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Strategies for Reducing CO_2 Emissions in the Transportation Sector

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Executive Summary

- With a share of 25 % in Europe and around 20 % in Germany, the transportation sector is one of the main emitters of carbon dioxide (CO_2). Transport-dependent CO_2 emissions are expected to increase over the next decades. The substantial drivers are the growth in air transport, international maritime transport and road freight transport.
- Utilizing the most recent data available, this report identifies key areas that require action and offers several recommendations:
- The Board of Academic Advisers to the Federal Minister of Transport, Building and Urban Affairs recommends adopting a two-part strategy: on the one hand, support of the post-Kyoto strategy and similar efforts to achieve an international Emissions Trading Scheme (ETS) that addresses CO_2 emissions in all sectors; on the other hand, identification and development of specific instruments to mitigate or reduce transportation emissions over the short- and medium-terms.
- We also recommend a European harmonization of the taxes and other duties on petroleum products and an alignment of the taxation of petrol and diesel.
- The Board of Academic Advisers further recommends expanding the road toll for road freight transport. The charges should be mainly based on vehicle weight.
- The substitution of fossil fuels by second-generation biofuels is basically reasonable, but the Board of Academic Advisers acknowledges the political and economic risks associated with the production and implementation of second-generation biofuels.
- We support more rapid integration of air transportation – including international flights – and of international maritime transport into the European ETS. Furthermore, SABT recommends an accelerated implementation of the Single European Sky (SES) mechanism in order to reduce CO_2 through improved airspace coordination.
- The Board of Academic Advisers recommends using urban development and land use mechanisms to reduce transportation volume and performance and encourage the transition to environmentally benign systems of transportation.
- In addition to technical and pricing instruments behavioral changes can be achieved by additional measures, taking advantage of the high public awareness of climate change. Essential for their success is the reliability of environmental political goals and programs.

Major Findings

1. Climate change is one of the major challenges of the coming decades and centuries. The G8 summit in Heiligendamm emphasized the willingness of the leading nations to implement CO_2 reducing actions and to retain fixed target values. The European Union has defined the reduction target to be 50% by 2050 and 20-30% less by 2020 based on 1990 figures, depending on the willingness of other countries to participate. The German Federal Government is willing to seek an additional 10% reduction in these target values. This requires significant efforts of all emitting sectors. With regard to transport policy the questions arise to which extent transportation should contribute to achieving the targets, and which measures are most advantageous for the transportation sector. There are reduction potentials in the transport sector that can be realized economically, but these are smaller than in other sectors of the economy. From an economic viewpoint, establishing different targets for the sector's varied polluters based upon specific avoidance costs is one recommendation.

2. Climate change is a global problem and requires global solutions. In the long-term reductions in CO_2 will only be achieved with international coordination. The three potential approaches to reach targeted goals are: 1. limit values for CO_2 enforced through legal regulation/administration; 2. coordinated global carbon taxation; 3. global trading of CO_2 emission certificates. This last measure offers the possibility of accounting for the situations of developing countries and emerging nations through the initial allocation of emissions rights (e.g., uniform distribution of the emissions rights per head). Assigning the country or sector with the appropriate CO_2 reduction would be solved according to the market principles in the sense that the greatest emitters purchase additional emissions rights. In addition, a cross-sectoral internalization of the external climate costs of transport can be achieved. Defining the most economically efficient measures would be clarified according to market principles. We note, however, that an efficient and transparent global institutional framework will be required to define the CO_2 emission caps, to administer and regulate certificate trading, and to control the emitters.

3. Meeting both long-term objectives and short-term requirements call for a two-part strategy. International efforts supporting the post-Kyoto strategy must be strengthened. Thus, it is necessary to define European-wide and national targets for 2050 and earlier. Global trading of emissions rights and the Clean Development Mechanism (CDM) need further development. The WTO-conforming border tax adjustments must be analyzed with regards to international competitiveness. On the other hand, transport-specific instruments that are already effective in the short and medium-term have to be employed. This report focuses on such specific measures.

4. According to the final report of the IPCC (November 2007), CO_2 reduction measures must be able to be implemented at short notice in order to limit the global temperature rise. This justifies the

proposed two-part strategy recommended by the Board of Academic Advisers, with its supplementing short and medium-term instruments. The transport sector emits approx. 25 % of total CO_2-emissions in Europe and accounts for approx. 20 %, of Germany's CO_2-emissions. Due to its dynamic growth the transportation sector needs to contribute to a significant CO_2-reduction. Since no single measure will achieve the established global targets alone, a bundle of instruments has to be defined that is economically efficient, ecologically effective and socially compatible. It needs to be considered that some transport subsectors show strong growth rates (aviation, maritime transport, road freight transport), while other subsectors (passenger transport in developed countries, also in Germany) show saturation. A differentiated treatment of the subsectors is required, as they imply different abatement options and also different abatement costs.

5. Currently, air transport contributes approximately 3% to global CO_2 emissions, but these emissions constitute scarcely half of the air sector's relevant influences overall, according to present knowledge. Air transport is subject to stringent economic incentives, but so far there are only small fiscal incentives for consumption and emission reductions. However, effectiveness of this measure requires distribution of emission rights to a large extent by auction, inclusion of inter-European flights and that certificate prices reach a relevant order of magnitude. International co-ordination will be crucial to the successful ETS implementation because long-distance flights often permit "bypassing" Europe. Encouraging national air transport control organizations to convert to the Single European Sky may result in CO_2 -reductions of up to 12% by avoiding detours according to the IPCC.

6. Currently, maritime transport contributes approximately 3% to global CO_2-emissions. It should be noted that this sector is a heavy polluter because propulsion technology and used fuels are not subject to environmental regulations, and the sector lacks economic incentives for emissions reduction. Similar to air transport maritime participants operate internationally, making national measures mostly ineffective. The EU could mandate CO_2 charges at continental ports, although there will be difficulties in implementation.

7. Road transport accounts for 18% of global CO_2 emissions. Currently, the EU levies ownership and mineral oil taxes, and an additional eco-tax in Germany We suggest cross-country harmonization of taxes and deliveries on all petroleum products as well as adjusting gasoline and diesel taxes to separate the incentives for new technology development from the fuel type. In a long-term perspective, substitution of fuel by technology should be targeted. Other ways to reach emissions reduction targets include altering the assessment basis for the ownership tax from the present combination of cylinder capacity and emission standards to standardized fuel consumption. The limit value definition for passenger car emissions – in average 130 g CO_2/km by the year 2012 – is seen

critically: False incentives and counterproductive effects can hardly be avoided when it comes to concrete implementation.

8. Road freight transport in Germany contributes approximately a third to total road transport emissions. The potential of CO_2 reductions in this subsector through behavioral modification (e.g., vehicle choice) is limited in comparison to road passenger transport, since the actors already plan their vehicle procurements and replacements according to purely economic criteria. Differentiated ownership taxation and tolls differentiated by the vehicle weight (so far tolls are predominantly differentiated by euro-classes that still lack CO_2 reference) can affect the vehicle demand. An expansion of the tolls to additional road and vehicle categories may create economic incentives to improve both passenger and freight performance. An expansion of the tolls on further road and vehicle categories creates incentives to reduce truck mileage.

9. Currently, rail transport contributes approximately 1% to transport emissions. The transportation of cargo by rail is on average approximately two thirds lower in CO_2 emissions than road freight transport, so that a shifting of transport from road to rail (and to inland waterways where possible) becomes reasonable. Rail transport also offers greater potential for efficiency improvements due to future technological advances in vehicle stock and operations.

10. Biofuel usage in principle appears to be a suitable means for reducing transport CO_2-emissions. However, supplying the quantities needed before substantial emissions reductions are realized depends upon rapidly establishing a new, large-scale industry that potentially will transform vast agricultural regions. Apart from the question of public acceptance this can lead to environmentally counterproductive effects (monoculture, soil degradation, emission of nitrous oxide, biocide dependency and groundwater pollution). The world food supply can also be affected negatively. Hydrogen technology, i.e. the employment of hydrogen as an energy source in mobile applications, has also intrigued policy makers and the public, yet the problems of global production and storage are unresolved.

11 The regional structures determining transport volumes, mileages, and the modal split must be taken into account in global emissions strategy. In addition, the potential of the polycentric structure of Germany as well as Europe should be increasingly exploited. Administrative and fiscal instruments can be used to influence land use patterns and commercial/industrial siting in order to reduce transport volume.

12. The rapid change in the public's perception of global warming and its dangers offers many opportunities to mitigate both public and private behaviors in the transport sector. "Soft policies" like

information and consultation should be applied to support the necessary technical and pricing measures, in order to affect a change, thereby moving towards low emission mobility patterns. Apart from a change in knowledge and attitudes, behavioral measures must address the complex sequences of behavior, and offer appropriate incentives and positive reinforcement.

13. Reliability is an essential component to stimulate intended reactions of the actors in the transport market to political price signals and of successful climate policy in general. This holds not only for economic incentives, but also for standards and other regulations, because the vehicles, planes and ships that will be produced until 2030 (and beyond) are in their conceptual stages today. Fundamental technological conversions in the energy sector require approximately two decades in order to reach full effectiveness. Therefore, the fundamental political conditions, not the details, must be specified both promptly and on a long-term basis.

14. A political strategy for the transport sector must also address fears of losses in growth and employment, since emissions reductions mandates will add to the costs in transport processes. Such cost increases could cause reduced mobility, declines in the division of labor, and productivity losses. The conflicting goals of reducing CO_2-emissions and maximizing economic welfare must be balanced in the arrangement of the CO_2-strategy for the transport sector and the choice of instruments. Positive growth effects will result if the industry develops and launches new technologies that enable low cost emission reductions; political decisions can raise the demand for clean technologies and may thereby create positive employment effects. CO_2-reduction is a global issue, so that promising environmental protection technologies are demanded world-wide; economies bringing such technologies promptly to the market could benefit from an improved competitive position and increasing export. The scientific advisory board is convinced that the costs to the economy for reducing CO_2-emissions are overcompensated by the prospective welfare gains of enforced climate protection in terms of avoided damages. The economic risks of CO_2-reductions can be considered to be under control.

15. The implementation of comprehensive emission reduction policies demands a fundamental shift in thinking about the transport sector's infrastructure, technology, and value chain. Possible solutions are often technically, economically and ecologically insufficiently investigated. Market participants and investors naturally prefer low-economic impact, short-term, and partial adjustment to complete overhaul. Yet, considering the extent and the time frame of required industrial and societal adjustment, we urge the EU and the German Federal Government to support promising academic research, particularly fundamental research, and pre-competitive technology development. This should be done without prescribing – ex ante – certain specific technology patterns. We suggest that industry's proper focus is the short-term development of technologies, especially those that have almost reached market maturity.

1 Introduction: CO_2-Emissions and Climate Change

There is a broad scientific consensus that greenhouse gases (GHG) emitted into the atmosphere since the industrial revolution have caused irreversible climate changes. Eleven of the last twelve years (1995-2006) are among the twelve warmest years since temperature recording began in 1850. Heightened media attention and the global scientific debate have placed climate change squarely before the public and policy makers. This has been proven lately by the award of the Nobel Prize for peace to the Intergovernmental Panel on Climate Change (IPCC) and the former US-Vice President Al Gore.

According to public opinion it is impossible to avoid an increase of the average temperatures of 2°C compared to the pre-industrial level. The most recent world climate report by the IPCC predicts a worst-case scenario of 6.4°C, although a warming of 1.8-4°C is considered probable. Most estimations fall in the range between 4 and 5°C.

The economic effects of climate change are another cause for concern. A study by the economist Nicholas Stern on behalf of the British government found that taking no actions to tackle climate change until 2050 could require 20% of worldwide GDP. Many underdeveloped nations will face food scarcity resulting from increased aridity, and both underdeveloped and urban areas will experience freshwater shortages resulting from changes in sea level, increased salinity and droughts The *Stern Review* concludes that the high costs of uncontrolled damages due to climate changes have to be compared to the costs arising from climate protection policies which are estimated to be only 1% of the worldwide GDP. Climate stabilization implies an increase no greater than 2°C in current global surface temperatures (also a target of EU climate policy).

The economic predictions for the global transport sector indicate that within two to three decades, CO_2-emissions from emerging and developing nations will outstrip those of the OECD nations which contributed 71% of CO_2 emissions in 2003. This prediction alone underlines the international dimensions of the problem as well as the absolute necessity of instituting global policies for all sectors and regions.

The European and German policies also make allowance for the threat of climatic changes. The EU has committed to reducing CO_2 emissions by 20% (the reference year is 1990) by 2020. Should an international agreement be reached, the target would be boosted to 30%. The German Federal Government aspires to a target of 40%.

According to present knowledge global heating is caused by emissions of methane (CH_4), nitrous oxide (N_2O), halogen hydrocarbons, ozone (O_3) and carbon dioxide (CO_2). With a predominant share of 55% CO_2 is mainly responsible for the anthropogenic greenhouse effect. Due to the fact that CO_2 has by far the largest share of transport greenhouse gas emissions this paper deals mainly with this gas.

Existing climate policies in Europe have focused on the major emitters of CO_2, industrial combustion and electricity generators. They are covered by the European Trading Scheme (ETS), which, after a three-year test phase (2005 - 2007), has entered, the Kyoto- phase in the year 2008 (2008 - 2012). After initial difficulties it has become institutionally established. Therefore no larger changes of the system are expected for the next trading period. However it needs to be considered how emission trading and the entire coordination of the international CO_2 politics will be organized after the year 2012, in particular whether the regional and sectoral scope of the ETS should be expanded. A suggested guideline offered by the European commission in 2006 suggests the inclusion of air transport in the ETS starting in 2011. A similar recommendation may also include maritime navigation.

Climate protection policies focus increasingly on the transport sector. It is economically efficient to proceed from a preferably wide basis while searching for least cost measures for CO_2 reduction. Finally the measurements with the smallest CO_2 reduction costs should be identified and implemented. The adjustment of ownership tax according to the specific CO_2 emissions or targets for the admixture of biofuels are measures currently under consideration. Furthermore the specific fuel consumption and thus the CO_2 emissions of passenger cars have to be specified more clearly. Obligatory standards of average fleet consumption however form a substantial element of the European climate protection policy in the transport sector. Therefore the European automobile industry is obligated to reduce the average CO_2-emissions from new vehicles by 2012 to 120 g CO_2/km[1] with technical measures. 10 g CO_2/km can be contributed by the use of biofuels and the installation of energy-efficient peripheral devices.

2 Contribution of the Transport Sector to the Climate Problem

2.1 Global and OECD Statistics

The transport sector has a large and rising share of the total output of CO_2 on a European and global level. Uncoupling economic growth and CO_2 emissions has not proven successful because past

[1] The specific CO_2 emissions are a direct measure of fuel consumption:

1 l/100km gasoline leads to 23.8 g/km CO2 emissions

1 l/100km diesel leads to 26.4 g/km CO2 emissions

The values depend to a small extent on the molecular composition of gasoline and/or diesel mixtures.

increases in energy efficiency are usually overcompensated by higher transport volumes. Concerning the absolute magnitude and growth rates of CO_2-emissions the emphasis lies on road transport.
In 2003, global transport contributed about 24% (5,940 million tons) of total CO_2-emissions. In contrast the share of the OECD nations was 30% (3,936 million tons). The largest component of transport sector emissions is allotted to road transport (approximately 18% of global emissions), whereas air and maritime transport each contribute approximately 3% of the global CO_2 emissions. Global transport emissions grew by 31% (1,412 million tons of CO_2) from 1990 to 2003. In the OECD countries, which are responsible for 66% of the global transport CO_2 emissions in 2003, the CO_2-emissions grew by 26% (820 million tons of CO_2) between 1990 and 2003. While the projected further rise of CO_2 emissions on a global level is attributed to the electricity and heat supply, the emission rise within the OECD states is predicted primarily in the transport sector.

2.2 European Union

The share of the transport sector from total CO_2-emissions in the EU-15 is approximately 25%. Whereas the CO_2-output in other sectors could be lowered, the EU transport emissions rose by around 26% between 1990 and 2004. By the year 2010 a further increase in CO_2-emissions is expected. International maritime and air transport, which are not covered by the Kyoto-protocol, registered with 59% the strongest increase between 1990 and 2004. Air transport alone shows a CO_2-emission increase of 86% between 1990 and 2004. It has to be pointed out that air transport possesses a higher climatic effectiveness than other transport modes due to emissions of nitrogen oxides, water vapor and other particles at a high altitude.

The CO_2 emissions of the transport sector are dominated, however, by road transport which accounts for 93% of transport CO_2-emissions (without bunker fuels); including the emissions from international maritime and air transport the share still amounts to marginally over 80%. Further growth of CO_2-emissions in the road transport sector of approximately 10 % is expected in Europe by the year 2015, which results mainly from growth in freight transport, while stagnation is expected for passenger transport.

2.3 Germany

In Germany the share of the transport sector is approx. 20 % of total CO_2 emissions; again the road transport components predominate. Contrary to global and European development, the CO_2 emissions of the road transport have hardly changed in Germany since 1990, whereby the emissions increased significantly until the end of the 1990s and dropped afterwards again.[2] There are considerable differences in the development of passenger and freight transport: CO_2 emissions from road freight

[2] This development is largely attributable to increased fuel efficiency, a demand shift in favour of diesel vehicles, behavioural changes in fuel purchasing in reaction to the eco-tax and global oil increase, and “tank tourism”..

transport rose almost 11% between 1995 and 2005, whereas emissions from road passenger transport decreased approximately 9 % in the same period. The current split of road transport CO_2- emissions between passenger and freight transport (approximately two-thirds to one-third) is forecasted to shift toward freight transport in the foreseeable future.[3]

3 The International Dimension

The reality is that reductions undertaken in the EU will be cancelled out if China and India fail to institute and enforce similar regulatory policies, and the US and Canada cannot bring per capita emissions into compliance. Therefore this report recommends pursuing a two-part strategy: Firstly the global problem of climate change must be addressed intensively in international negotiations and contracts. Europe's function as a role model can enable and legitimize the "pressure" of the European Union on its trade partners in order to push them to adapt the needed climate solutions. At the same time, environmentally efficient, technological and organizational solutions are developed for the European market. With a time delay, those technologies can also be used on an international level. The direct local efforts are thus important for the following reasons: (1) as a direct contribution to the reduction of greenhouse gas emissions (2) to enforce the technology development, (3) to ensure reliability, and (4) to create global leverages. This report recommends six instrumental "types" to exert maximum international leverage:

(1) Espousal of a Global Cap and Trade System

In principle, the US has accepted that the stabilization of the climate requires a post-Kyoto contract under the aegis of the UN starting in 2012. This contract will cap total anthropogenic GHG emissions under a defined limit on relatively short notice. We note that for the first time the US has moved to the position taken by the UN and the EU that the cap must reduce current GHG emissions to approximately half by 2050. Thus chances to agree on a cap and trade system and thereby to achieve "climate fairness" have clearly improved.

(2) "Climate Fairness" (Contraction and Convergence)

"Climate fairness" or climate equity policies can be organized according to the principle of contraction and convergence. First nations are provided with permits according to their current

[3] The difference in the dynamics of the sector is revealed by the development of the energy consumption: While the fuel consumption of the whole German transport sector remained practically unchanged since 1995, the share of fuel consumption of railways and the share of fuel consumption of individual motorized transport have decreased from 1995 to 2005 (-11 PJ for railways; -150 PJ for individual transport). In 2005 the total energy consumption was 9,173 PJ (international bunker fuels excluded; 1 PJ = 10^{15} Joule = 10^{9} MJ; the combustion of 1 l gasoline produces 33MJ of thermal energy).

emissions. Over the long-term the permits will be gradually reduced in stages to a level corresponding to equal emission permits per capita. Such an international system exhibits the highest attainable economic efficiency possible. Further, it internalizes the costs of climate protection in the world market with the least possible administrative expenditure. Once a universal system of cap and trade is established, theoretically it would be possible to replace today's sectoral European saving targets by taxing crude oil directly.

(3) Introduction of Process-related and Product-related Standards in Europe

The introduction of process-related and product-related standards throughout Europe offers interesting potentials for climate regulation. For example, companies exporting to Europe will have to comply with these standards. The requirements of the WTO have to be considered during the implementation of these standards.

(4) Charging of so far exempted emitters

Europe should establish charges for processes which are harmful to the climate within its borders and beyond them. The charging should address those who are up to now exempt from payment obligations by applying appropriate measures; e.g.: for international maritime and air transport. Conformity with international contracts has to be ensured. It is recommended to fully exploit the role of the European Union as the largest common economic area in the world.

(5) Establishment of a Climate Label

The EU could consider a standardized "low-emissions" label that is privately awarded but under public control. It should emblematize climate adequacy in line with EU regulations. Thereby it is important to include all primary products on a world-wide level.

Under current WTO conditions the EU cannot enforce that EU principles are followed word-wide. However, the EU can try to set up the necessary transparency for consumers by creating the respective labeling providing information about the types of primary products of companies. Provided with the appropriate information the well-informed consumer can finally decide which products to buy. Although it is questionable whether such a label is consistent with the WTO regulations, we suggest that it is simpler to align such an instrument with the WTO than to make a large number of border tax adjustments (cf. 6). Therefore the introduction of a climate label could and should be pursued, simultaneous to the introduction of border tax adjustments.

(6) Accompanying trade-policy measures

Process-related standards concerning the energy efficiency of the production of certain products introduces the ever-present danger of substantial distortions of competition in international trade. Increased requirements for energy efficiency of the production processes will inevitably lead to considerably higher cost burdens and competitive disadvantages for the affected European industries. It is to be expected that some sectors will seek relocation to free-riding countries. A possible preventive measure is the introduction of border tax adjustments, yet it is questionable whether and under what circumstances this type of instrument can be aligned with WTO regulations. Under WTO jurisdiction, measures restricting trade can be only be instituted under very specific conditions. These conditions occur if the restricted measures are vital for the protection of significant environmental goods. Only after contract negotiations fail are states allowed to impose preventative, one-sided measures (border tax adjustments). Therefore, consideration of EU border tax adjustments should apply primarily to industries and products with high energy and emissions expenditures.

4 The National Dimension: Options for CO_2 Reduction in the Transport Sector

Ideally, climate policies should regulate all emitting sectors from an economics perspective, e.g., via a global emissions trading scheme. In the short- and medium-term, however, the extent to which global solutions can be applied is unknown. Since immediate actions are required to reach reduction goals by 2020, local/regional and sector-specific instruments are indispensable. They have the advantage of being simple to use, but can also produce unwanted alternate behaviors and distortions of intermodal and international competitive positions.

The identification and conversion of suitable, short-term instruments is a core element of this report's recommendation to pursue a two-part emissions strategy. What follows is a description of the relevant instruments for the different components of Germany's transport sector.

4.1 Road Transport

4.1.1 Point of Inception

World-wide road transport exhibits considerable growth of GHG emissions. While in Germany, the increase in emissions by the rapidly growing freight transport is already overcompensated by declining emissions of the individual passenger transport, the public and political discussion almost exclusively focuses on the latter. For European passenger cars limit values of 120 g CO_2/km are currently discussed, which shall be applied to the average fleet of newly registered passenger vehicles by 2012.

The numerous possibilities for emissions reductions in road transport apply to:

- Technology: To a certain extent emissions can be lowered by using more efficient engines in lighter bodies; the question to be answered is how many additional regulatory instruments will accelerate efficiency technology
- Fuel substitutes, e.g., biofuels
- Usage: Annual distance driven per vehicle, and driving "style", e.g., behavioral modifications

Possible starting points for emission reduction differ depending on type and intended purpose of the specific vehicle. The annual road performance plays a large role in determining whether expensive automotive technologies for consumption reduction will pay off. In addition, the spectrum of vehicle use is important: Vehicles mainly operated over short distances, with a lot of stop and go traffic, particularly profit from a reduction of the vehicle mass, from measures to recuperate brake energy, from an incentive systems to encourage economic driving etc. On the other hand vehicles which are predominantly used over long distances, can benefit from the reduction of effective driving resistances (rolling and air resistance) and from improvements of the specific consumption of the vehicle propulsion system.

4.1.2 Specific Instruments

4.1.2.1 Cars and Light Vehicles

Extensive studies of passenger vehicles have found that emissions reductions of 30-40% are technically feasible, e.g. by reductions of engine sizes as well as by the minimization of ancillary fuel consumption and driving resistances. However, the considerable technological progress regarding drive train modifications (e.g., hybrids) is largely overridden by the trend to higher masses, higher engine performance and energy consuming equipment for new vehicles.

A technical development regarding specific CO_2 emissions of 130 g/km for all new passenger cars would reduce emissions by 5.4% by 2012 and approximately 21% by 2020. This implies that the national CO_2 emissions of passenger transport would be reduced to approx. 89 millions tons CO_2 (minus 23 millions t compared to 2006), if the age distribution of the passenger car fleet remains constant. Realizing this political goal requires the use of more costly technologies. Even in an optimistic scenario with large learning and scale effects the total CO_2 avoidance costs could be very high. Moreover, changed vehicle purchase decisions and an adapted car use are likely to cause substantial rebound in terms of vehicle mileage.

Additional potential for lowering emissions consists in aligning vehicular designs with the expected transport requirement, for example, scaling down the size and profile (the possibilities have been partially explored in series vehicles like Audi's Duo and A2 3l; Volkswagen's Golf Eco and Lupo 3 L; Toyota's Prius and Honda's Insight). Development costs, however, are significant, ranging from 50-200 million Euros to produce variants of existing car types to over 1,000 million Euros for new designs. In the past, the demand for vehicle types with low fuel consumption remained small. On the one hand, these vehicles often were "half-hearted" developments on the basis of existing series products. On the other hand, barriers to purchase have included unwillingness by consumers to abandon "status-conscious" vehicles, pay high prices for untested designs, and early or persisting technological bugs. So far only minor attempts were undertaken in order to define the vehicle characteristic "status" different from vehicle size, engine performance and comprehensive equipment.

Driver assistance systems that seamlessly instruct drivers to drive more economically are also a technical option to reduce CO_2 emissions reductions. The simplest technology employs shift indicator lights or adaptive transmission controls. More complex systems could e.g. involve the topography of the planned route, or could take into account current traffic conditions and local traffic light circuits. But to date, there are no incentives for manufacturers to install these advanced technologies, as the potential customer base seems to be small.

4.1.2.2 Heavy Vehicles

In order to assess technological options for the reduction of fuel consumption in road freight transport it is useful to differentiate between short-distance and long-distance road transport. Heavy vehicles used for short-distance transport are mainly operated under urban traffic conditions (stop and go) and have a limited annual mileage. For this type of truck the optimization of the conventional diesel drive train is the most important technological option. Besides, a small number of short-distance trucks are already equipped with compressed natural gas (CNG) propulsion. For a few years trucks with hybrid drive are developed and offered in small series in Japan; they still have an experimental character.

By comparison, the technological potential for improving long-distance operations to achieve lower emissions and greater fuel efficiency is smaller. To date, technology has been focused on better diesel engines and their exhaust treatment and recuperating thermal energy from exhaust gas and cooling water. Weight-reducing possibilities are converted into an increase of the pay load, thus effecting consumption per ton, not per vehicle. Further technical potential exists in allowing larger units for road transport and in electronic coupling systems (convoy system). Moreover, some measures to reduce the driving resistances (rolling friction, air resistance) may be useful. Fuel consumption can also be lowered by as much as 5% by driver education and possibly by electronic driving assistance systems. The optimization of freight trip schedules may contribute to a reduction of empty runs, thus improving capacity utilization and decreasing fuel consumption per vehicle.

4.1.2.3 Modern Vehicle Technology for Consumption Reduction

Consumption reducing measures initially entail substantial extra costs in vehicle development and production, even if these extra costs could be lowered due to learning effects over the course of time. For rational market participants high fuel prices should function as powerful incentives to acquire new driving habits and/or purchase efficient vehicles. However, the actual willingness to pay for fuel efficient vehicles seems to be comparatively small, at least according to private buyers' choices. Consumer education provided by government and vehicle manufacturer can play a relevant role. Since a large percentage of passenger cars is purchased or leased by fleet operators it should be cost-effective to educate this smaller group of decision-makers who may be required to act more rationally than private buyers.

For vehicle manufacturers, the achievement of ambitious fuel saving goals is associated with very high expenditures for R&D and even higher costs for the setup of production capacities. In addition, highly efficient engines require precisely specified and standardized fuels. This condition is given in the European Union, in the USA the development just began; on many other markets the condition is not fulfilled yet. Therefore vehicle manufacturers are required to foster expensive parallel technological developments for different regional markets. In order to hold the manufacturing costs down, component systems are applied. Hence, the realistic fuel savings potential of modern vehicle technology is lower than its theoretical potential.

Technical measures for a reduced fuel consumption often conflicts with the target of further reductions of local pollutant emissions (CO, NO_x, HC, and particle). Vehicle components for the reduction of local pollutants directly (e.g. via increased exhaust gas back pressure) and indirectly (via increased vehicle weight) influence its fuel efficiency. Regarding vehicle weight, an additional conflict between the objectives of fuel efficiency and of safety may arise, too. As tighter emission standards for local pollutant become mandatory, so the technological requirements for the construction of the overall vehicle system rise.

4.1.2.4 Alternative Fuels

Additional to the vehicle-based technical measures it is also possible to substitute fossil-carbon-based fuels with alternative fuels and propulsion systems. E.g. the use of compressed natural gas (CNG) as fuel is widespread. However, the theoretical potential of CNG to contribute to the reduction of road transport CO_2 emissions is limited, mainly because CNG vehicles need to be equipped with heavy and voluminous tanks, which increase the vehicle weight and hence diminish potential efficiency gains.

Another substitution option is the admixture of fuels produced from biomass to standard fossil-carbon-based fuels. At present biodiesel is a priority in Germany (vegetable oils are esterified using methanol). Brazil relies on ethanol (produced from sugar cane and added to petrol). The US government's very favorable agricultural subsidies promote growing corn for ethanol manufacture of 10% ethanol gasoline (E85). Cellulosic ethanol (produced e.g. from the rapidly growing monocrop, switchgrass) still remains in the developmental stage. In the future, these second-generation fuels (biomass-to-liquid) could be precisely adapted to the requirements of demand (designed fuels), but as yet the respective industrial production process are still unavailable.

The CO_2 reductions of biodiesel and ethanol are in the range of 30-70% compared to conventional fuels. The CO_2 reductions for second-generation fuels are 50- 90%. The global run-up in food prices, coupled with the vast amount of land required for the production of vegetative material (approximately 70% of the surface of Germany, or a half hectare per vehicle) rule against widespread use of these alternative fuels. Other negative factors are: soil acidification, eutrophication of water, deforestation, overuse of pesticides, pollution, loss of habitat, and biofuel import costs.

The costs per ton of CO_2 that are economized by using biofuels are high (> 100 €). Usage in stationary applications should give smaller costs with the same CO_2 reduction. Obligatory insets and/or admixture quantities for biofuels for the most part are uneconomical and inefficient. Significantly better would be a tax exemption for biomass in the context of a general input-oriented carbon taxation. Because of the various national incentive mechanisms (ratio regulation for biofuels, market incentives, renewable energy legislation) competition among the different uses of biomass instead became a race for subsidies. Consistent structuring and harmonization are urgently required. The mechanisms should be arranged to favor acceptance of the most cost-efficient utilizations (most probable is using biomass in stationary gas, warming and power generation) and to continue to use fossil energy in consumption-optimized vehicles at least medium-term.

Another possibility, often discussed in the public, is hydrogen. Its suitability as fuel for petrol engines has been convincingly demonstrated, although unsolved problems with production, transport and vehicle storage make it doubtful whether this option is applicable Germany-wide. A hypothetical supply to Germany (produced by electrolysis from water) requires approximately 1,200 TWh,[4] not to mention creating the supporting infrastructure from scratch. This report concludes that conversion before 2030 is hardly conceivable.

[4] Power generation for 2007 in Germany was appropriately 636,5 TWh (140.5 TWh from nuclear and 39.5 TWh from wind).

A further possibility employs electric vehicles for daily travel under 100 km; these short-distance trips represent approximately half of the energy consumption of motorized individual transport. We note that failure rates and manufacturing costs of efficient batteries remain high. Accordingly providers of electric vehicles must assume higher risks. Since they are restricted in their performance characteristics (small range, daily and long recharging times) we surmise that electric vehicles will only play a minor role in the future. Since electricity in Germany and in most European countries is generated from coal-fired stations, substantial CO_2 emissions result from the usage of an electric vehicle (for a Smart ev approximately 70 g/km; for a Smart cdi: 87 g/km). Again we can expect only a minimal contribution to achieving Germany's emissions goals by 2020.

4.1.2.5 Price Approaches that Influence the Demand for Fuels

The central element of Germany's emissions policy is the so-called eco-tax. Consumption and thus CO_2 emissions of the transport sector are to be lowered by the increase in the price of fuel. Relatively carbon-poor and regenerative fuels will be tax-supported. The measure applies directly to the activity (burning fuel) producing the emissions. The absolute fiscal charges (eco-tax plus fuel taxes) correlate with the amount of carbon output. The system is simple to handle and causes small transaction costs. However, the fuel- and eco-tax carries several problems. At present, the rates of taxation are selected in such a fashion that they do not correspond to the specific emission values of the fuels.[5] E.g. for a stringent application of the causation principle in the transport sector a higher tax for diesel fuel would be required. The tax also differentiates according to the purpose of consumption on the grounds that the small price elasticity of the demand in road transport requires a very high tax rate in order to achieve significant emissions reductions (it also applies to nearly all other consumption sectors in a similar manner). It should be noted that some of the observed decrease in fuel consumption can be attributed to "tank tourism", i.e. refueling abroad.

Another approach aligns the ownership tax with the vehicle's CO_2 emissions to create an additional incentive to purchase relatively consumption-poor vehicles. Similar taxes exist that are based on normal consumption and are paid at the time of purchase (Austria's NoVA, or "normal consumption fee"). The misalignment between tax level and actual emissions, however, is unfavorable; the measuring procedures used to determine normal consumption do not reflect the material operating conditions (driver's use of air conditioning, for instance). In some cases fuel consumption can be 60% higher than the norm measured in the driving cycle. Furthermore, differences in individual user behavior can not be captured by the ownership tax (guzzlers are treated no differently from eco-

[5] Germany's current taxation related to CO_2 emissions including the VAT on the energy tax in €/t CO_2 is: 330 for gasoline, 211 for diesel, 71 for autogas, and 82 for natural gas (CNG).

conscious operators). Finally, there is no incentive for manufacturers to equip vehicles with systems that reduce consumption based on operator behavior.

More use of road performance-dependent tolls will likely reduce demand for transport, produce less congestion and promote greater utilization of freight capacity. Theoretically, this would also offer possibilities for controlling temporal demand for transport over price. German-wide implementation for all vehicle categories would be cost-intensive because of substantial installation and operating expenses.

4.1.2.6 Emissions Trading for Road Transport

Besides price-based instruments quantity-based ones can also be used. Here the inclusion of road transport into the European Emissions Trading Scheme and/or the establishment of a separate trading system for road transport will be considered. The possible emissions trading variants for road transport comprise downstream, midstream and upstream options:

- Downstream: Individual road users are issued certificates for the emissions they cause. Seeing the ecological costs of their transport usage allows road users to take adaptive actions. This option is unrealistic due to the prohibitively high transaction costs.
- Upstream: Applies only to fuel producers and importers so the transaction costs are small. The appropriate certificate holding can be verified relatively easily in the context of the fuel tax collection; also the avoidance of double certified petroleum products not used in the transportation should be relatively unproblematic. A price signal is passed on here only indirectly by transferring the certificate costs to the road users. For the individual road users the incentive effect is de facto the same as that of an eco-tax. However, contrary to taxes, the aspired emission reductions are reached surely within the trading system. In order to maintain a constant fuel price path, such a scheme requires a correct estimation of the price elasticity of the demand. This depends, however, on many measured variables like the economic development, the course of the weather, the trends and time currents of tourism etc. A precise regulation therefore might be very difficult.
- Midstream: Applies only to vehicle manufacturers. Defaults are created for the average CO_2 emissions of (new car) vehicle fleets. If the actual average emissions fall below the default, credits are generated that can be sold to manufacturers that cannot maintain emissions standards. The positive effect of this emission trade variant is the anchoring of the certificate obligation for those who have direct influence on vehicle efficiency so far as it is defined by the technical design. This option cannot control the total emissions of road transport because the measurement of the emission quantity occurs via estimations accounting for the number of vehicles and annual road performance (in reality the actual average emission also depends on driving style). Since these parameters are unknown in advance, the total CO_2 emissions of

transportation are not controllable with such a system. This problem would remain, if instead of credits for average emissions absolute emission quantities would be traded. Furthermore, the lack of monitoring absolute emission quantities causes significant difficulties in interlinking a "midstream" emission trading scheme for the transportation to the ETS.

Finally, the long-term goal should be an open emission trading scheme including all sectors. Only with such a general scheme the (marginal) avoidance costs of CO_2 will be adjusted over all sectors and emitters, and the economic costs of the emission reduction will be minimized. For the inclusion of the transport sector in a general scheme the “upstream” trading scheme is the most suitable.

4.1.2.7 Regulatory Instruments

The preference for regulatory instrument usage in road transport assumes that the players in the transport market react irrationally to price signals. It can be observed that (above all) private vehicle buyers do not factor in future costs of fuel when making purchasing decisions; therefore, demand for more fuel-consuming vehicles continues. Generally the employment of regulatory instruments should be limited to scenarios for which market based instruments do not work or are not applicable (at justifiable expenditure), since regulatory measures usually exhibit a smaller economic efficiency. Regulatory approaches, for instance speed limits, and mandating admixture ratios or technical defaults, usually display a particular avoidance and/or technology path. Decisions about the most attractive avoidance options should be left primarily to market participants. The regulatory policy’s objective is to establish suitable incentives to stimulate rational adjustment reactions by market participants (purchase of low-consumption passenger cars, lowering operator speeds, optimizing logistics in freight transport, changing the modal split).

4.1.2.8 Promotion of Research

The implementation of a policy of consistent GHG minimization requires a fundamental restructuring of the supply of energy sources, the use of these energies in vehicles, the conception of these vehicles, the operation of roads, the information and the training of the users etc. Contributions to potential solutions are only partly known so far, and still often economically and ecologically insufficiently assessable. For the next product generation relevant technologies are developed by the market participants according to today's and expected future economic and technological framework conditions. Thereby they must consider existing structures in R&D, production and distribution as well as their ability of bringing their products onto the global market. Thus the scope for solutions is necessarily tighter than possible in principle.

Considering the urgency and the long-term nature of the necessary transformations, the process of the search for optimal solutions must be accelerated by a systematic support of applied research. The

German Federal Government and the European Union should support therefore, besides fundamental research, also the precompetitive development of technologies, field tests for promising, but in their effects and operational behavior not yet completely visible solutions, new principles for the organization of relevant operational and organizational structures as well as the creation of relevant research and development methods. This should be done without pre-defining certain solution methods. A political research strategy should proceed without an ex-ante definition of certain solutions (e.g. "hydrogen", "fuel cell", "electric drive"), but with a consistent examination of the possible and probable contributions on a basis of clearly defined criteria.

4.1.2.9 Increased Transparency, Information Campaigns and Reliability

A condition for economically rational and ecologically effective adjustment reactions is that all participants see the same information regarding the relevant decision parameters. For example buyers of vehicles should see consumption and emissions data not only on the basis of norm consumption in the test cycles. The positive and negative consumption effects of vehicle components (transmissions, driving profile assistant, AC, electronic accessories, , etc.) should be fully transparent.

A substantial condition for transparency is measurement standardization. Unfortunately, earlier measuring procedures have given rise to the development of technical solutions that lead to good test values but that do little or nothing to improve transport. Single vehicle purchasers and fleet buyers should also see the financial consequences (fuel costs over the average lifetime[6]) possibly by a graphic label similar to the energy consumption information attached to household appliances. False incentives such as company cars with unlimited free gasoline should be reconsidered.

It goes without saying that reliability and transparency of climate policies is especially critical for manufacturers who operate on long timeframes, and for the private and public financial sectors that rely on transparent information concerning taxes, subsidies and penalties.

4.1.3 Evaluation

At present Germany and the EU are pursuing a political strategy consisting of price instruments (eco-tax, planned alignment of the ownership tax with the CO_2 emissions level, truck toll) and regulatory instruments (emissions standard, mandatiory admixture ratios for biofuels, as described). The general trend is towards a changed ownership tax computation, and of standards towards lower emission vehicles. The implementation of mandatory emission standards is justified by the technical potential of

[6] Energy is also consumed in vehicle manufacturing The resulting emissions amount to roughly 15% of the GHG that are emitted during the typical cycle of a vehicle. Only a small part can be recovered via recycling or reuse.

reduction in the passenger car range, and the failure of the voluntary self obligation of the European automobile industry. As explained above, this approach is sub-optimal, in large part because concrete arrangements for emissions do not offer incentives to vehicle manufacturers. For example, weight-oriented defaults could favor heavier vehicles. The other approach, mandating admixture ratios, is also sub-optimal because, for example, the emissions reductions are bought at a high price (in the form of higher avoidance costs and intensified land use competition).

Generally the encouragement of the regulatory instruments should remain limited to those areas where market based instruments do not work or are not applicable. The default of a certain avoidance and/or technology path usually results in higher financial burden for the emission reduction than in the optimal case. The task of the policy should be setting suitable incentives and institutional basic conditions as well as the supply of necessary information. Besides, soft measures can stimulate behavior towards lower carbon mobility samples (mobility consultation, consciousness-shaping, improved public suburban transport, etc.) in an efficient way for sustainable transport.

A long-term policy goal for road transport should include a global emissions trading scheme. Creating a market for CO_2 emissions acts as a counterweight to the market power of fossil fuel suppliers . An upstream scheme appears most beneficial economically. Parallel flanking measures (town planning, infrastructure development, etc.) have to be embraced in order to reduce the avoidance costs of the road transport.

Finally, in the transport sector - as in all other consumption sectors - the goal to substitute more energy consumption should be pursued by the use of increasingly more efficient technology. Since this technology leads to substantially higher costs and prices, the consensus may not go for the necessary and desired, higher investments. Today's situation with relatively cheap, inefficient energy conversion technology and high consumption must be transferred gradually into a situation with very efficient, therefore usually expensive, energy technology and low consumption. This process will only materialize in the long run, in view of an efficient GHG minimizing policy and the unsuitable differentiation of the taxation of fuels and combustibles. It has to be a goal of a forward-looking, long-term oriented policy to charge all emitters CO_2 equally, so that a uniform carbon price results and that the reduction targets will be achieved. The interests of the vehicle manufacturers and of the climate policies run here in principle parallel. However, the transition of today's situation to the outlined future is difficult because of the enormous need for adjustments; therefore strong reservations exist. The goal could be a transport policy oriented on a long-term basis of defining such a development path together with the relevant participants, of creating the conditions for its implementation and of keeping the risks and unwanted side effects controllable. One can see a first approach in the "transportation energy strategy" (“Verkehrswirtschaftliche Energiestrategie”), in which beside the Federal Government many original equipment manufacturers (OEM) and power suppliers are involved. In the frame of this strategy the future supply of the transport sector with final sources of energy is being discussed.

4.2 Air Transport

4.2.1 Point of Inception

Air transport contributes – according to the IPCC – with 3.5% of the anthropogenic CO_2 emissions. This is significantly less than road transport, but its impacts substantially degrades the upper atmosphere (e.g. vapor trail formations, alterations in cloud cover, suspension of particulates and the like). Aviation's GHG emissions increased by around 73% from 1990 to 2003. A growth rate of approximately 4% per year and an expected doubling of air transport by 2020 (compared to the year 2000) are predicted. Air transport is growing about twice as fast as the world economy, mainly driven by the growth of low cost carriers. Almost 4 billion passenger kilometers were realized globally in 2006.

The environmental consequences of aviation's high growth could be partially offset by substantial technical progress. The specific fuel consumption for each seat dropped from 1990 to 2003 by 50%. This was achieved through improved aerodynamics, lighter constructions and more efficient engines. At roughly the same time, the industry underwent enormous competitive repositioning (from 1992 to 1998 the number of air transport companies rose by 25%), resulting in increased price pressures (seats, fuel, labor, operations). Liberalization since 1987 (distance and approach rights)[7] – most recently affecting transatlantic air transport between Europe and the US –, the emergence of low cost carriers, and the expansion of the Schengen-Agreement with Eastern Europe facilitated this tendency. Yet, as the efficiency improvements can not keep pace with the demand growth, aviations fuel consumption and GHG emissions will further increase.

So far air transport is not subject to GHG reduction policies. According to the rules of the Kyoto Protocol and various supplementary bilateral agreements of aviation operating countries, CO_2 emissions from international air transport are not considered in the GHG inventories of the contracting states. The International Civil Aviation Organization (ICAO),[8] a subsidiary of the UN, develops and administers the emissions regulations. Although an international emissions trading scheme has been discussed, the ICAO states have not come to an agreement. Currently the EU proposes at least a

[7] See the 8 formalised "liberties of air" based on the rights to flyover and to commercial transport between two foreign states without penalising the mother country of the air transport firm (so-called cabotage).

[8] The International Civil Aviation Organization was founded in Chicago in 1944 to set standards for civilian air transport. 190 states belong to the ICAO that is affiliated with the UN.

European-wide approach: at the end of 2006 the EU Commission submitted guidelines for the integration of air transport into the EU ETS.

An absolute limit on aviation emissions is possible only by drastic interventions effecting demand. Nevertheless climate policy measures are inevitable for a transport sector undergoing rapid growth. These should address both the specific fuel consumption of aircrafts as well as the demand side of the market. On the supply side fuel savings can be obtained directly by use of the most modern aircraft by air transport companies.[9] Further fuel savings potential can be gained from the improvement of capacity utilization (number of sold seats and/or air freight tonnage), adjusting vehicle usage to demand, assuming a sufficient fleet size and variety. Fuel savings can also be obtained by weight reductions,[10] and possibly fuel adjustments, analogous to road transport.

A specific problem for regulating air transport is the complexity of the link between its emissions in high altitudes – an aircraft flies at approx. 11 km altitude and releases its emissions into the stratosphere – and the greenhouse effect. Apart from the increase of the CO_2 concentration in the atmosphere, air transport affects the climate in particular by the formation of vapor trails and so-called "Contrail Cirren", the change of ozone and methane concentrations by nitrogen oxide emissions as well as the emission of soot and sulphate aerosols (PM). "Contrail Cirren" are two-dimensional cirren that are generated from vapor trails of aircrafts. At temperatures of up to -40 °C the vapor trails do not represent a problem. If air becomes colder and damper, the vapor trails do not dissolve, but absorb more water vapor from the environment and grow to thin ice clouds. These ice clouds are called cirren. The impact of these cirren and the Contrail Cirren on the greenhouse effect remains insufficiently analyzed. It is possible that the impact on global warming is just as great as the pollutant emissions of airplanes. We have estimated that the entire climate effectiveness of air transport amounts to double or quadruple the pure CO_2 effect.

Global air transport contributed so far approx. 0.05 W/m^2 to the radiative forcing, which is 3% of the entire anthropogenic radiative forcing of approximately 1.6 W/m^2 with uncertainties up to 5%.[11] An

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[9] Thus, Lufthansa has reduced its specific fuel consumption (6.2 litres kerosene per 100 person kilometre in 1991) by 30% to 4.4 litres in 2006. Using an emission of 2.5 kg CO_2 per litre kerosene as a basis, the emissions reduction for a flight from Frankfurt to Cape Town amounts to 420 kg.

[10] Lufthansa has stated it could reach up to 5 millions litres of fuel savings, representing 12,500 t $CO_{2,}$ per year by improving interior technology, e.g., lighter-weight passenger seating.

[11] The radiative forcing is a quantitative measure for climate impacts. A positive radiative forcing value implies heating up and vice versa. It measures the anthropogenic heating effect in terms of Watts per square meter.. The radiative forcing can be computed with comparatively simple methods; it does not consider, however, the various interactions of the climate system.

exact quantification is not possible at present due to the insufficient understanding of the physical processes and the dependence on the site of emission. Hence, a permanent restriction on CO_2 emissions would be insufficient and possibly even counterproductive, since measures to decrease the fuel consumption can come along with the amplification of other climate effects of air transport. Therefore, an emissions trading scheme that is based on CO_2 only during its introduction phase, should be accompanied by measures addressing other greenhouse effects of air transport. These could for example include limit values for nitrogen oxide emissions or the limitation of flight altitude in those regions, where vapor trails and cirrus clouds emerge with high probabilities. Regarding the proposal of the EU Commission to include air transport into the EU ETS, a proposal to include nitrogen oxides into the assessment base has been announced for 2008.

4.2.2 Economic Considerations

Climate change and the appropriate counter measures incur costs which are not born by the actors in the air transport market. Using figures from the IPCC the following rough calculation can be set up: The IPCC estimates the annual climate change costs in the range of 1-3% of the world's GDP until 2030. Linear apportionment of these costs means that Germany's national expenses total 20 to 60 billion € per year.[12] 3.5% of this sum correspond to 0.7 to 2 billion € per year, the financial amount to be contributed by air transport, accounting for its share of overall CO_2-emissions.

With a transport capacity in Germany of 6 billion ton kilometer (passengers and freight together) annually (reference year 2006), aviation produces 10-50 € environmental costs per 100 ton kilometer. Set in comparison to operational costs (essentially fuel, fees, leasing, labor) of German air transport firms (e.g., Lufthansa, Air Berlin) of about 50 to 80 € per 100 ton kilometer internalization of environmental costs would constitute approx. 30-50% of air companies' total costs.

4.2.3 Specific Instruments

4.2.3.1 Pricing Instruments

A price should be assigned to the scarce resource *GHG absorption capacity of the atmosphere*, so that airlines include the environmental costs of their transport volumes in their calculations and business plans. Potential instruments are:

[12] According to the International Monetary Fund (IWF) the world gross domestic product was USD 48.145 trillion in 2006. For Germany USD 2.897 trillion, 6.02% of the world's gross GDP, were determined. According to the IPCC the world-wide costs of climatic change thereby lie between USD 481.45 billion (325.30 billion €) and USD 1,444.35 billion. (975.91 billion €).

- Kerosene Taxation: A pricing of climate damaging emissions is omitted in air transport so far almost entirely. Exemption of kerosene from mineral oil taxation moved into the focus in the course of the climate debate; this exemption is increasingly seen as environmentally counterproductive and distorting the competition between the transport modes. Thus, taxation of kerosene is a plausible means to include aviation into a climate strategy for the transport sector. The implementation of such taxation measures is, however, juristically complicated due to the international character of air transportation, which implies the existence of a multitude of multi- and bilateral agreements. Local tax schemes feature the risk of arbitrage effects through avoidance strategies of obliged parties.
- Emission-Dependent Starting and Landing Fees: CO_2 dependent starting and landing fees can be taken into account as an alternative price instrument to control the climate impact of air transport. The fees should seize actual emissions as precisely as possible – however, under consideration of the resulting transaction costs. Lump-sum charges on flight ticket independent from the exact CO_2-emissions – as introduced for example in the UK – do not internalize the environmental costs sufficiently and offer no incentives for investments in clean technologies; they work only indirectly in terms of decreased demand for air transport services. A macroeconomic optimal reduction path over all sectors is reached only if the price per ton of CO_2 in air transport corresponds with the CO_2 prices in other sectors. The airports in Frankfurt and Munich introduced an emission-dependent component in their airport fees by the beginning of 2008; per kilogram of nitrogen oxide (NO_x) emitted 3 € have to be paid. The emission-dependent charges are substituting and not additional to existing charges, no additional financial burdens are imposed.

  Alternatively to emission-dependent starting/landing fees and maybe even cheaper, aviation's external climate costs could be included in the air traffic control charges. However, with regards to the Chicago Convention legal complications are to be expected.

4.2.3.2 Emission Trading

A promising alternative to the price approaches – also for aviation – is emissions trading. Since further emission growth is expected in the future, a (semi-)open trading scheme should be preferred to a closed scheme in order to avoid excessive costs of inappropriately massive cuts in air transport volumes. The current proposal of the European commission provides for such a scheme, that allows air transport to buy certificates from the remaining ETS sectors, but airlines cannot sell certificates into these sectors. It is planned that the certificate obligation starts from 2011 for intra-European flights and from 2012 for all flights, which take off or land at European airports. The airlines are entities obliged to surrender certificates, because they have the most immediate influence on technical and operational reduction options. Furthermore, their number is sufficiently small so that the control costs remain reasonable; on the other hand, the number of market participants is satisfactorily large to prevent the abuse of market power. Through the semi-open link to the existing EU ETS, trade between the different emitting sectors is possible, so that emission reductions can take place where they cause the smallest macroeconomic costs. Obstructions for the actual implementation of the planned scheme may result from the rejecting attitude of the USA, as the emissions trading scheme can fully exploit its potentials only if non-European are also included. The additional burden to passengers – 4 € to 40 € price increase for a medium distance ticket at ETS CO_2-prices of 20 € to 30 € per ton – and airlines seems bearable, taking into account the low price sensitivity of air transport demand. This appraisal may not be transferable to the low cost segment, because the incurred extra costs constitute a significant share of the ticket price.

4.2.3.3 Logistical Optimization Potential/Single European Sky

Further substantial emission savings potentials exist in the optimization of air routes as well as in the avoidance of waiting loops. Here, the harmonization of European air space can play a significant role (implementation began with the Single European Sky (SES) directive in 2004). The respective optimization potential can be found in a change from an airspace structure orientated at national borders to origin/destination-oriented structures using functional airspace blocks (FAB). Political support for the European Joint Undertaking (JU) SESAR is important in order to exploit these potentials. Realization of the SES allows to avoid detours, which constituted with 4.7 million tons CO_2 approx. 5% of aviation’s entire CO_2-emission in 2006. Moreover, the creation of sufficient capacities at airports can prevent unnecessary waiting loops in the air and on the ground. The latter is important in particular for German inland short-distance flights: a reduction in the waiting times of take offs of about 5 to 8 minutes in each case could save up to 30,000 tons kerosene annually at Frankfurt airport.

4.2.4 Evaluation

The planned implementation of air transport into the EU ETS is an efficient instrument for internalizing the climate costs of the sector and decelerating its rapid growth in emissions. Internalizing the external climate costs of aviation by means of CO_2-dependent starting and landing fees or via air traffic control fees is also likely to work economically efficient upon appropriate design. Moreover, political emphasis should be put on the realization of the Single European Sky. In view of the various climate impacts of aviation, additional measures to account for the non-CO_2-emissions of air transport are required and need to be pushed forward. We would like to point out that climate policy for the aviation sector should aim at a reduction of emissions compared to the expected emission path and not necessarily at absolute reduction compared to the status quo. Climate policy should take advantage of the willingness of actors in the air transport market, e.g. from the low cost segment, to contribute proactively and voluntarily to climate protection efforts.

4.3 Navigation

4.3.1 Point of Inception

The inland waterway transport contributes only a small share of the total emissions of Germany's transport sector.[13] Data collection for inland transport is controversial: official statistics do not consider fuel consumption of foreign vessels on German waterways as well as refueling of German vessels outside of Germany accurately. The date regarding specific CO_2-emissions per ton kilometer is not clear, either:.[14] Accounting for the detours implicit to the use of inland navigation, it can perform – in terms of CO_2-emissions per ton kilometer – better or worse than rail transport, but both modes regularly perform better than road freight transport. Inland navigation is exempted from mineral oil taxation and until 2008 it was not subject to emission regulations.

The inland network is not subject to the oil tax and or emissions restraints. In accordance with EU directives 97/68 and 2004/26, obligatory limit values are specified for exhaust emission from inland navigation vessel engines, which are obligatory for type permissions from 2008 and for all new engines starting from 2009. New engines already attain these limit values, which are not explicitly aligned to climate protection intentions. Since inland navigation vessels are relatively old - the age of the engines is indicated on average with more than 30 years - they do not feature the modern engine technology with respect to emission reductions and energy efficiency.

Regarding its contribution to global warming international maritime shipping is of higher relevance than inland navigation. Its share of the worldwide CO_2-emissions amounts today to approx. 3%, which is roughly similar to aviation's CO2-emissions.. Between 1950 and 2000 the energy consumption of maritime transport increased by a factor 4.3, and between 1990 and 2005 CO_2-emissions increased by almost 50%. If no effective strategies are developed, CO_2 emissions (and the SO_2 emissions) will double again by 2050[15]. The International Maritime Organization (IMO), a subsidiary organization of the United Nations, is in charge for the regulation and reduction of GHG from international maritime transport, which are not included in the Kyoto-relevant national emission inventories just like international air transport. So far there have been no definite actions taken in order to mitigate the

[13] In 2004 the CO_2 emissions of the inland navigation and coastal shipping were about 0.9 millions tons.

[14] The BMVBS should consider commissioning the compilation of reliable and indisputable data at least regarding the quantifiable environmental aspects (energy consumption, emission) compared to alternative transport modes, and differentiated for several groups of goods.

[15] Additionally to CO_2 emissions, maritime transport is one of the substantial emitters of NO_x, SO_2, heavy metals and soot. They result from the use of cheapest residual oils (with sulphur contents of 2.7% up to more than 4%) and from the engine – unregulated –technology uncompromisingly designed for optimal efficiency.

emissions growth of maritime transport. Therefore, the European Union considers taking unilateral measures similar to the aviation sector.

Potential reduction options are the acquisition of modern efficient vessels, retrofitting measures for the existing, long-life fleet as well as optimizations of the operating procedures. Among latter measures are for example a deceleration of the driving speed and the optimization of loads, fleets and routes. In order to induce the realization of these potentials, an appropriate regulatory framework is required.

Regarding the implementation of climate policy measures maritime transport and air transport show some similarities. Both transport modes feature high growth rates in the course of the globalization and both are characterized by their international dimension, whereas little attention was dedicated in the recent past to CO_2 emissions of maritime transport in contrary to the road and air transport sector.

4.3.2 Specific Instruments

4.3.2.1 Pricing Instruments

Raising the price of the CO_2 emissions of the maritime transport can induce technical changes and behavior adoptions. Possible instruments are:

- Fuel taxation: Taxation of fuel for navigation would be a relatively easy first step towards a reduction of navigation's CO_2-emissions; this holds in particular for inland navigation. This approach can be justified by the internalization of external climate costs, and by understanding that navigation uses public transport infrastructure without covering its costs. In view of the necessary amendment of respective international agreements („Mannheim document “) and with respect to the fact that inland navigation vessels can usually be refueled also outside national borders, a regulation on the European Union level to needs to be targeted. Concerning maritime navigation a multiplicity of legal questions and the issue of potential tax evasion have to be clarified before maritime bunkers can be actually taxed. Hence, fuel taxation of international bunkers is practically not feasible in the short-term.
- CO_2-dependent harbor fees: In the light of the legal difficulties to implement internationally coordinated fuel taxation, the introduction of – legally less problematic – emission-dependent harbor fees for maritime navigation is to be examined. Beyond merely covering GHG, such environmentally orientated harbor fees should also address local pollutants emitted by the vessels.

4.3.2.2 Emissions Trading

The inclusion of the maritime transport in an international emission trading scheme or the ETS is a promising approach for internalizing external climate costs. If a suitable regulation for international air transport is obtained, its transferability should be examined for maritime transport.

The inclusion of maritime transport into an international emission trading scheme or into the EU ETS is a promising approach for internalizing navigation's external climate costs, and it is currently discussed on the European level. If a suitable regulation for international air transport is obtained, its transferability to maritime transport should be examined. In case of maritime transport, additional complexity accrues from the fact that on international maritime transport routes freight is partially turned over several times; hence, it has to be clarified which assessment basis is most appropriate for calculating the amount of certificates to surrender.

4.3.2.3 Technical Regulations and Research Promotion

An EU-level regulation is recommended to encourage the installation of modern engine technology in older vessels. Beyond that the establishment of innovative technologies can be advanced by research encouragement and support of market introductions.

In order to reduce the energy consumption of inland navigation to the lowest technically feasible measure, an EU-level regulation has to be considered that encourages the installation of modern engine technology not only in new vessels, but also in older, already operating vessels. Moreover, the establishment of innovative technologies should be promoted by means of R&D encouragement as well as support of market introduction.

4.3.3 Evaluation

The EU's first step could include CO_2 emissions in harbor fees, and after a successful start of emissions trading of air transport, transfer the trading mechanism to maritime. Maritime inclusion into ETS appears to be the most efficient solution long-term, due to the implementation of a comprehensive, minimal cost- emission reduction path. Beyond one-sided measures at the EU level, the German Federal Government can officially acknowledge the IMO as global administrator of GHG regulations for emissions by international maritime transport.

The fuel consumption and thus the CO_2-emissions of the vessels essentially depend on the operating speed. Only by decreasing the operating speed, which seems attainable via price incentives, the energy consumption can decrease significantly. It needs to be mentioned that market-based climate policy measures are in general politically and juristically more easily accomplishable for inland navigation than for maritime navigation. However, since navigation emissions are dominated by international maritime transport, taking measures to tackle its emissions is indispensable.

The EU could start with the inclusion of CO_2-emissions into the harbor fees; upon successful implementation of an emission trading scheme for air transport it should be transferred to the navigation sector. The inclusion of navigation into the EU ETS seems to be the most efficient solution on a long-term basis, because it allows pursuing a cross-sectoral, cost minimizing reduction path. Beyond unilateral measures on an European level, we recommend working towards global solutions under IMO rules.

4.4 Rail Transport

4.4.1 Point of Inception

Measured by passenger kilometers and ton kilometers rail has the least CO_2 emissions. Besides, its share of the total emissions of the transport sector is small. Given a sufficient operating grade rail transport is an efficient and environmentally sound carrier, due primarily to low steel-on-steel rolling friction. From 1990 to 2002 the DB AG reduced CO_2 exhaust by 25%.

A major factor favoring rail is that power plant CO_2 emissions related to the rail operations are already integrated into the ETS. More than 80% of the annual traction power of about 1 billion train kilometers is driven with electrical drive and 30% of the electrical power for rail operations is generated by hydroelectricity (the remaining 70% is generated by nuclear (40%) and fossil fuels (30%)). The traction mode diesel engine performs at best 20% of the train kilometers in the German network. This mode is most used on light railways where the DB mostly uses modern cars with engines optimized for fuel efficiency. Hence, other transport sectors, especially air and road transport should get a higher priority when it comes to developing and realizing measures for the reduction of CO_2 emissions. That does not release the rail transport from its duty to use all opportunities to save energy, though. Further savings are possible by increased utilization of passenger transport and improvements of train and operating technologies. Important leverages for efficiency improvements include:

- Fluid operation: Each acceleration of a heavy freight train produces high energy costs that can hardly be regained during deceleration. A fluid operation without sudden reductions in speed and with no speed restriction sections will improve energy savings and lower emissions.
- Behavioral modifications: Rail companies teach their traction unit drivers to operate efficiently. The resulting energy savings in the passenger transport sector can reach up to 15%. The ICE provides technical assistants with signals that cut off traction without causing delay. Sufficient reserves (time bonuses) are built into the schedules. In contrast, rail freight transport shows minor potential for such savings due to the lack of exact, small, meshed specified operating times.
- Modern equipment: the use of modern electric locomotives and state-of-the-art train cars can make possible remarkable energy savings. Almost all of Germany's fleet has been modernized. An energy recovery system and an energy efficient transformation in the rail cars were part of the modernization. The modernization of the diesel engines also brought remarkable savings per ton kilometer driven. However, due to higher operating grades of trains and higher train mileages, general diesel and power consumption showed little decrease.

4.4.2 Specific Instruments

Specific instruments should be used to capture the full potential of efficiency improvements. Where appropriate,[16] a shift of the modal split for the benefit of rail will reduce overall emissions. For those reasons a strengthening of the competitiveness of rail transport is to strive for.

4.4.2.1 Liberalization and Market Opening

To improve rail’s competitiveness with road transport it is necessary to achieve extensive integration of the national transport systems. Creating a single European rail market strengthens competition among the rail companies and rail’s competitiveness with other modes of transport.

4.4.2.2 Enhanced Interoperability

Given the pursuit of internationalization of the transport sector, rail borders should be eliminated. Implementing the Technical Specification for Interoperability (TSI) and the European Rail Traffic Management System (ETRMS) contribute to system compatibility (the new automatic train control system ETCS and the GSM-R radio system are largely established in Germany). All such innovations support international competitiveness, shorten travel times and reduce system O&M costs.

4.4.2.3 Further Electrification

Extending rail electrification throughout the EU encourages more passenger and freight use of this sector. In Germany almost every important track is already electrified (in addition to the light rail, only a few connecting passages, e.g., Nuremberg- Dresden and some international links to Eastern Europe await electrification). The reasons for the delay in electrification are the high costs for stationary facilities. They require a minimum amount of trains per day in order to refinance the costs of electrification by the gains generated from the sale of electricity.

4.4.2.4 Price Incentives

DB Energie, the neutral company for railway infrastructure, supplies the German rail system with energy (electric current and diesel). DB Energie also owns the power supply network down to the catenary wire. Cars are equipped with electricity meters that measure the energy recovered into the network during deceleration. The lack of efficient battery systems means that only a portion of the energy recovery can be used elsewhere. Rail transport companies could be stimulated to apply more energy-saving technologies.

[16] With low occupancy rates, or the acceptance of large detours (taking the journeys into account) rail can also exhibit a worse climatic balance than road transport.

4.4.2.5 Additional Research

To gain the efficiency of the rail transport and to strengthen its competitive position the following innovations should be emphasized:

- Energy Recovery and Energy Feed: New methods to recover energy are already under study. The increasing use of rail cars with distributed traction opens up new possibilities to test batteries for transformer substations and advances in technology that enable installation of smaller, lightweight batteries in vehicles. Innovations for the tramway sector can be adopted for regional railways. Freight trains equipped with small electrical engines combined with small batteries that are charged in the block train enable the train to move in sidings and switching yard stations without the need of a shunter.
- Automatic Central Buffer Clutch for Freight Cars: The "jerk-free" and delay-free braking on electrical impulse for passenger transport is not possible with freight trains due to the lack of electrical connections between cars. Only by the development of an automatic central buffer clutch that is compatible with the present technology would make a break-through possible. Longer and heavier trains are possible, because the braking distances are shortened and the wear drops. On the long term enormous energy conservation is also possible. The high cost of investment prevents use of this type of clutch. Price incentives in the form of route price deductions could incite rapid introduction of this new technology.
- Intelligent Guidance of Trains though Bottlenecks: Improving operating and disposition systems should make it possible to channel trains through bottlenecks without stops. Based on the current operating situation a short-time prognosis supports a driving route to the approaching trains (similar to the queue regulations during air approaches to airports). Thereby freight trains could be targeted for energy efficient rolling and without stopping/driving.

4.4.3 Evaluation

In comparison to other transport components, rail transport contributes the least emissions, and a major portion of rail-related CO_2 emissions from electricity generation are already integrated into the ETS. Therefore, a climate oriented transport policy should favor energy efficiency improvements and promote a usage shift to rail transport (passenger and freight). However, the support of the modal shift towards rail should not occur unconditionally, since rail transport is quite polluting for only minor capacity utilization.

Beside the utilization, the type of power generation and the diesel share determine the real environmental impacts of rail transport. In addition, the aspects of detours and intermodal changes must be considered. Especially if stations and/or intermodal terminals are accessed by less environmentally benign modes (air and road), the environmental advantages of rail transport is questionable. This becomes even more obvious if one considers that the "house to house" connections per train are probably on average 20 % longer than the direct travel by car. If one additionally takes in account that the extent of capacity utilization of trains is - at least in some parts - relatively small, it appears plausible that in some cases a CO_2 exhaust comparison between car and train favors the car. Particularly, this is obvious for e.g. family travels, where the average poor utilization rate (1.3 people for each trip with 5 seats), is substantially higher.

Improvements in the interoperability of national rail systems and the creation of a European market for rail transport are crucial next steps to stabilize rail's competitive position in freight transport. Politics should work towards these goals by setting up an appropriate framework. Moreover an intact and well maintained infrastructure contributes to relatively non-polluting rail transport.

5 Spatial-structural Contributions to a CO_2-Reduction

Schemes for a reduction of the general transport performance – or at least a moderation of its increase – also have an impact on the energy consumption and on the CO_2 emissions of transport; apart from vehicle-technological and transport-operational as well as economic measures. Hence, transport should be influenced by space-structural and urban arrangements, as well. Those contributions are operating on a long term basis, though. The dependence of the transport-caused fuel and/or energy consumption on the habitat density is well-known. It is also a matter of fact that the specific transport performance (per inhabitant) from residences located in the city centers is considerable smaller than the transport performance of residences in out of town areas. The specific transport performance also increases from the closer suburbs to the outskirts. Thereby the suburban locations tend to produce more demand for transport and to show higher specific CO_2 emissions than locations in the city centers.

The initial position and development tendencies of the spatial regional structure and the location patterns of urban and/or regional land uses in Germany show potentials to curb the socio-structural and eco-structural caused increase of transport volumes. Most of the settlement area as well as most of the sub-areas of metropolitan regions and densely populated areas have a poly-centric structure. This structure is a necessary but not sufficient condition to avoid transport or at least to limit the demand for transport and transport services. Besides, cities - both metropolitan and large cities as well as mid and small towns - possess more and more unused lands and waste space in industrial areas, public thoroughfares and military areas that can be converted to avoid long journeys to outer suburbs. Those potentials are accompanied by the increasing "city affinity" of different social groups (old or unmarried persons, single parents, singles, civil partnerships without children, young households) when they choose the location for their residences. Upcoming economy sectors like "creative industries", knowledge clusters, Research and Development, trade, and service industries also exhibit such a "city affinity" when they choose the location for their enterprises. The above-named "city affinity" assists to fulfill the potentials of a settlement system which avoids unnecessary transport. The following strategies can support policies promoting concentration of urban transport:

- urban density/aggregation with accessibility to employment and jobsites, supply facilities, services and cultural and recreational facilities
- proximity/neighborhood and/or mix of urban functions and uses by diverse populations
- locales designed to maximize greenspace (public parks, greenbelts, etc)

Above all, a good urban and city-regional accessibility means a promotion of the use of non-motorized means of transport and of use of the local public transport. Both means of transport exhibit a lower specific CO_2 exhaust (per passenger and/or per unit transport expenditure). The attractiveness of both promotes an intensified creation of multi-modal mobility.

Transit oriented development along efficient local public transport axes (regional train, suburban train, green belt trains, metropolitan railway etc.) is an integrated approach of space and transport design. According to this approach centers of residence and facilities have to conglomerate around the train stations. Transit oriented development shows high potentials for the avoidance of transport, for modal shift in transport and for a reduction of the specific CO_2 exhaust.

Even if these basic patterns of the settlement structures exhibit only low potentials for changes on the short and medium-term, the fact that households and companies change their location rather frequently should not be underestimated. When choosing a new location households and companies might very well base their decision on the criteria of transport avoidance and/or CO_2 reduction and energy saving. This requires quantitatively and qualitatively suitable location options, supporting consultation for the choice of location as well as suitable location marketing. In the context of such a consulting the determination of the individual effects regarding energy consumption, the CO_2 emissions and mobility costs can affect the choice of location.

Long-term effectiveness and viability of an energy-efficient and CO_2 reducing settlement development requires integrated concepts for location patterns, space structure and settlement structure as well as for the transport services offered and the transport infrastructure. Only if location patterns support non-motorized mobility and public local transport mobility and make this mobility more attractive, the offers of public local transport, transport by bicycle and by foot, can generate the desired effects on transport and score the aspired goals of energy-efficiency and CO_2 reduction. At the same time transport measures upgrading public local transport and transport by bicycle and by foot (concepts for public local transport, “pedestrian and bicycle-friendly city”) act supportively. The same is true for transport management measures (“park space management”, “traffic calming”) and mobility management measures. Poly-centric urban settlement patterns show potentials to avoid transport, to reduce the transport needed and to induce modal shifts. Those potentials can manifest in reduction of energy consumption and CO_2 emissions caused by transport.

6 Change of Behavior

Overcoming the negative results of motorized individual transport can not be achieved solely by technological innovations that reduce the consumption of energy and natural resources. The necessary development of low carbon technologies ("efficiency strategy") has to be accompanied by measures aiming at the decrease of transport demand (sometimes called "sufficiency strategy"). Basing measures of climate protection only on technological improvements – especially of motor vehicles – is unfavorable over the long-term, because then there is no necessity to modify personal transport behaviors. Assuming a further rise in demand for passenger transport, with even greater demand for freight transport, a vital part of the technologically-gained improvements in fuel consumption and in CO_2 emissions again will be subsumed by the very same rise in demand. However, behavioral measures will reduce emissions by reducing the demand for transport.

Similar to an energy conservation strategy, a transport economy strategy employing economical, educational and enforcement tools can be lastingly effective. In fact, given a car-dependent way of life, low-emission behavior is hard to establish as an appealing option, rapidly. Especially in terms of mobility, changes of behavior are associated with great efforts. The reason is that changes in this field are often experienced as an intrusion into the mainly custom-controlled design of the way of life which is based on long-ranging decisions. However, the recently observed process of change of the cognition of climate change and the influence of CO_2 emissions, also partly includes a reflection about the unfavorable effects of individual behavior. This "window of opportunities" can promote the political and public acceptance of measures which were discussed to be environmentally reasonable for years. Cognition and willingness are necessary but insufficient conditions for behavioral changes. Measures trying to actually affect behavior have to put the stress on changes of knowledge and attitude; moreover, they have to illustrate the consequences of certain behavior, For this purpose, as a first step incentive systems are particularly effective.

Individual measures alone, without informing the actors in the passenger and freight transport market, cannot achieve the goal of a sustainable CO_2 reduction. A policy package of technological, infrastructural, economic and behavioral measures that cross references the components of Germany's transport sector appears most promising. The charm of technological solutions is that they free us from the need of behavioral changes. Measures affecting knowledge, attitudes and behavior are burdened with the fact of being less well accepted and often just display their effects in the long term. However, on a long-term basis, a bigger share of transport managed by environmentally friendly transport modes and a reduced use of private motor vehicles will lead to vigorous reductions in fuel and energy consumption and therefore CO_2 emission. Small, but successful, behavioral changes initially will set the tone for long-term societal alterations. Established, effective measures that create the basic conditions and that induce new behaviors include:

1. <u>Affecting overall behavioral patterns</u> aims to change the activity patterns of commuters and of shopping and leisure activities. In order to reduce the experienced comparative advantages of motor vehicle usage, the conditions for alternative transport modes needs to be enhanced. Simultaneously the costs for individual motorized traffic use should rise. Amongst others, those conditions include the development of flexible transport systems, a decentralization of services and a simplified car-free accessibility to as many places as possible. Especially for car owners new concepts for the usage of their cars ("use instead of possess") and an increased occupancy rate (aspired goal e.g.: 2 persons) have to be included into the mentioned conditions. These and similar instruments could be bundled into urban government initiatives for the promotion of slow traffic following Switzerland's example. Pro climate protection marketing on all levels is necessary: purchase decisions, mobility habits, and transport and handling habits. The change of social standards in favor of environmentally sound behaviors needs incentives, behavioral role models and feedbacks of positive results from campaigns. On the other hand a change also relies on a shift of codified standards.

2. <u>Public awareness, marketing campaigns and incentives to promote environmental friendly transport</u> such as: personal and institutional travel planning and travel blending; car sharing/pooling/dedicated high occupancy vehicle (HOV) lanes; communal vehicles and motorcraft (example NL: Buurtbus) could be realized in the short term; Thereby a positive enhancement of the desired behavioral changes is essential (for example: spits mijden, NL, 2007). The environmental benefit should not remain abstract. Actual prices have to be observable in order to increase the rationality of deciding behavior. For example "pay as you drive" insurance policies and diagnostics and acknowledging systems in the car which directly provide information about consumption and emissions (contingent behavior management) can be conducive. The possibilities of technological support for the stabilization of behavioral changes are not yet exhausted by any means. It is important to interlock environmental benefits with an increase in road safety by changing mobility habits and driving behavior. Environmentally-conscious driving (e.g. lower speeds, less acceleration, less lane changes) has to be supported by incentives for participation (for example: Eco-Drive). Thereby environmental driving enables changes of social standards towards ecological criteria; for example a change from the highly positive valuation of travel time towards a higher valuation of reduced fuel consumption.

Public discussions should be added to these examples. Those discussions can sharpen people's consciousness of environmental problems. At the same time they can clarify goals, generate ideas and increase acceptance. This consensus is necessary and difficult to achieve, at the same time. Even if such measures have been often proved to be effective already research on the efficiency and on the acceptance of measures steering behavior are needed urgently. Both single measures and strategic packages of measures aiming to reduce to the CO_2 emissions of the transport sector require further research.