settlement and production structures, regional economies
- Provide consumer information
- Promote rail freight transport
- Promote environmentally friendly modes of transport (public transport, pedestrian, cycling)
- Low rolling resistance tyres and low-viscosity oils
- Speed limit (80 km/h on trunk roads and 100 km/h on motorways)
- Promote economical driving behaviour
- CO_2-related vehicle tax for cars
- Charges and taxes on air transport

The potential mentioned can only be fully exploited if all measures identified are pursued with equal priority in the transport sector. Only then will it be possible to reduce emissions of climate gases in the transport sector to an acceptable level.

Provided that the eco-tax is continued and the toll on heavy-duty vehicles is raised to the Swiss level, the intensive promotion of rail freight transport will make a considerable contribution of over 20% to the overall scenario. This is due to the fact that volumes in road freight transport are currently rising sharply and will continue to do so. One of the main focuses of any successful climate protection policy must therefore be promoting rail freight transport.

All further measures make the same contribution of around 10% to the potential for reducing CO_2 emissions in the overall scenario described. It is therefore not possible to single out any further individual measures for reducing CO_2 emissions from the overall package. Similarly, individual measures cannot be pursued with less intensity or ignored entirely.

In the overall scenario described, the potentials for lowering fuel consumption have been largely exhausted. By contrast, the reduction in vehicle kilometres in road transport through the selected measures is only 8%. Here other possible starting points are revealed with which the CO_2 emissions from transport can be reduced beyond the extent of the overall scenario.

For example, SCENARIO 2 of the federal government's Transport Report 2000 shows that an increase in the volume of traffic in rail transport by further 12% (freight transport) to 20% (passenger transport) by comparison with SCENARIO 1 with a corresponding reduction in road kilometres of between 5% (freight transport) and 9% (passenger transport), could save a further 5.6 million tonnes CO_2. This corresponds to a further reduction in CO_2 from transport of 3 percentage points.

In the medium to long term, far higher potentials could be exploited by consistent low-transport settlement planning which, through compact settlement structures, a good mix of functions, provision of shopping, services and recreational facilities and work opportunities close to where people live, keeps daily trips short, focuses regional development along public transport corridors and optimises new business locations on the basis of transport criteria. More attention must be given to ensuring that regional economic development does not have the effect of generating traffic.

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